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A look at the focus shift in innovation literature due to Covid-19 pandemic

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ARTICLE INFO

Keywords:

Innovation literature
 COVID-19 pandemic
 Bibliometric analysis
 Business and economics

ABSTRACT

This study explores the problems related to the development of innovation research in the field of business and economics and the change in their characteristics following the coronavirus disease 2019 (COVID-19) pandemic. We compile a comprehensive bibliometric analysis of 17,277 pre-epidemic publications and 4,240 post-epidemic publications from the Web of Science. Using bibliometric methods and visualization tools, we present the changes in these publications following the COVID-19 pandemic, and identify the influential countries and regions, sources, and references, and obtain features of keywords over time. The results show that innovation research is rich in content, and involves a wide range; it has been focusing on emerging topics, such as those concerning low-carbon, innovation forms, and epidemic environments, following the COVID-19 pandemic. This study contributes to the body of knowledge on innovation, and helps to understand the features and structures of innovation research in business and economics.

1. Introduction

Innovation research, as a necessity for management and knowledge, has been receiving increasing attention in the age of information technology and this dynamic and complex environment. Although innovation studies are not an emerging topic, an increasing number of studies are being conducted following the introduction of innovation forms and changing global situations. The global lockdown owing to the coronavirus disease 2019 (COVID-19) pandemic resulted in abrupt shut down of core businesses, worldwide recession, and a huge crisis for firms (Galanakis et al., 2021). There have been major changes in daily life and work routines; innovation is a vital strategy for organizations to survive and recover from the crisis (Zhong et al., 2022). As many industries have been drastically affected and there exists uncertainty in markets, it is necessary for firms to overcome such challenges and barriers; the crisis is also propelling waves of innovation activities (Amankwah-Amoah, 2021). For example, sustainable innovation is imperative for achieving organizational survival and success in the turbulent market environment of the digital age and following COVID-19 pandemic. Lee et al. (2021) presented convergence innovation, powered by the exponential fusion effect of various objects, technologies, ideas, and strategies, as a new sustainable core competence of organizations. Focusing on technology innovation, Shin et al. (2020) examined the impact of the expected interaction and expected cleanliness on perceived health risk and hotel

booking intention for reducing guest interaction with employees and enhancing cleanliness as an essential risk-reduction strategy. In the supply chain field, the COVID-19 pandemic has exposed businesses and societies to the shortfalls of normal patterns, and their long-lasting impact on supply chains. Nandi et al. (2021) provided insights into making supply chains more resilient, transparent, and sustain-able, and supply chains needing to develop localization, agility, and digitization characteristics. Galanakis et al. (2021) investigated the potential innovations in the food sector during the COVID-19 crisis, which may be regarded as the innovations with the highest potential in the food supply chain in the new era. Therefore, recent studies have gradually shown that firm-level innovation measures related to strategy, management, and performance have played a vital role in building flexible and sustainable organizations after the global epidemic. This study explores the problems of how innovation research develops and what characteristics they present in business and economics, following the COVID-19 pandemic. A review of innovation research generates theoretical and practical relevance; the literature involve the institutional theory and legitimization of innovative behavior, theory of reasoned action and technological acceptance model, determinants of innovation adoption, diffusion theory, and the relative importance of theoretical cornerstones (van Oorschot et al., 2018). Little attention has been paid to performing a comprehensive review of innovation research in the field of business and economics observing the pre and post COVID-19 pandemic

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<https://doi.org/10.1016/j.jbusres.2022.02.067>

Received 3 December 2021; Received in revised form 17 February 2022; Accepted 23 February 2022

Available online 28 February 2022

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conditions. There is a compelling need to study the changes in innovation research following the COVID-19 pandemic from multiple aspects, and help in understanding the structure, development, and characteristics related to innovation.

To examine the focus shift scientifically and comprehensively in innovation literature in business and economics following the COVID-19 pandemic, we conduct a bibliometric analysis, a mature and effective method involving the extensive intersection and combination of philology, mathematics, and statistics, to visually show the characteristics of the relevant publications. Bibliometrics is a popular theory as well as a branch of intelligence science that presents the evolution of and relationships among items of a subject or a journal and visually presents the topics and research directions by analyzing the relevant literature. Bibliometrics, as a type of scientometric discipline, applies statistical methods to evaluate scientific activities and provide quantitative analysis of academic literature in a certain journal or field of research; it highlights the main features and merits of the study in a structured way (Wang et al., 2021b). Until date, bibliometrics has been widely applied to present the evolution of a certain journal or a specific field by analyzing the relevant literature (He et al., 2017). Recent studies have shown that a bibliometric analysis could bring about profound development and changes in publications in various fields, including male infertility research (Baskaran et al., 2021), artificial intelligence (Wamba et al., 2021), smart contracts on blockchains (Ante, 2021), and the intellectual evolution of social innovation (Forouidi et al., 2021). On the other hand, several influential and academic journals, such as the *Journal of Business Research* (Donthu et al., 2020), *European Journal of Operational Research* (Laengle et al., 2017), *Journal of Knowledge Management* (Gaviria-Marin et al., 2018) and *Technological and Economic Development of Economy* (Yu et al., 2019), have also explored their structure and evolution using bibliometric analyses to better understand their scope and development and inspire creative work.

The purpose of this study is to examine the focus shift in innovation literature in business and economics following the COVID-19 pandemic through a bibliometric analysis, and to explore an informative overview of innovation research that is a rapidly developing research direction with progress in technology and dynamic environments. Employing bibliometric methods, this study attempts to fulfill the following objectives. (1) To reveal the annual tendency of innovation research and explore the productive sources, countries and regions, and highly cited publications observed before and after the COVID-19 pandemic; a performance analysis is conducted via some accepted indicators, such as the number of publications and the number of citations, which help in determining the influential publications from multiple aspects. (2) To recognize high-quality innovation-related publications that are co-cited; a co-citation analysis with the help of sources and references is performed, considering the pre-epidemic and post-epidemic literature. Furthermore, a dual-map is presented to outline the relationship between citing references and cited references as well as research fields. (3) To identify the keywords of innovation research from the perspective of co-occurrence strength that eventually shapes visible clusters; a co-occurrence analysis is conducted at the density and overly levels, and it provided the subjects related to COVID-19 in the post-epidemic literature. (4) To assess the features of keywords in different periods, and the relationship with county and region; a conceptual structure analysis is conducted to present thematic maps, trend topics, and three-field plots observed before and after the COVID-19 pandemic.

In this study, the contributions are presented primarily in four ways. (1) We present an up-to-date assessment of the innovation literature, delineate the annual number of publications and citations, and provide information on the most productive sources, countries and regions, and highly cited publications in the pre-epidemic and post-epidemic literature. (2) With the identification of the influential sources and references within innovation research, we present co-citation networks and intertwining networks used to dual-map the connections observed before and after the COVID-19 pandemic. (3) We highlight the keyword perspective

of innovation research using co-occurrence degrees in different clusters, which is relatively important for recognizing research trend in the pre-epidemic and post-epidemic literature. Moreover, we identify the motor, niche, emerging or decline, and basic themes of innovation literature and show the topic trends and three-field plots observed following the COVID-19 pandemic. (4) Innovation research is rich and constantly changing in the context of the COVID-19 crisis. We present an objective and comprehensive view, discuss the perspectives of popular issues, avenues for future research, and implications for innovation research in the fields of business and economics. The bibliometric review at this stage may find new perspectives and inspire scholars who are interested in innovation research to think creatively.

The rest of this paper is organized as follows. Section 2 presents the data source and bibliometric methods. In Section 3, performance analysis, co-citation analysis, co-occurrence analysis, and conceptual structure analysis are presented, followed by the findings of the analyses. Section 4 discusses the popular issues, avenues for future research, and the implications and limitations of this study. Section 5 concludes the study.

2. Data source and methods

To comprehensively review innovation-related publications before and after the COVID-19 pandemic from a historical perspective of its evolution, we collected reliable data materials and applied bibliometric methods. Fig. 1 shows the empirical quantitative research framework.

2.1. Data source

To explore the change in the characteristics of innovation literature before and after the COVID-19 pandemic, we collected two data sets using the Web of Sciences; on February 11, 2020, when the World Health Organization named the new strain coronavirus as COVID-19. The WoS system provides available publications with detailed information, and many databases, including the Science Citation Index Expanded (SCI-Expanded), Social Sciences Citation Index (SSCI), Arts and Humanities Citation Index (A&HCI), Conference Proceedings Citation Index-Science (CPCI-S), Conference Proceedings Citation Index-Social Science and Humanities (CPCI-SSH), and Emerging Sources Citation Index. Considering that the earliest search time was 1900 in the WoS system, we collected the pre-epidemic literature as the first data set from 1900 to 01-01 to 2020-02-11, and the post-epidemic literature as the second data set is from 2020 to 02-11 to 2021-11-06. Consistent with the purpose of this study, we suppose the title of publication contains the term “innovation” and the publication belongs to the research area of business and economics since our primary focus is in the mechanisms that affect innovation from an economics viewpoint. Focusing on publications with article type in English, the search process in this study for data jointly combines the search string with the Boolean operator as follows:

- (1) For the first dataset,
 - Database = Core Collection database;
 - Title = (innovation) AND Language = (English) AND Document type = (Article) AND
 - Research area = (Business economics);
 - Timespan = 1900-01-01-2020-02-11;
 - Indexes = SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, ESCI.
- (2) For the second dataset,
 - Database = Core Collection database;
 - Title = (innovation) AND Language = (English) AND Document type = (Article) AND
 - Research area = (Business economics);
 - Timespan = 2020-02-11-2021-11-06;
 - Indexes = SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, ESCI.

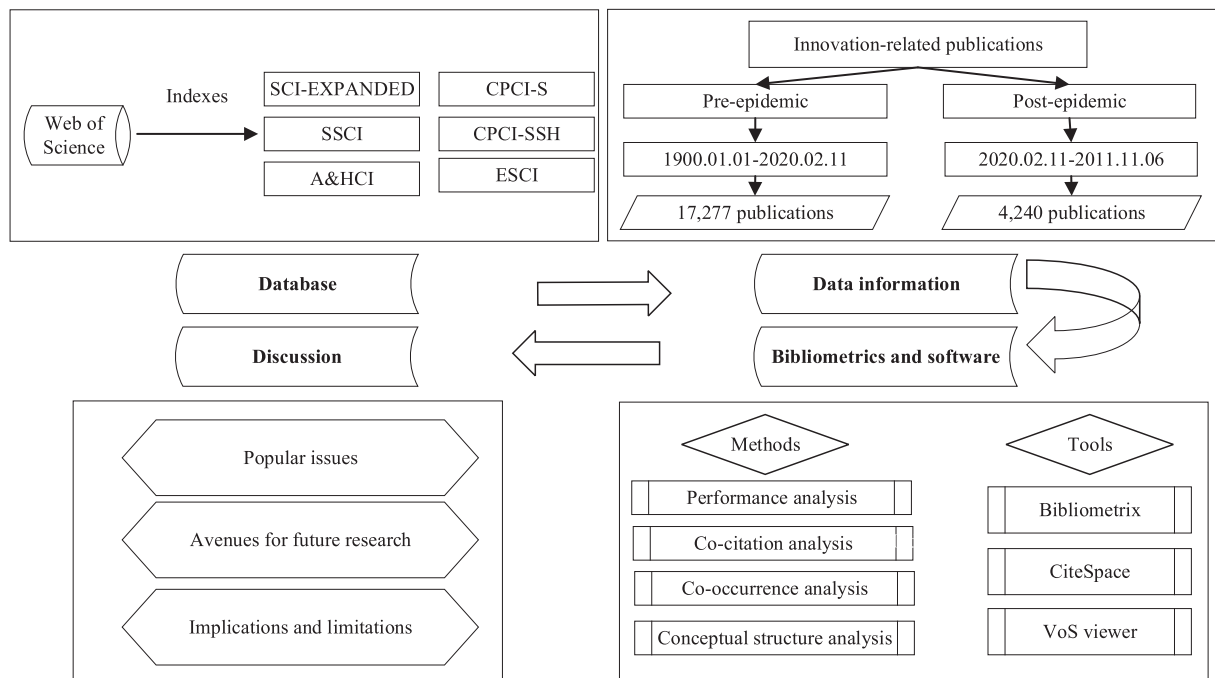


Fig. 1. The research framework and process of this study. Sources: Authors' own research.

The selected publications are exported in plain text format and comma-separated values format, containing detailed information, such as bibliographic, keyword, and citation information. Finally, there were 17,277 pre-epidemic publications for the first data set and 4,240 post-epidemic publications for the second data set with respect to innovation literature.

2.2. Methods

Using collected data sets, this study focuses on four aspects to reveal the structure and development of innovation-related publications observed before and after the COVID-19 pandemic with the help of bibliometric methods and visualization tools.

The first aspect is performance analysis. This presents the overall trend of relevant publications and measures the prolificacy and influence of an item analysis, such as document, country or region, and source (Wang et al., 2021a). Performance analysis provides a holistic view of publications for each item and lays the foundation for subsequent studies with local perspectives. Some scientific indicators, accepted by the scientific community, are used to show the representative features of publications, such as the number of publications, number of citations, and number of average citations (Mingers et al., 2015). In this way, the rankings of each item could be different according to the considered indicator, and researchers further explored and interpreted the results in terms of their interests or requirements (Hsieh et al., 2009). In this section, Bibliometrix (Aria et al., 2017), an open-source instrument based on the R language, is used to present the development of publications and their citations, as well as the distribution and cooperation of countries and regions on the global map.

The second aspect is co-citation analysis. This identifies a field trend of an item (e.g., reference, source) and measures the proximity degree if some publications are often cited together so that they are identifiable with a cluster in citation maps (Xu et al., 2021a). Under such a situation, co-cited items are regarded as being more related, and the number of citations reveals their similarity and influence. Dual-map overlay analysis (Chen et al., 2014), considering both the citations of references and sources, provides a publication portfolio analysis to reveal the relationships between the types and sources of publications. In this

section, the VOSviewer (van Eck et al., 2010), an excellent knowledge mapping tool, presents the co-citation landscapes reflected in networks with respect to sources and references. Additionally, CiteSpace (Chen, 2006), as a complementary tool, conducts a knowledge panorama of the dual-map overlay using the "JCR Journal Maps" function.

The third aspect is co-occurrence analysis. This is a form of content analysis, as well as a quantitative method considering occurrence of keywords, to support knowledge mining and understand the research direction and central theme (Xu et al., 2021b). Keywords identify the basic units of a certain field and provide a view of the knowledge structure and research trends. When two keywords appear together in publications, the correlation degree is recorded to present the total strength (Wang et al., 2021c), it provides an appropriate way to assist in understanding the topics or subjects of a certain field (Caputo et al., 2021). In this section, the VOSviewer is used to provide a visual relationship of keywords and their popular degrees based on the size of the nodes and the thickness of the links. Moreover, the overlay visualization in the VOSviewer identifies the development of keywords over time and provides particular attention from scientific organizations in recent years, to a certain extent.

The final aspect is conceptual structure analysis. This provides a spatial depiction in terms of keywords, countries and regions, and references. Focusing on keywords in publications, a thematic map is applied to divide types of keywords into four different quadrants to obtain an intuitive overview of the research subjects (Rodríguez-Soler et al., 2020). The trend topic reveals dynamic hot keywords with potentially transformative changes over the time slice. Furthermore, the three-field plot empowers the interrelationship and transformation rules of items to show the evolutionary paths, which is beneficial for researchers to capture potential development of a certain field in the future (Xie et al., 2020). In this section, the software tool Bibliometrix was used to obtain visual results with respect to innovation-related publications observed before and after the COVID-19 pandemic from the perspectives of the thematic map, trend topic, and three-field plot.

3. Findings

A bibliometric analysis of innovation-related publications was

conducted to compare changes in multiple aspects observed before and after the COVID-19 pandemic. Using the two datasets and methods described in Section 2, the results of the performance, co-citation, co-occurrence, and conceptual structure analyses are provided to present the changes in the features of and evolution in innovation literature following the COVID-19 pandemic.

3.1. Performance analysis

The first and second datasets consist of 17,277 and 4,240 innovation-related publications, respectively, in business and economics over time. Fig. 2 shows the number of publications and their citations per year until November 6, 2021, and the start year is from 1939, because the first document was published in 1939 (Dickinson, 1939).

In Fig. 2(a), the number of publications shows an obvious increasing trend over time, peaking in 2020. Since 2010, the annual number of publications is greater than 500, indicating that innovation has been increasingly recognized as playing a vital role in business and economics, and scholars have paid more attention to innovation research in the past 10 years. In Fig. 2(b), the average number of citations per year presents considerable fluctuations, especially over the past two decades. There are several obvious peaks in 1990, 2006, and 2021, indicating that innovation literature published in these years has a far-reaching impact on business and economics.

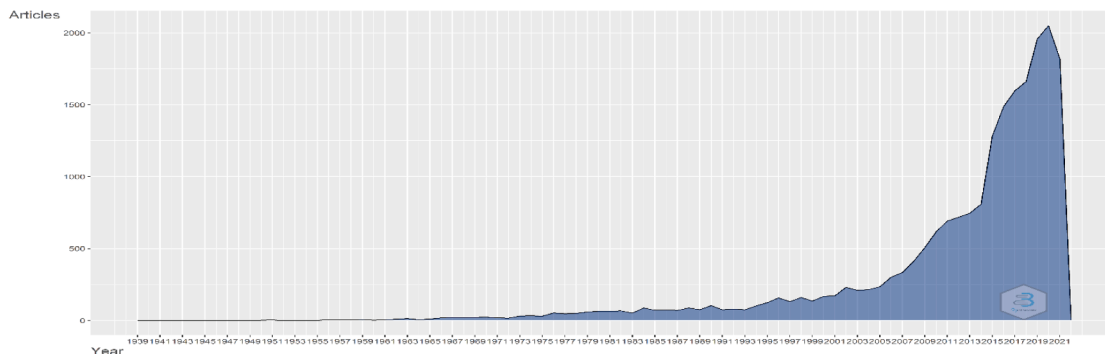
To understand the features of pre-epidemic literature and post-epidemic literature in terms of county or region, Fig. 3 provides country and region distribution and collaboration of innovation-related publications observed before and after the COVID-19 pandemic. In general, these publications cover 157 countries and regions, most of which are in Europe, Asia, and America. The pre-epidemic literature contains 149 countries and regions and the post-epidemic literature contains 117 countries and regions. Fig. 3 demonstrates two collaboration relationships concerning countries and regions, following the COVID-19 pandemic, indicating the structural features of the innovation-research network. The results show a similar cooperative

relationship, but with different numbers of publications and degrees of cooperation.

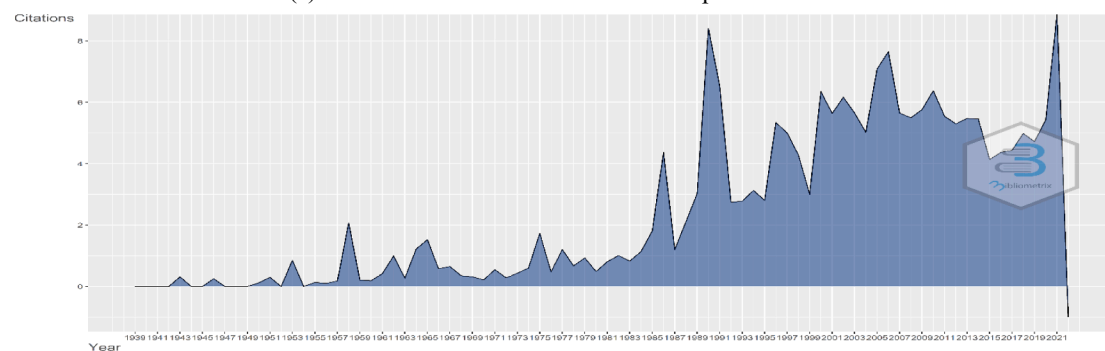
Tables 1 and 2 list the top 10 sources and countries and regions with respect to the number of innovation-related publications in terms of pre-epidemic literature and post-epidemic literature, respectively. Due to different time spans, the number of pre-epidemic publications is significantly larger than the number of post-epidemic publications, regardless of the source and country or region. Moreover, comparing pre-epidemic and post-epidemic literature, half of the top 10 sources is different, and only one of the top 10 countries and regions is different. In Table 1, the journal *Research Policy* ranks first with 804 publications, followed by *Technological Forecasting and Social Change* with 575 publications and *Technovation* with 437 publications. The USA is the leading country with 11,556 publications, followed by England with 4,330 publications, and China with 3,023 publications. In Table 2, the *Journal of Technological Forecasting and Social Change* is the first with 215 publications, followed by *Journal of Business Research* with 176 publications, and *Technology Analysis Strategic Management* with 131 publications. The *European Journal of Innovation Management*, *Marketing and Management of Innovations*, *Industrial Marketing Management*, *Journal of the Knowledge Economy*, and *Journal of Knowledge Management* are five of the top ten sources in post-epidemic innovation-related publications. China ranks first globally with 1,040 publications, followed by the USA with 726 publications and England with 498 publications. They are still ranked as the first three countries following COVID-19 pandemic, but their rankings have changed. Brazil has become one of the top 10 countries in terms of post-epidemic literature, which is different from the pre-epidemic literature.

To find influential innovation-related publications published before and after the COVID-19 pandemic, the number of citations recorded is considered a vital indicator for measuring the quality of documents. Tables 3 and 4 list the top 10 cited innovation-related publications with detailed information in the pre-epidemic and post-epidemic literature, respectively.

Before the COVID-19 pandemic, the most influential innovation-

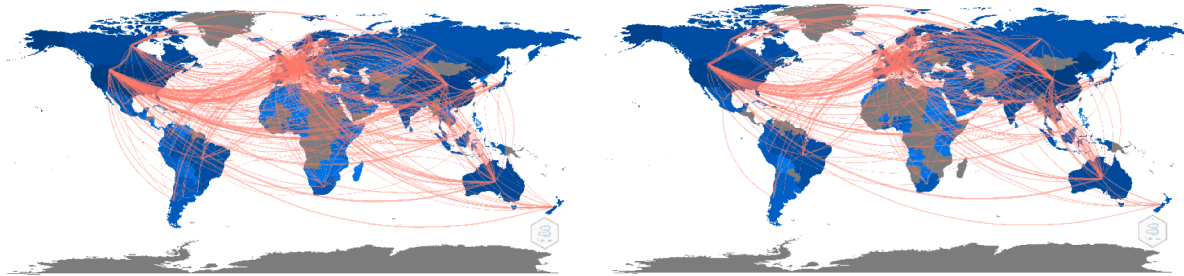


(a) Annual number of innovation-related publications.



(b) Average citations of innovation-related publications per year.

Fig. 2. The number of innovation-related publications and the number of citations per year. Sources: Authors' own research.



(a) The distribution and collaboration of pre-epidemic literature. (b) The distribution and collaboration of post-epidemic literature.

Fig. 3. The distribution and collaboration of innovation-related publications in terms of country/region. Sources: Authors' own research.

Table 1

Top 10 sources and countries/regions in terms of pre-epidemic innovation-related publications.

Source	Number	Country/Region	Number
Research Policy	804	USA	11,556
Technological Forecasting and Social Change	575	England	4,330
Technovation	437	China	3,023
International Journal of Technology Management	413	Germany	2,417
Technology Analysis Strategic Management	403	Spain	2,346
Journal of Product Innovation Management	329	Italy	1,893
Journal of Business Research	304	Netherlands	1,889
R&D Management	300	Canada	1,810
International Journal of Innovation Management	210	France	1,634
Research Technology Management	203	Australia	1,626

Sources: Authors' own research.

Table 2

Top 10 sources and countries/regions in terms of post-epidemic innovation-related publications.

Source	Number	Country/Region	Number
Technological Forecasting and Social Change	215	China	1,040
Journal of Business Research	176	USA	726
Technology Analysis Strategic Management	131	England	498
European Journal of Innovation Management	125	Italy	394
International Journal of Innovation Management	96	Spain	327
Research Policy	89	Germany	313
Marketing and Management of Innovations	72	France	228
Industrial Marketing Management	65	Australia	226
Journal of the Knowledge Economy	59	Brazil	205
Journal of Knowledge Management	58	Netherlands	190

Sources: Authors' own research.

related document was published by [Cohen et al. \(1990\)](#) in *Administrative Science Quarterly*, with the most citations (15,319), far outnumbering the second-most cited publication. This study proposes a new perspective on learning and innovation with respect to absorptive capacity, which is useful in business and management. These highly cited documents regarding business, management, information science and library science, and economics were published in impactful journals, such as *Administrative Science Quarterly*, *Research Policy*, *Information Systems Research*, *Economic Journal*, *Organization Science*, *Academy of*

Management Journal, and *Strategic Management Journal*. Among them, the *Administrative Science Quarterly* is the most published journal, followed by *Research Policy*. In addition, these documents were published earlier, from 1986 to 2006, the reason may be that publications need time to be widely read, recognized, and cited. These studies related to innovation mainly focus on learning innovation ([Brown et al., 1991](#); [Cohen et al., 1989](#); [Cohen et al., 1990](#)), technological innovation ([Moore et al., 1991](#); [Teece, 1986](#)), interorganizational collaboration and innovation ([Damanpour, 1991](#); [Etzkowitz et al., 2000](#); [Powell et al., 1996](#)), architectural innovation ([Henderson et al., 1990](#)), and open innovation ([Laursen et al., 2006](#)).

After the COVID-19 pandemic, there were not many differences in terms of citations. [Singh et al. \(2021\)](#) published the most influential innovation-related document in the *Journal of Business Research*, with the most citations (105). This study focuses on management knowledge value, knowledge-sharing practices, open innovation, and organizational performance in business. These highly cited publications refer to business, information science and library science, management, engineering and industry, operations research and management science, and environmental studies, and were published in famous journals in the fields of business and economics, such as *Journal of Business Research*, *Journal of Knowledge Management*, *Industrial Marketing Management*, *Technovation*, *International Journal of Human Resource Management*, *Business Strategy and the Environment*. Among them, the *Journal of Business Research* is the most published journal, followed by *Technovation*, and these published journals are quite different from journals of pre-epidemic literature, indicating that influential journals on innovation literature have been transformed to a certain extent. Furthermore, the top 10 cited publications focus on open innovation ([H. Chesbrough, 2020](#); [Singh et al., 2021](#)), innovation performance ([Ferreira et al., 2020](#); [Papa et al., 2020](#); [Santoro et al., 2020](#); [Wang et al., 2021](#)), model innovation ([Ghezzi et al., 2020](#)), innovation management ([Leonidou et al., 2020](#)), energy innovation ([Bekun, & Khan, 2021](#)), and marketing innovation. Note that two highly cited publications have made innovation research in the COVID-19 crisis environment. One concerns the managerial implications of open innovation to recover faster from COVID-19 ([H. Chesbrough, 2020](#)). The other is a study of Chinese firms' responses to the COVID-19 crisis; it is related to marketing innovation during a global crisis. This shows that the research on innovation is gradually becoming a hot topic with respect to the COVID-19 pandemic, and there may be an increasing trend to further study innovation-related research in such an environment.

3.2. Co-citation analysis

To identify the similarity citations of innovation-related publications, we conducted source co-citation analysis and reference co-citation analysis, observing the conditions before and after the COVID-19 pandemic, respectively. [Figs. 4 and 5](#) show the source co-citation networks of the pre-epidemic and post-epidemic literature, respectively. Each color represents a category. The size of the node indicates the

Table 3

The top 10 cited innovation-related publications in the pre-epidemic literature.

No.	Authors	Title	Citations	Source	Type of WoS
1	(Cohen et al., 1990)	Absorptive-Capacity-A new perspective on learning and innovation	15,319	Administrative Science Quarterly	Business; Management
2	(D. J. Teece, 1986)	Profiting from technological innovation-Implications for integration, collaboration, licensing, and public policy	4,459	Research Policy	Management
3	(Powell et al., 1996)	Interorganizational collaboration and the locus of innovation: Networks of learning in biotechnology	4,162	Administrative Science Quarterly	Business; Management
4	(Moore et al., 1991)	Development of an Instrument to Measure the Perceptions of Adopting an Information Technology Innovation	3,649	Information Systems Research	Information Science & Library Science; Management
5	(Henderson et al., 1990)	Architectural innovation-The reconfiguration of existing product technologies and the failure of established firms	3,648	Administrative Science Quarterly	Business; Management
6	(Cohen et al., 1989)	Innovation and learning: The two faces of R&D	3,468	Economic Journal	Economics
7	(Brown et al., 1991)	Organizational learning and communities-of-practice: Toward a unified view of working, learning, and innovation	3,399	Organization Science	Management
8	(Damanpour, 1991)	Organizational innovation-A metanalysis of effects of determinants and moderators	3,227	Academy of Management Journal	Business; Management
9	(Etzkowitz et al., 2000)	The dynamics of innovation: from National Systems and "Mode 2" to a Triple Helix of university-industry-government relations	3,003	Research Policy	Management
10	(Laursen et al., 2006)	Open for innovation: The role of openness in explaining innovation performance among UK manufacturing firms	2,893	Strategic Management Journal	Business; Management

Sources: Authors' own research.

Table 4

The top 10 cited innovation-related publications in the post-epidemic literature.

No.	Authors	Title	Citations	Source	Type of WoS
1	(Singh et al., 2021)	Top management knowledge value, knowledge sharing practices, open innovation and organizational performance	105	Journal of Business Research	Business
2	(Papa et al., 2020)	Improving innovation performance through knowledge acquisition: the moderating role of employee retention and human resource management practices	99	Journal of Knowledge Management	Information Science & Library Science; Management
3	(H. Chesbrough, 2020)	To recover faster from Covid-19, open up: Managerial implications from an open innovation perspective	98	Industrial Marketing Management	Business; Management
4	(Santoro et al., 2020)	Collaborative modes with Cultural and Creative Industries and innovation performance: The moderating role of heterogeneous sources of knowledge and absorptive capacity	83	Technovation	Engineering, Industrial; Management; Operations Research & Management Science
5	(Z. N. Wang et al., 2021)	Intellectual capital and firm performance: the mediating role of innovation speed and quality	78	International Journal of Human Resource Management	Management
6	(Ghezzi et al., 2020)	Agile business model innovation in digital entrepreneurship: Lean startup approaches	78	Journal of Business Research	Business
7	(Leonidou et al., 2020)	An integrative framework of stakeholder engagement for innovation management and entrepreneurship development	73	Journal of Business Research	Business
8	(Baloch et al., 2021)	Modeling the dynamic linkage between financial development, energy innovation, and environmental quality: Does globalization matter?	70	Business Strategy and the Environment	Business; Environmental Studies; Management
9	(Ferreira et al., 2020)	Dynamic capabilities, creativity and innovation capability and their impact on competitive advantage and firm performance: The moderating role of entrepreneurial orientation	58	Technovation	Engineering, Industrial; Management; Operations Research & Management Science
10	(Wang et al., 2020)	Marketing innovations during a global crisis: A study of China firms' response to COVID-19	52	Journal of Business Research	Business

Sources: Authors' own research.

number of the cited-source after standardization, and the links refer to the co-citation relationship between the two connected sources. The thicker the link, the more co-citations between the two connected sources. Hence, a link represents the number of sources co-cited with the target source, and the total link strength is the sum of the connected source and the cluster depending on the weight calculation (Wang et al., 2021c). In Fig. 4, let the minimum number of citations of a source be 1,000, 116 of the 141,228 cited sources meet the threshold, and are divided into four clusters. In Fig. 5, we set the minimum number of citations of a source to 500, and 85 of the 46,768 cited sources meet the threshold, which are divided into four clusters.

To obtain more detailed information, Tables 5 and 6 list the indicators of innovation-related publications per cluster of cited sources in the pre-epidemic and post-epidemic period, respectively. According to Fig. 4 and Table 5, Cluster 1 in red contains 47 sources, Cluster 2 in green includes 39 sources, Cluster 3 in blue contains 20 sources, and Cluster 4

in yellow includes 10 sources. The most co-cited sources observed before the COVID-19 pandemic in the four clusters are *Research Policy* (37,372), *Journal of Product Innovation Management* (14,118), *Academy of Management Journal* (18,214), and *Strategic Management Journal* (27,902). Similarly, co-cited sources following the COVID-19 pandemic are divided into four clusters according to Fig. 5 and Table 6: each cluster involves 28 sources in red, 26 sources in green, 23 sources in blue, and 8 sources in yellow. The most co-cited sources following the COVID-19 pandemic in the four clusters are *Journal of Business Research* (4,973), *Strategic Management Journal* (8,613), *Research Policy* (11,424), and *Technological Forecasting and Social Change* (3,858), respectively. Among them, the *Research Policy* and *Strategic Management Journal* are both the most co-cited sources in a cluster, regardless of the data sets, indicating that publications from these two sources have provided valuable references for scholars to study innovation. Moreover, the *Journal of Business Research*, *Journal of Cleaner Production*, and *Journal of Business Ethics* are

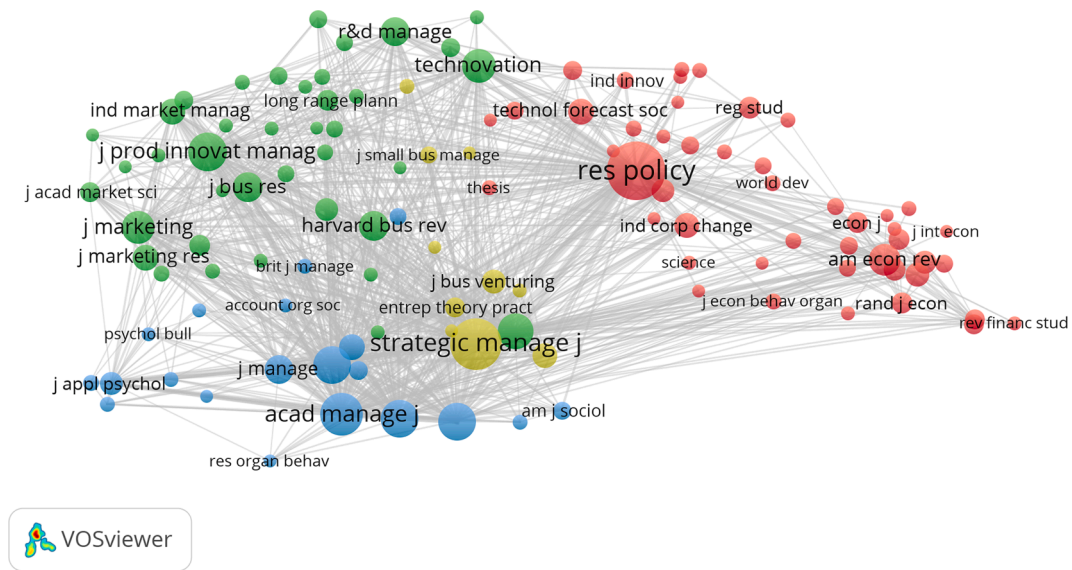


Fig. 4. The source co-citation network of innovation-related publications before COVID-19 pandemic. Sources: Authors' own research.

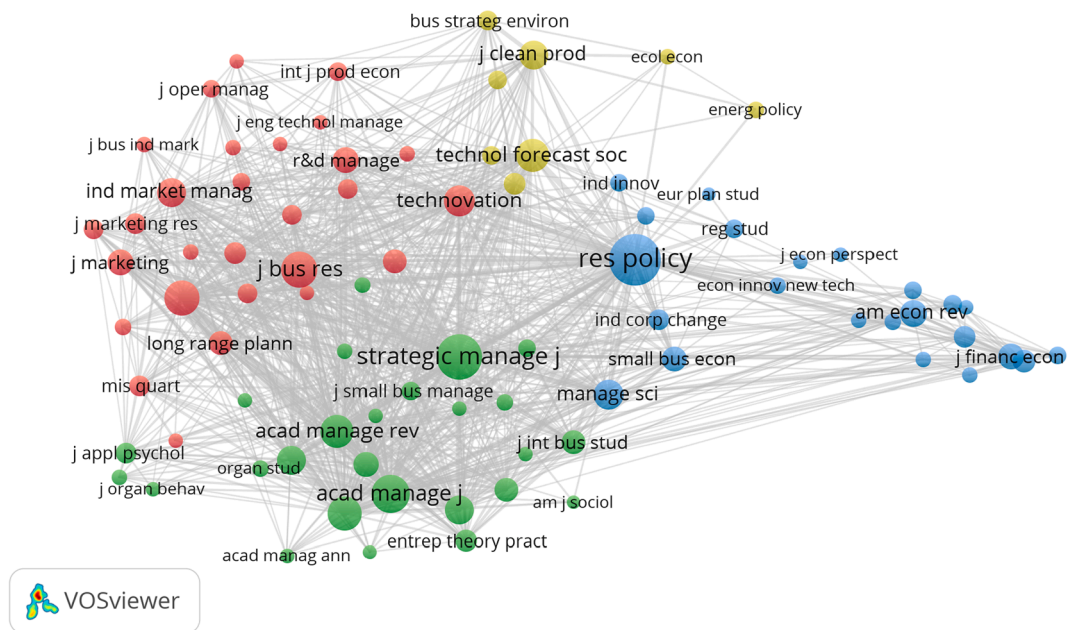


Fig. 5. The source co-citation network of innovation-related publications after COVID-19 pandemic. Sources: Authors' own research.

the top three most cited sources in co-citation clusters following the COVID-19 pandemic, indicating that they have published influential documents related to innovation in the past two years that researchers have co-cited these publications, especially for *Journal of Business Research*.

Figs. 6 and 7 provide the reference co-citation networks of the pre-epidemic and post-epidemic literature, respectively. In Fig. 6, let the minimum number of citations of a reference be 400, and then 40 of the 389,024 cited references meet the threshold, which are divided into four clusters. In Fig. 7, we set the minimum number of citations of a reference as 100, and then 46 of the 164,064 cited references meet the threshold, which are divided into five clusters.

Tables 7 and 8 list the indicators of cited references per cluster in terms of the pre-epidemic and post-epidemic literature, respectively. Combining Fig. 6 with Table 7, Cluster 1 in red contains 16 references, Cluster 2 in green includes 10 references, Cluster 3 in blue contains 8

references, and Cluster 4 in yellow includes 6 references. The most cited references observed before the COVID-19 pandemic in the four clusters are Nelson (1982) with 1,154 citations, Cohen et al. (1990) with 2,002 citations, Fornell et al. (1981) with 1,011 citations, and Barney (1991) with 1,002 citations, respectively. According to Fig. 7 and Table 8, co-cited references following the COVID-19 pandemic are divided into five clusters, and each cluster involves 13 references in red, 10 references in green, 9 references in blue, 7 references in yellow, and 7 references in purple. The most cited references following the COVID-19 pandemic in the five clusters are Fornell et al. (1981) with 469 citations, Cohen et al. (1990) with 500 citations, Nelson (1982) with 149 citations, D. J. Teece et al. (1997) with 281 citations, March (1991) with 270 citations, respectively. Comparing Tables 7 and 8, Nelson (1982), Cohen et al. (1990), and Fornell et al. (1981) are the most cited references in a cluster in terms of two data sets, indicating that these documents have made great contributions to innovation research since published.

Table 5
Indicators of the pre-epidemic publications by co-citation analysis per cluster of cited sources.

Cluster	The number of cited sources	Top 3 most cited sources	citations	Total link strength
1	47	Research Policy	37,372	1,316,736
		American Economic Review	9,063	244,896
		Technological Forecasting and Social Change	5,440	174,860
		Journal of Product Innovation Management	14,118	656,610
2	39	Management Science	12,034	542,782
		Technovation	10,587	466,497
3	20	Academy of Management Journal	18,214	881,678
		Organization Science	13,709	685,251
		Academy of Management Review	13,682	881,678
		Strategic Management Journal	27,902	1,355,582
4	10	Journal of International Business Studies	4,962	246,888
		Journal of Business Venturing	4,477	221,653

Sources: Authors' own research.

Table 6
Indicators of the post-epidemic publications by co-citation analysis per cluster of cited sources.

Cluster	The number of cited sources	Top 3 most cited sources	citations	Total link strength
1	28	Journal of Business Research	4,973	241,089
		Journal of Product Innovation Management	4,547	244,790
		Technovation	3,412	171,883
2	26	Strategic Management Journal	8,613	469,727
		Academy of Management Journal	5,596	294,622
		Organization Science	4,266	236,069
3	23	Research Policy	11,424	444,191
		Management Science	3,143	152,070
		American Economic Review	2,343	73,574
4	8	Technological Forecasting and Social Change	3,858	151,636
		Journal of Cleaner Production	2,877	103,514
		Journal of Business Ethics	1,537	69,731

Sources: Authors' own research.

Furthermore, Laursen et al. (2006), Aghion et al. (2005), Romer (1990), David J. Teece (2007), Grant (1996), and Jansen et al. (2006) are the most cited references in co-citation clusters following the COVID-19 pandemic, indicating that these publications have had a significant impact on innovation research during these years and collectively influence future research directions.

Considering publications and their references, dual-map overlay networks were conducted by CiteSpace, observed before and after the COVID-19 pandemic, as shown in Figs. 8 and 9, respectively. As can be seen, there are two base maps in the figures. Specifically, the left base map represents citing journals of publication, whereas the right base map represents the cited journals of publications. In this way, new publications fall on the left, while their references fall on the right. These two base maps are linked together to display the citation structure according to the citation relation, as well as the discipline distribution of innovation-related journals. In addition, the ovals represent the journal

groups, and the size of these ovals matches the number of journals in a discipline domain (Jin et al., 2019). The different colored connecting lines represent citation paths, indicating the links between different disciplinary regions. The lengths of the vertical and horizontal elliptical axes are proportional to the number of relevant publications and the number of participating authors. As a result, there are some compelling observations through perusal by calculating the z-score-scaled frequency of the citations.

In Fig. 8, there are four main citation trajectories in the first dataset, revealed by two light blue lines and two dark blue lines. These are from 6. *Psychology, Education, Health* to 7. *Psychology, Education, Social*, 6. *Psychology, Education, Health* to 12. *Economics, Economic, Political*, 10. *Economics, Economic, Political* to 12. *Economics, Economic, Political*, and 10. *Economics, Economic, Political* to 7. *Psychology, Education, Social*. The frontier research indicates that these disciplines are actively involved in innovation research, and they rely on knowledge foundations from back guidance.

In Fig. 9, there are three main citation paths in the second dataset with two light blue lines and one dark blue line. The specific trajectories were found to be 6. *Psychology, Education, Health* to 7. *Psychology, Education, Social*, 6. *Psychology, Education, Health* to 12. *Economics, Economic, Political*, and 10. *Economics, Economic, Political* to 12. *Economics, Economic, Political*, respectively, indicating the closer and more important interactions among these domains.

Combining Fig. 8 with Fig. 9, powerful and productive journals for innovation research are identified considering references observed before and after the COVID-19 pandemic. In terms of citing journals, *Research Policy*, *Technological Forecasting and Social Change*, and *Technovation* published more innovation-related documents of pre-epidemic literature, while *Technological Forecasting and Social Change*, *Journal of Business Research*, and *Technology Analysis Strategic Management* focused more on innovation-related documents of post-epidemic literature. Correspondingly, cited journals, such as *Research Policy*, *Strategic Management Journal*, and *Academy of Management Journal*, have always provided robust sources of knowledge on innovation research, both pre-epidemic and post-epidemic.

3.3. Co-occurrence analysis

Co-occurrence analysis reveals the features of publications and indicates the current research hotspots to a large extent because they are the most frequently used or influential words in a document (Wang et al., 2021a). Using the VOSviewer, co-occurrence networks of high-frequency keywords are observed before and after the COVID-19 pandemic, as shown in Figs. 10 and 11, respectively. Each node represents a keyword, and the larger the node, the higher the frequency of the keyword. Similarly, each color represents a cluster, and the link between the nodes indicates the co-occurrence of these two keywords. The distance between keywords directly reflects their relevance, and the shorter the distance, the stronger the relationship between them (Shi et al., 2020). In the first dataset, we set the minimum number of occurrences of a keyword to 100, and 193 keywords met the threshold of the 28,661 keywords were divided into four clusters. In the second dataset, there were 12,819 keywords in total. We set the minimum number of occurrences of a keyword as 100, and 63 keywords that met the threshold were divided into three clusters.

Tables 9 and 10 list the detailed information per cluster of the co-occurrence analysis in the pre-epidemic and post-epidemic period, respectively. According to Fig. 10 and Table 9, Cluster 1 in red contains 79 keywords, Cluster 2 in green includes 48 keywords, Cluster 3 in blue contains 40 keywords, and Cluster 4 in yellow includes 26 keywords. The highest co-occurrence degrees of keywords observed before the COVID-19 pandemic in the four clusters were innovation (4,376), performance (3,213), strategy (1,313), and knowledge (1,832).

In terms of Fig. 11 and Table 10, co-occurrence keywords observed after the COVID-19 pandemic are divided into three clusters, and each

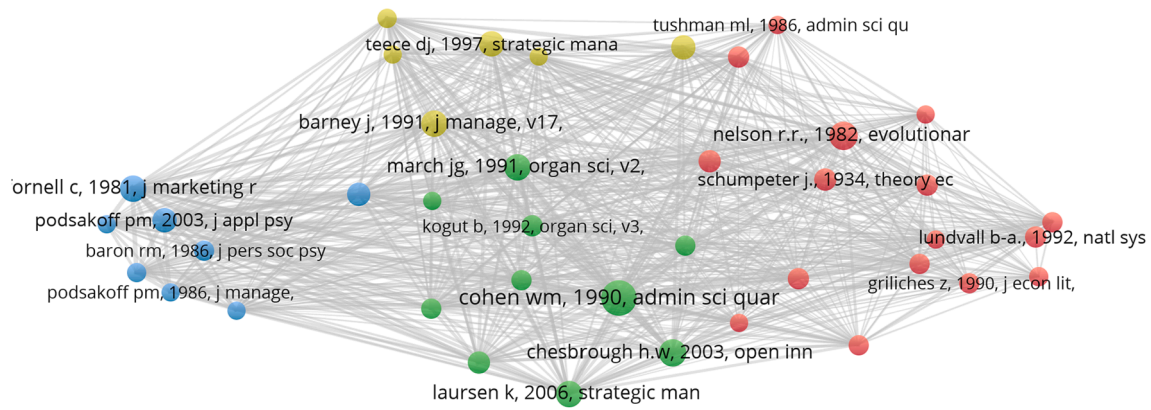


Fig. 6. The reference co-citation network of innovation-related publications before COVID-19 pandemic. Sources: Authors’ own research.

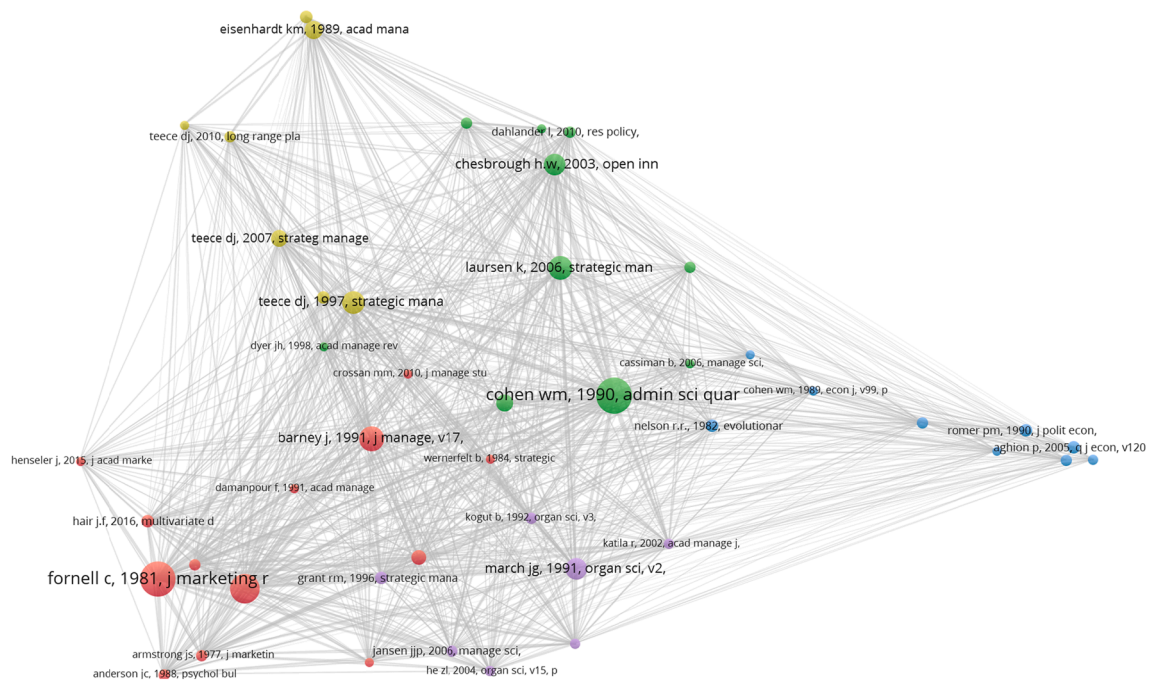


Fig. 7. The reference co-citation network of innovation-related publications after COVID-19 pandemic. Sources: Authors’ own research.

Table 7
Indicators of the pre-epidemic publications by co-citation analysis per cluster of cited references.

Cluster	The number of cited references	Top 3 most cited references	Citations	Total link strength
1	16	Nelson (1982) D. J. Teece (1986) Schumpeter (1934)	1,154 696 686	4,061 2,566 1,893
2	10	Cohen et al. (1990) H. W. Chesbrough (2003) March (1991)	2,002 1,055 956	7,581 3,241 3,843
3	8	Fornell et al. (1981) Podsakoff et al. (2003) Damanpour (1991)	1,011 861 734	3,617 3,334 2,146
4	6	Barney (1991) D. J. Teece et al. (1997) Eisenhardt (1989a)	1,002 900 813	4,057 4,043 1,639

Sources: Authors’ own research.

cluster involves 23 keywords in red, 22 keywords in green, and 18 keywords in blue, where the highest degree keywords in the three clusters are absorptive capacity (314), performance (1,030), and innovation (1,042), respectively. Among them, “innovation” and “performance” are both the highest co-occurrence keywords before and after COVID-19 pandemic, indicating that they play important roles in innovation-related research. Moreover, “firm performance” and “product innovation” became the top three most common keywords in clusters observed after the COVID-19 pandemic, indicating that innovation research has paid more attention to firm performance and product innovation in recent years.

To better reveal the temporal development and specific features of keywords in different groups following the COVID-19 pandemic, we set the minimum number of occurrences of a keyword as 10, and 220 author keywords met the threshold. Fig. 12 shows the overlay co-occurrence network of keywords in the post-epidemic literature by the VOSviewer. The tool colored each keyword in the diagram based on a score that is determined by the average published year for each keyword (Caputo et al., 2021). As a result, the final visualization shows that a dramatic change in keywords occurred between 2020.4 and 2020.8. The

Table 8
Indicators of the post-epidemic publications by co-citation analysis per cluster of cited references.

Cluster	The number of cited references	Top 3 most cited references	citations	Total link strength
1	13	Fornell et al. (1981)	469	1,793
		Podsakoff et al. (2003)	380	1,629
		Barney (1991)	315	1,234
2	10	Cohen et al. (1990)	500	1,932
		Laursen et al. (2006)	310	1,369
		H. W. Chesbrough (2003)	267	985
3	9	Nelson (1982)	149	502
		Aghion et al. (2005)	144	195
		Romer (1990)	141	158
4	7	D. J. Teece et al. (1997)	281	1,307
		Eisenhardt (1989b)	224	431
		David J. Teece (2007)	199	901
5	7	March (1991)	270	1,177
		Grant (1996)	151	729
		Jansen et al. (2006)	134	635

Sources: Authors' own research.

earlier the keyword used the time, the darker the keyword noted the color, from purple to yellow. From a temporal view of the co-occurrence network, most studies concentrated on “innovation efficiency,” “transformational leadership,” and “knowledge management” knowledge management in the earlier stages. In the latest period, some research themes have gained more attention, such as “COVID-19,” “exploratory innovation,” and “frugal innovation.”

For a closer look at topics related to COVID-19, Fig. 13 provides the overlay co-occurrence network of keyword “COVID-19” in the post-epidemic literature. As we can see, studies on COVID-19 refer to “blockchain,” “entrepreneurship,” “innovation,” “emerging markets,” “digital innovation,” and “small and medium-sized entrepreneurship” from far to near, respectively, which show the characteristic that innovation research has been more focused on advanced technologies applied to firms and small and medium-sized entrepreneurship under epidemic environment and the age of information technology. Taken together, innovation studies have evolved from the previous focus on topics of performance, knowledge, and management to more practical

and business or economics-oriented topics in recent years, especially following the COVID-19 pandemic.

3.4. Conceptual structure analysis

To reveal the intellectual structure observed before and after the COVID-19 pandemic, Figs. 14 and 15 show the thematic map of innovation-related publications in business and economics, respectively.

Using Bibliometrix, the top 2,500 high-frequency keywords were considered during each period, and the thematic map was divided into four quadrants with various topics in terms of centrality and density, which provides an intuitive overview of hotspots in innovation-related literature. Centrality measures the level of inter-cluster interaction and explains how well the current keyword is connected to other keywords, whereas density gauges the level of intra-cluster cohesion, and indicates how tightly the keywords in the cluster are connected (Forliano et al., 2021). In this way, well-developed and vital keywords for the relevant field are often located in the first quadrant (upper-right) that could be considered as motor topics. Keywords in the second quadrant (upper-left) are regarded as highly specialized and isolated topics, which are denoted as niche themes. With low-centrality and low-density characteristics, keywords in the third quadrant (bottom-left) may be emerging or declining topics, which have received less attention from researchers. Keywords in the fourth quadrant (bottom-right) are regarded as basic topics that cover important future research directions but are not receiving effective attention at this stage (Lam-Gordillo et al., 2020). Furthermore, each circle represents the keywords with the highest frequencies in the thematic map. The size of the circle is determined by the keyword frequency, and the higher the frequency, the larger the circle.

Before the COVID-19 pandemic, “model,” “systems,” and “adoption” were popular topics of innovation-related publications. The highly specialized topics were related to “behavior,” “creativity,” and “work,” while “financial performance” may be an emerging theme in business and economics. Note that “research and development,” “technology,” and “firms” are at the boundary between the first and fourth quadrant, indicating that these topics may be well developed and gradually become basic themes in innovation research. At the same time, “performance,” “knowledge,” and “impact” are also at the boundary between the third and fourth quadrant, representing that these characteristics may evolve into basic themes from emerging topics in terms of innovation-related studies.

Following the COVID-19 pandemic, “technological innovation,” and “India” have become motor themes, probably because of technology age

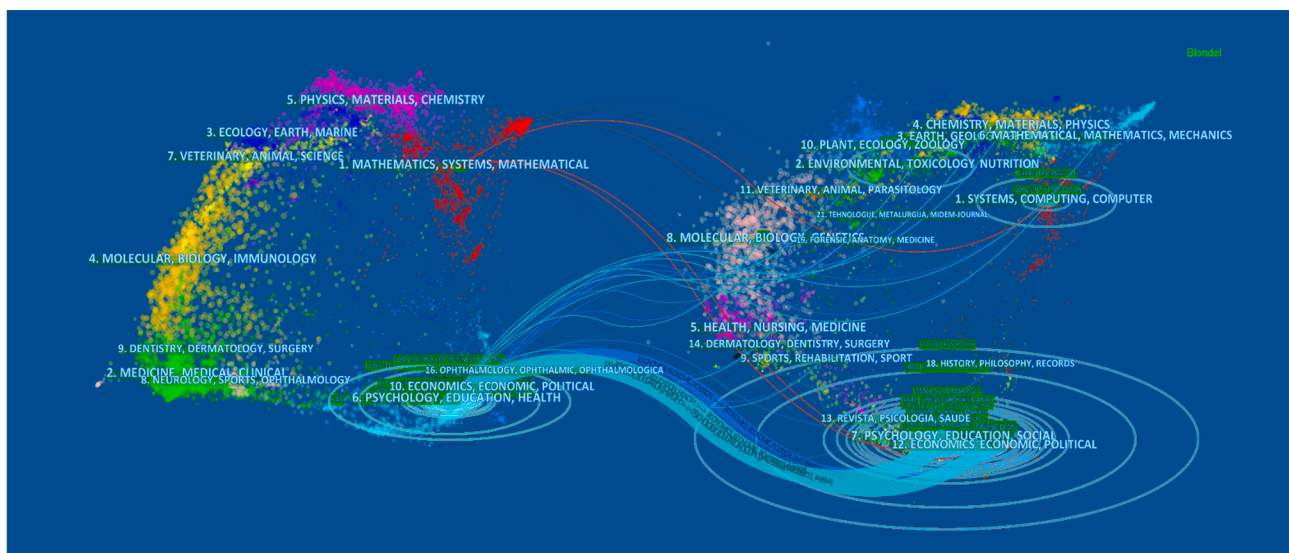


Fig. 8. The dual-map overlay of innovation-related publications before COVID-19 pandemic. Sources: Authors' own research.

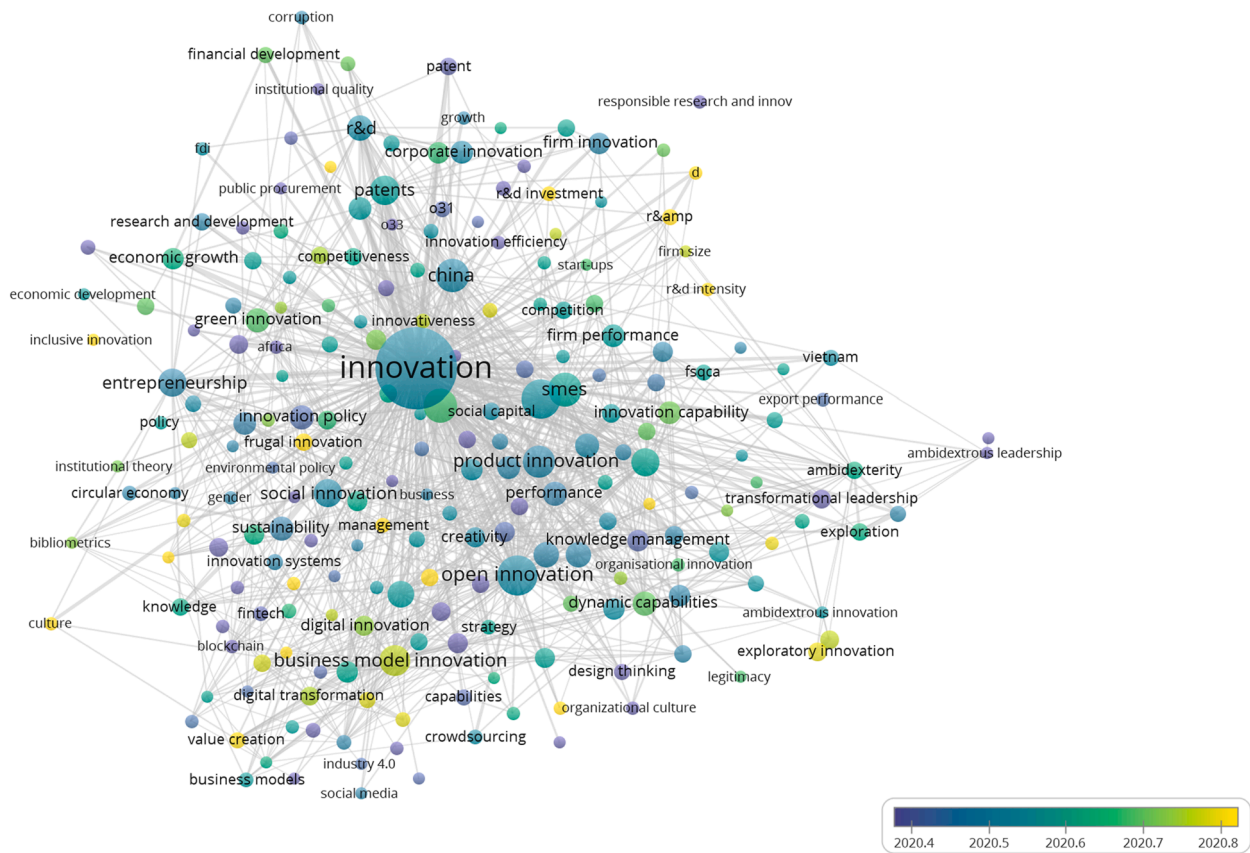


Fig. 12. The keyword overlay co-occurrence network of innovation-related publications after COVID-19 pandemic. Sources: Authors' own research.

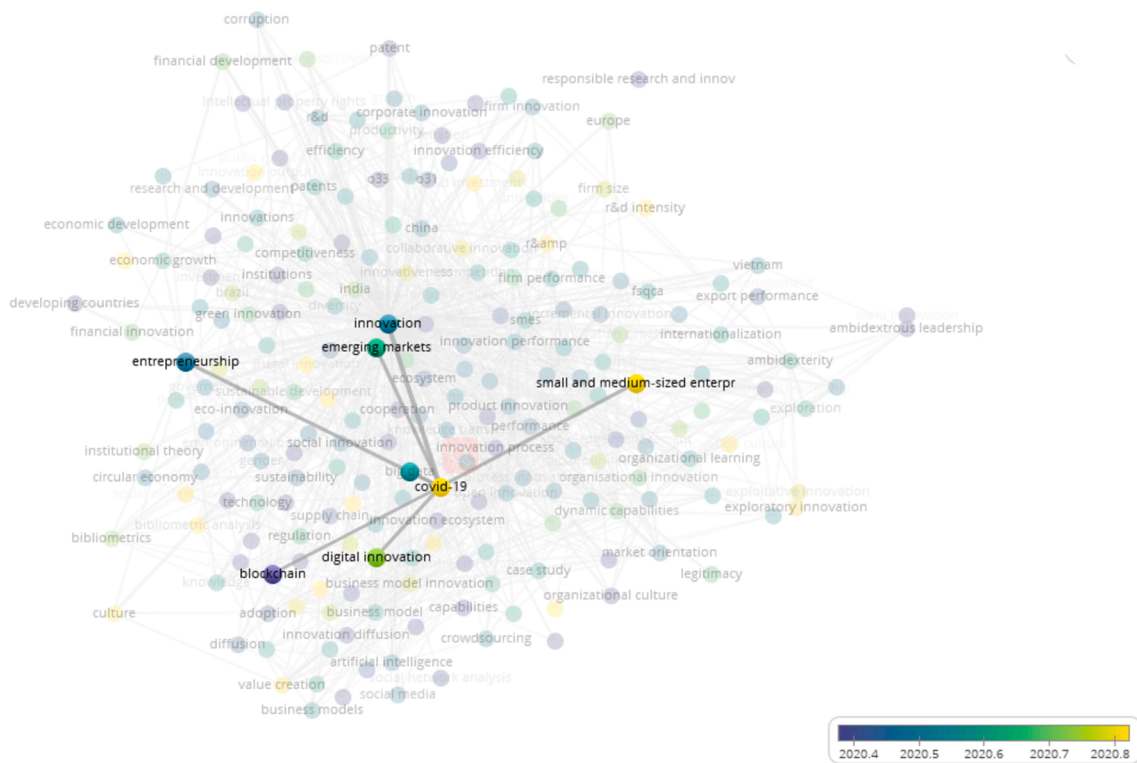


Fig. 13. The overlay co-occurrence network of keyword "COVID-19" in the post-epidemic literature. Sources: Authors' own research.

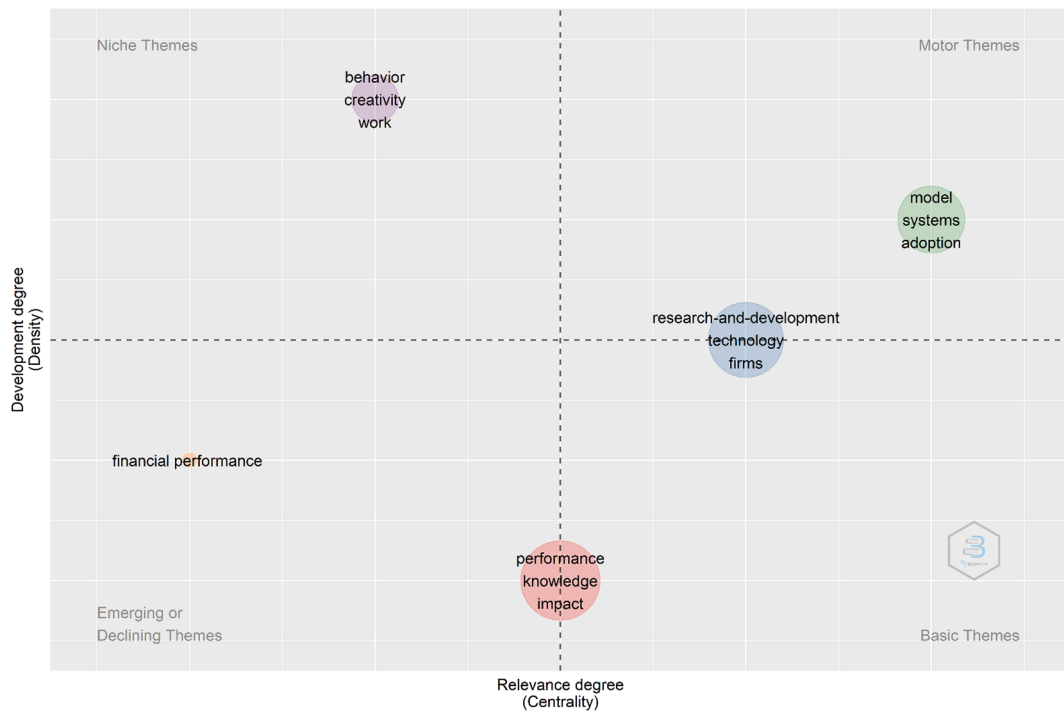


Fig. 14. The thematic map of innovation-related publications before COVID-19 pandemic. Sources: Authors’ own research.

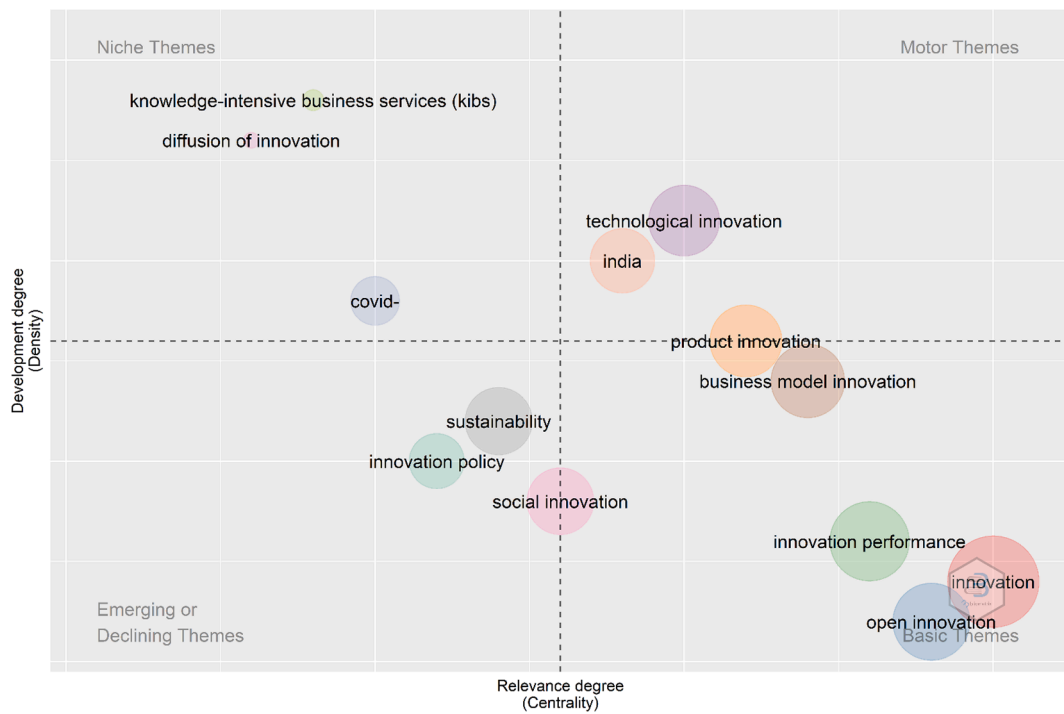


Fig. 15. The thematic map of innovation-related publications after COVID-19 pandemic. Sources: Authors’ own research.

Germany. In this way, we learn what the mainstream is with respect to topics, sources, and countries and regions. For example, researchers from USA pay more attention to innovation-related topics, such as “performance,” “research and development,” and publish their studies in journals such as *Journal of Product Innovation Management* and *Research-Technology Management*.

Similarly, Fig. 19 shows a three-field plot of the post-epidemic literature. From the left field, “performance” is the most salient

keyword, like the pre-epidemic literature. Other terms, such as “impact,” “firms,” “absorptive capacity” are all examined as the critical keywords. In terms of the middle field, *Technological Forecasting and Social Change* are the most active sources, followed by the *Journal of Business Research, Technology Analysis, and Strategic Management*. From the right field, China has become the most relevant country, followed by England, Italy, and the US. This implies that scholars or institutions from China focus more on innovation-related topics like “performance,”

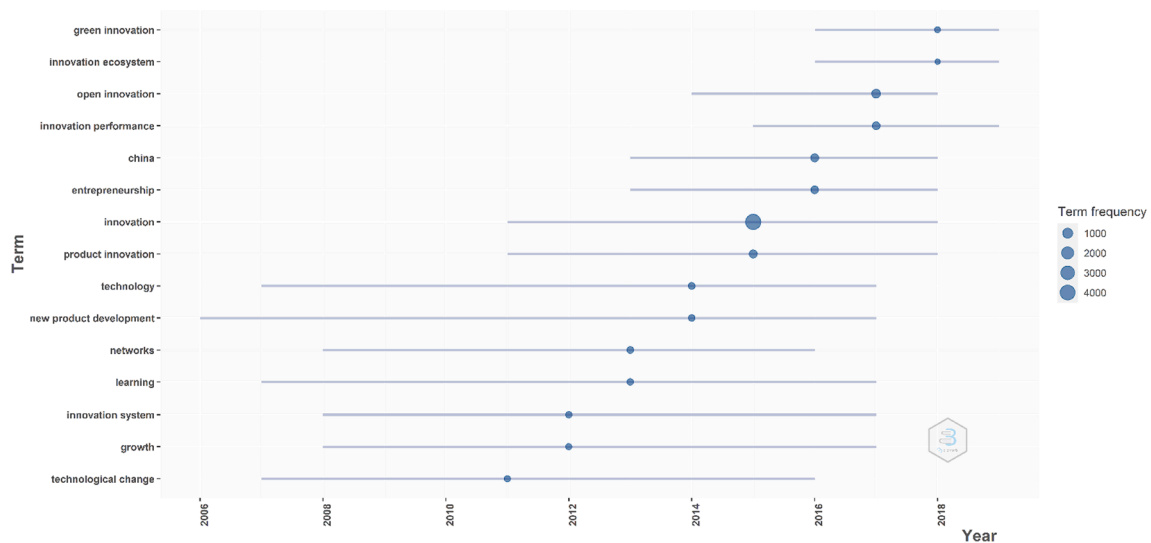


Fig. 16. The trend topics of innovation-related publications before COVID-19 pandemic. Sources: Authors’ own research.



Fig. 17. The trend topics of innovation-related publications after COVID-19 pandemic. Sources: Authors’ own research.

“impact,” and publish their studies in journals such as *Technological Forecasting and Social Change*, *Technology Analysis and Strategic Management*. Compared with three-field plots before and after the COVID-19 pandemic, there are certain changes in the relationships among keywords, sources, and countries and regions of innovation-related publications, and this provides a new range of activities for future research.

4. Discussions

In this section, we further discuss innovation-related research in business and economics observed before and after the COVID-19 pandemic based on the results of the above-mentioned analysis from the perspectives of popular issues, avenues for future research, implications, and limitations.

4.1. Popular issues

Innovation research has been a hot topic and has received increasing attention from scholars since 2010, according to the annual number of publications and citations. The bibliometric results reveal some popular

research directions and issues based on the dual-map overlay. Current studies have paid more attention to performance, research and development, knowledge, management, and strategy of innovation in the fields of *Psychology, Education, Health, Social, Economics, Economic, Political*, indicating that innovation research has shown an interdisciplinary trend. Keyword clusters based on co-occurrence analysis show a degree of popularity to a certain extent, and we summarize three popular issues of innovation-related research observed before and after the COVID-19 pandemic.

The first popular issue, observed before the COVID-19, pandemic is related to innovation, research and development, and technology, with the strongest link strength. The increasing complexity of technology development is rapidly changing the effectiveness of scientific and technological policies (Ekboir, 2003). Almost all firms, regardless of their size or industry type, consider R&D and technology in innovation. Even a world-class firm does not ignore research and development in innovation and technology throughout its management and value chain. The entrepreneur’s motivation, business planning, and cooperation in research and development activities constitute significant factors when considering the core dimension of innovation adoption. Following the

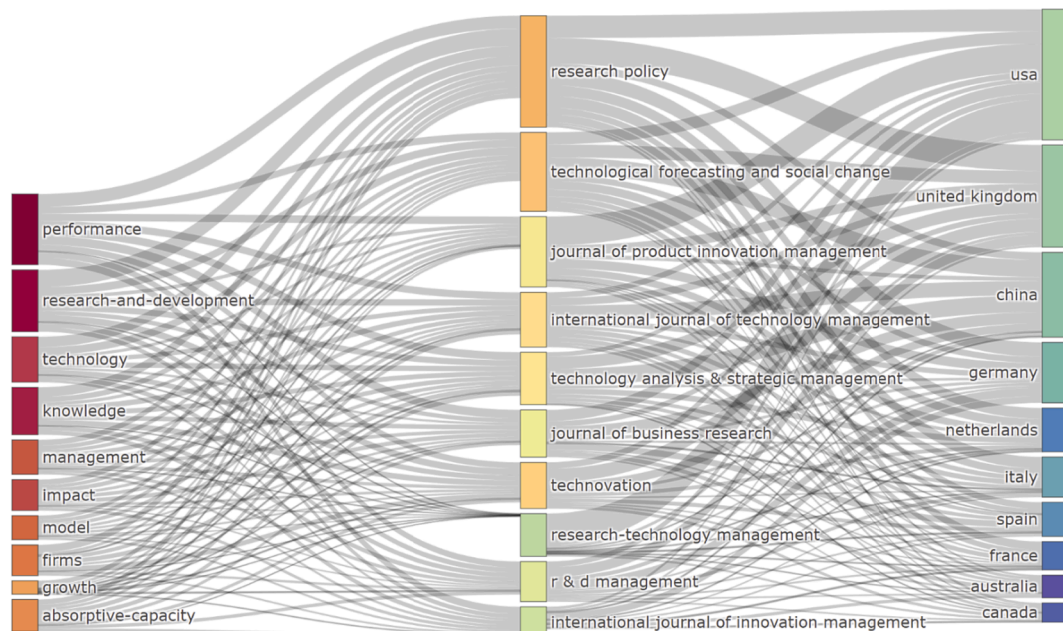


Fig. 18. The three-fields plot of innovation-related publications before COVID-19 pandemic. Sources: Authors' own research.

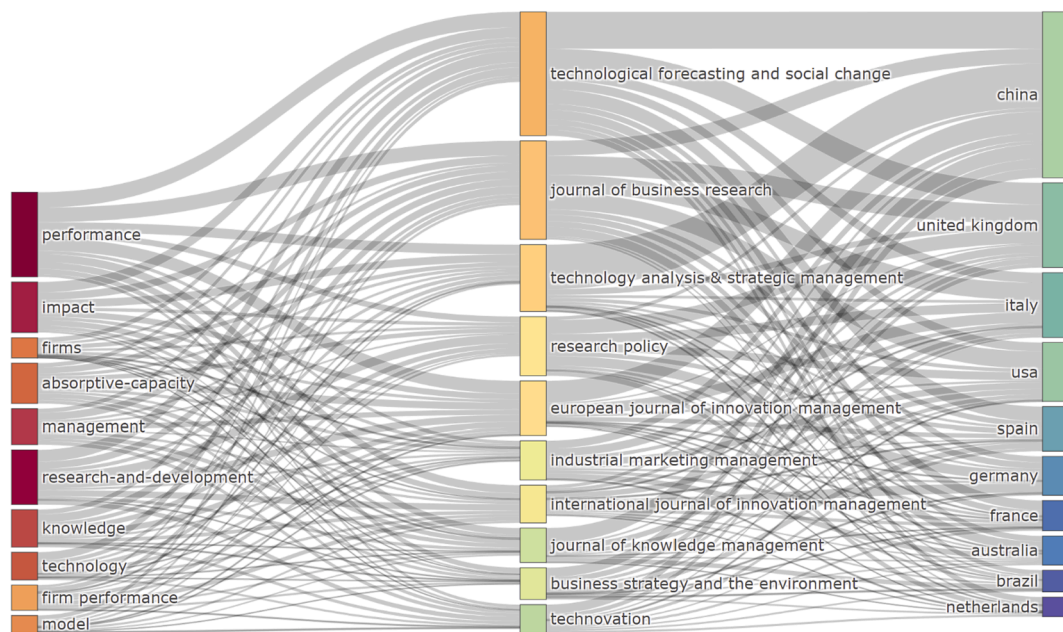


Fig. 19. The three-fields plot of innovation-related publications after COVID-19 pandemic. Sources: Authors' own research.

COVID-19 pandemic, “impact” seems to present a more important connection to innovation than “technology.” Recent studies have focused on this type of innovation research. For example, research and development, patent, and trademark as the determinants of innovation have a significant impact on economic growth (Gyedu et al., 2021). Firms innovate from a set of innovation indicators, such as product, process, organizational, and marketing innovations, to help managers capture the level of innovativeness in these firms’ development (Martinez-Roman et al., 2017). Product innovation is represented by information and communication technology, which refers to a production mode with innovation as the main carrier, especially for green product innovation (Song et al., 2020). Many process industry firms still face challenges for process innovations, but digitalization and Industry 4.0, technologies show great potential from a technological perspective and

promise to provide novel opportunities to industrial firms (Chirumalla, 2021). In terms of organization innovation, it could be embedded in collaborative networks formed by cooperative relationships between partners, and collaborative relational features, such as diversity and strength, which reflect the distribution of a collaborative network, are important factors for organization innovation (Liu et al., 2020). Marketing innovation involves the implementation of new marketing methods that involve significant changes in product packaging, placement, or pricing to market a product, but does not invoke any changes in the core product, and marketing managers expect marketing innovation to positively affect firm value (Tang et al., 2021).

The second popular issue, observed before the COVID-19 pandemic, is related to performance, management, and impact, incorporating theories, empirical studies, and futuristic views on advanced

technologies. For instance, the interest in management innovation is growing and the conviction about its significant role in boosting an enterprise's competitive advantage and performance has recently gained ground (Krasnicka et al., 2018). Drawing on innovation and family business literature, Arzubiaga et al. (2019) examined the largely overlooked family effect in exploratory and exploitative innovation-performance processes via the moderating impact of the family firm image and family involvement in the top management team. Following the COVID-19 pandemic, “knowledge” related research has been conducted in a greater number than “impact” related research in the context of innovation in this group. Some studies have been related to knowledge innovation. For example, in today's business environment with fast-growing communication and information technologies, knowledge management capabilities are a valuable source of innovation. Knowledge management capabilities lead to business model innovation, and their effect is dependent upon the firm's orientation toward risk-taking (Hock-Doepgen et al., 2021). Top management knowledge value and knowledge-creating practices influence open innovation, which, in turn, influences organizational performance (Singh et al., 2021).

The third popular issue, observed before the COVID-19 pandemic, is related to strategy, model, product development, knowledge, absorptive capacity, and network, merging the third and fourth clusters in the co-occurrence analysis. For example, the effectiveness of open innovation differs significantly among firms. The reason could be that there are different ways of implementing open innovation strategies, or it could be the ignorance of the explicit role of business model (Zhu et al., 2019). Advancements in information technology have made organizational boundaries very porous, thereby resulting in a trend toward leveraging external knowledge for innovation. Under such an environment, Cui et al. (2018) offered managers strategies to successfully conduct open innovation projects in deploying effective information technologies and leveraging various types of openness during the two phases. After the COVID-19 pandemic, scholars have paid more attention and time to “firm performance” and “product innovation.” For instance, study whether open innovation practices in firms favor technological innovations and their drivers. Madrid-Guijaro et al. (2021) proposed a model of open innovation based on the human capital approach and the commitment to learning with an emphasis on risk-taking and the formalization of an innovation strategy.

In general, keyword analysis in this study establishes an initial classification to present three popular issues of innovation-related research that are literally spread across a variety of areas in both theory and application, and could have far-reaching implications in the post-epidemic era.

4.2. Avenues for future research

Based on the keyword overlay co-occurrence network and trend topics over time, we summarize three avenues for future innovation studies, following the COVID-19 pandemic, from the perspectives of low-carbon, innovation forms, and the epidemic environment.

In current innovation research, traditional carbon-related studies have faced certain challenges owing to a lack of technologies. However, technology has long been perceived as a dual edged sword for the environment, which assesses its true role in the environmental improvement or deterioration (Tao et al., 2022). To overcome these challenges, scholars have attempted to research green innovation in recent years. For example, the pilot project of low-carbon cities is an important effort to align national goals for climate change governance with local governments' low-carbon behavior. Song et al. (2020) found that the nested structure has a positive effect on policy innovation in pilot projects of low-carbon cities with weak incentives and weak constraints. Although innovation transitions have garnered significant attention, there are also concerns about the elitist character of low-carbon transitions. It is necessary to recognize and foster transitions from the peripheries that offer important opportunities for progressing

low-carbon innovation in practice and open the door to deeper structural transformations (Tirado-Herrero et al., 2021). In the future, innovation research on low-carbon innovation will be a hot topic in line with international policy, particularly for green innovation. First, low-carbon innovation addresses economic and environmental concerns. The patterns of low-carbon convergence determine the effectiveness of mitigating the adverse consequences of climate change. In the context of climate change, low-carbon energy transition and the development of a carbon-neutral society were the most important areas for innovation even during the COVID-19 pandemic; global industrialized nations are grappling with transforming energy networks to support a low-carbon future.

Considering innovation forms, the traditional issues in innovation literature are management, technology, performance, and knowledge. Technologies such as computer vision, internet of things, big data, and artificial intelligence are penetrating all facets of value chains. Taking the industry as an example, it is engaged in an accelerated automation race where industrial automation converts value chains into intelligent, data-driven systems. Companies need to pay attention to the development of related technologies to profit and must incorporate external flows of knowledge to succeed in innovation (Nylund et al., 2020). Different innovation forms can promote managers by consolidating an organization's innovation programs in one place, and they are important for managers to choose the right options for improving the adoption of information technology tools. In general, various innovation forms, such as open innovation, collaborative innovation, and living innovation ideas, have emerged as core strengths of innovation research.

As for innovation research conducted after the COVID-19 pandemic, researchers have paid more attention to innovation in various systems, such as public health systems and economic systems. H. Chesbrough (2020) discussed how to manage innovation as part of the recovery process and derived some lessons from how we have responded to the virus so far, and what those lessons imply for managing innovation during recovery. Brem et al. (2021) analyzed the effects of the COVID-19 pandemic on certain technologies and how to improve our lives and presented technologies that relate directly to the treatment of the virus as well as those that have been used to adapt to the living conditions under this crisis. Therefore, innovation research in post-epidemic environments will attract more scholars to study this topic.

Overall, these avenues could expand upon existing innovation research and identify new perspectives that have been developed in recent years. Future studies may assess innovation research in business and economics by considering low-carbon, innovation forms, and the epidemic environment.

4.3. Implications and limitations

Innovation research is an increasing trend of significant managerial importance, referring to empirical research and a theoretical framework. This study benefits researchers, policymakers, and practitioners in several ways. Focusing on innovation research, this work provides researchers with a comprehensive review and intellectual structure observed before and after the COVID-19 pandemic in the fields of business and economics. Using a series of bibliometric analyses, we summarize the popular issues and avenues for future research. Evidence indicates that scholars augment existing efforts to stress the development view of innovation research and adapt to a post-epidemic environment. In addition to portraying the popular topics emphasized in the existing literature, this exercise identifies multiple research directions in both innovation forms and complex environments, such as collaborative innovation, open innovation, digital technologies, low-carbon policy, and information technology. These popular issues and research fronts have important implications for academics, companies, and policymakers.

Although this study analyzes innovation literature conducted before and after COVID-19 from multiple aspects to minimize the drawbacks,

there are two main limitations. One limitation is related to the dataset. The data in this study were obtained from a single database, the Web of Science database, which may have led to missed publications. In further studies, various databases, such as Google Scholars and Scopus, will be considered for data collection. Another limitation is that there is a bigger gap in the number of innovation studies conducted before and after the COVID-19 pandemic, which may reduce the impact of COVID-19 on innovation research. We will further focus on this study, build upon the results, and expand on these findings. Despite these limitations, this study provides a multidimensional view of innovation research observed before and after the COVID-19 pandemic and could suggest some important implications for related researchers, policy makers, and practitioners.

5. Conclusions

The insights and contributions provided in this study pertain to the focus shift in innovation literature following the COVID-19 pandemic; the study conducts a bibliometric analysis from multiple aspects. Such analyses integrate the results of the characteristics, structure, and development of innovation-related research in business and economics. The main findings are as follows. (1) In recent years, evidence from a performance analysis has shown that innovation research presents an increasing trend and has a greater impact on the relevant studies worldwide. (2) *Research Policy*, *Strategic Management Journal*, *Academy of Management Journal*, and *Journal of Product Innovation Management* were the most influential journals with respect to innovation research before the COVID-19 pandemic, while *Journal of Business Research*, *Technological Forecasting and Social Change* were the most co-cited sources following the COVID-19 pandemic. (3) The top three productive countries before the COVID-19 pandemic were the US, England, and China; following the pandemic, they are still the most productive countries but differ in their rankings. Brazil has become one of the top 10 productive countries in terms of post-epidemic literature. (4) A co-occurrence analysis reveals that “innovation” and “performance” are always the highest co-occurrence keywords in innovation-related research. Following the COVID-19 pandemic, studies related to “blockchain,” “entrepreneurship,” “innovation,” “emerging markets,” “digital innovation,” and “small and medium-sized entrepreneurship” are considered under the post-epidemic environment. (5) According to the conceptual structure analysis, keywords with different features (motor, niche, emerging or decline, and basic) are identified during each period, and potential topics, such as low-carbon, innovation forms, and the COVID-19 crisis, may be the core research directions of the current phase in innovation research.

Based on the results of the analyses, popular issues, avenues for future research, implications, and limitations have been discussed, confirming that innovation research is a promising research direction based on theories, empirical studies, and futuristic views on advanced technologies. In terms of implications, it is important to establish an innovation framework, such as sustainable innovation, open innovation, and green innovation, to improve performance and management in business and economics. For example, innovation measures pave an effective way for the generation of new resources and learning products, which are useful for training managers and employees on digital competences and e-learning in the COVID-19 scenario. Facing the age of information technology and following the COVID-19 pandemic, depending on innovation-related measures, the effects of management and knowledge would be improved from an overall perspective; innovation research is necessary for sustained development and adapting to a complex and dynamic environment. Risk perception of the COVID-19 pandemic has the role of enhancing the link between long-term relationships and innovation capability. It provides a reference for policymakers to understand how the COVID-19 pandemic has affected innovation activities. Enterprise managers react with agility by rethinking and making their resource fluid. This study provides a

comprehensive review of the innovation literature observed before and after the COVID-19 pandemic and identifies multiple aspects of innovation-related publications using a bibliometric analysis, using popular keywords, hot research direction, and most influential studies, which include the theoretical and practical research of innovation conducted before and after COVID-19 pandemic. This work aims to help scholars better understand the features and structures of innovation research in business and economics. Policymakers and researchers alike can use this study to develop innovation research guiding sustainable development following the COVID-19 crisis and its recovery. In general, this study has important implications for academics, companies, and policymakers.

In the future, we will continue to focus on innovation research in the post-pandemic era from the perspectives of both theory and application. More advanced technologies, such as machine learning, linguistic and sentiment analysis, and text mining, will be used to conduct a scientific and comprehensive study.

CRediT authorship contribution statement

Xinxin Wang: Writing – original draft, Formal analysis, Data curation, Conceptualization. **Yong Qin:** Writing – original draft, Software, Methodology, Investigation. **Zeshui Xu:** Writing – original draft, Supervision, Project administration, Funding acquisition. **Marinko Škare:** Writing – review & editing, Supervision, Resources, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgments

This work was supported by the National Natural Science Foundation of China under Grant Nos. 72101168, 71571123, 71771155; the Fundamental Research Funds for the Central Universities under Grant YJ202063; and China Postdoctoral Science Foundation under Grant No. 2021M692259.

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