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Review

Discovering Themes and Trends in Digital Transformation and Innovation Research

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Abstract: In recent years, the relationship between digital transformation and innovation became very popular topics, attracting extensive attention, and inspiring a number of documents. Although much literature discusses the intersection of both fields, most works offer neither a complete nor a truly objective overview of the current state of research. Therefore, there is a need for a comprehensive and objective review of research themes to analyze the intersection. For this purpose, based on the literature collected from the Web of Science (WoS) database published between 1994 and 2021, co-word analysis was carried out to explore research themes and identify the most salient themes in digital transformation and innovation research. The results of scientific output show that digital transformation and innovation is attracting increasing academic interest of scholars from many countries and different fields. The distribution of high-frequency keywords shows that the research in this field is multidisciplinary, including not only many economic and management fields, but also many classical theories and research methods. The clustering results of keywords reveal five clusters of themes: diffusion and adoption of technology and innovation, digital innovation management, digital transformation management, digital platform and ecosystem, and digital entrepreneurship and economy. According to the results of strategic diagram and performance analysis, digital innovation management and digital transformation management are the mainstream of research, while digital platform and ecosystem and digital entrepreneurship and economy have strong development potential. This study provides a snapshot of the thematic development of digital transformation and innovation research, enabling researchers to better master the current situation and suggesting the development trend in the future.

Keywords: digital transformation; innovation; co-word analysis

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1. Introduction

Over the past decade, as a multifaceted and multidimensional phenomenon [1,2], digital transformation dramatically changed the way of doing business [3,4], and firms began to rethink their innovation activities to deal with the challenges and opportunities brought by digital transformation [5]. Recent research in digital transformation and innovation tried to unpack these implications in more specific terms. For example, some studies tried to propose the framework on digital transformation from different innovation perspectives, such as business model innovation [6], and innovation diffusion [7]. Some studies explored the ways of the firm's restructuring the innovation activities to respond to digital transformation, including the reconfiguration and design of the business model innovation process [8–10], the evolution of cross-boundary innovation process [11], and the search and recombination mechanisms of innovation [12]. More broadly, studies show how the different aspects of digital transformation promote innovation processes and outcomes, including analyzing the role of digital technologies in fostering service innovation [13], developing ambidextrous innovation [14], unlocking product–service system innovation [15],

identifying the effect of digital transformation strategies on service innovation [16], and discussing how the level of digital transformation enable business model innovation [17], promotes green process innovation [18], and enhances innovation performance [19].

The rapid advance of research on digital transformation and innovation has come with a need to examine how knowledge is accumulated and developed, and to identify the most important research topics. Accordingly, previous studies made a few important attempts to scrutinize some specific issues [20]. Some journals organized special issues to discuss this topic. In October of 2019, Research Policy published a special issue on the digital transformation of innovation and entrepreneurship. Similarly, in February 2021, the Journal of Product Innovation Management also published a special issue on digital transformation and innovation management. Furthermore, in March of 2021, the Journal of Business Research published a special issue titled "digital or not—the future of entrepreneurship and innovation". In September of 2021, the Journal of Management & Organization published a special issue on digital transformation, robotics, artificial intelligence, and innovation. Recently, in April 2022, Information & Management published a special issue on digital business transformation in innovation and entrepreneurship. Furthermore, previous systematic reviews were performed on this topic, most of which used qualitative methods. Some of these reviews focused on various technological factors, such as artificial intelligence and innovation management [21], as well as Industry 4.0 and sustainable innovation [22]. There were several reviews about digital innovation. A literature review was also conducted from the cross-disciplinary perspective [23]. Additionally, other systematic studies on different aspects of digital innovation, for example with a focus on the development process [24] or the innovation logic [25], on a specific sector [26] or SME [27], and on the employee [28], were carried out. Some reviews recently examined the digital transformation of business model innovation [29,30]. More recently, scholars used bibliometric methods to study this topic, such as using the co-citation analysis to explore the research streams of digital innovation [31] and to investigate the relationship between open innovation and Industry 4.0 [32], as well as employing the bibliographic coupling analysis to map the field of data-driven innovation [33].

Even though these research endeavors provided scholars with an improved understanding of a certain research theme in digital transformation and innovation, a more comprehensive understanding of the overall picture and development of research themes in the field—here being built upon recent literature—is missing. Therefore, this study represents an attempt to disentangle existing and interconnected research streams by performing a co-word analysis, which will hopefully gain meaningful syntheses and help provide researchers with a better understanding of the development state in the digital transformation and innovation field.

The rest of the paper is organized as follows. In Section 2, we discuss the study method and data collection. Section 3 presents the scientific output, summarizes the keywords distribution, then outlines the analysis results obtained from the co-word analysis and elaborates on the findings. Section 4 provides the main conclusions, clarifies the limitations, and indicates future of research.

2. Methodology

2.1. Research Method

Compared with the traditional literature review methods, bibliometric analysis can overcome subjective analysis and has easily accessible databases to synthesize previous research findings. Bibliometric analysis allows scholars to analyze and visualize the state and the evolution of the research field, as well as provides a better understanding of the research fields. In view of this, bibliometric analysis is widely used in various disciplines, such as knowledge management [34], sharing economy [35], electronic word-of-mouth [36], open innovation [37], and organizational learning [38].

In this study, we used an important method of bibliometric analysis, co-word analysis, to carry out our quantitative research. As an important method of bibliometric analysis,

co-word analysis explores the interactions between keywords in a given research field to be identified and described. This approach analyzes the frequency of the co-occurrence of two keywords and reveals the topics and trends in a certain discipline [39]. Co-word analysis is used to explore the intellectual structure of the internet of things field [40] or the coronavirus field [41], to study the topics of technology foresight [42] or library and information science [43], and to analyze the literature in social media research [44] or brand equity research [45] with other bibliometric analysis methods. Furthermore, this method is widely used in the field of innovation [46–48] and was recently used to analyze digital transformation [49,50].

Our research used three phases proposed in previous studies [51,52]. The specific details and the relevant tools used are described below. In the first stage, the research themes are detected. First of all, we extract the frequency of keywords and the co-occurrence frequency of two keywords, which can be used to design a co-occurrence matrix and co-word network. Secondly, we cluster keywords to themes and visualize the relevant themes. In the second stage, the strategic diagrams and thematic networks are built. Based on the results of clustering keywords, we calculate the centrality and density of each theme, as well as draw and describe the strategic diagram. Meanwhile, the strategic diagrams can be supplemented by adding the number of papers and citations associated with the theme to represent more information. Moreover, the characteristics of the thematic network are also further analyzed. In the third stage, the performance analysis is carried out. This process can evaluate the relative contribution of themes to the whole research area and identify the most prominent sub-fields.

In the entire research process, co-word analysis is carried out using some software. Bibexcel is a software tool for bibliometric analysis designed by Swedish scientist O. Perrson. K, and allows for processing of the file format from the WoS databases [53]. In our study, based on the WoS plain text format after deleting duplications and normalizing, Bibexcel is employed to identify the most frequently used keywords and calculate the frequency of keyword occurrences to build the keyword co-occurrence matrix for further analysis. Pajek is a Slovenian free software particularly suited to analyse and visualize the large and complex networks [54]. In our study, Pajek is used to calculate the network indicators and divide the keyword co-occurrence matrix into subcommunities that represent different research subfields. VOSviewer is a software tool for constructing and viewing bibliometric maps based on network data [55]. In our study, based on the keyword co-occurrence data, VOSviewer is applied to optimize the visualization of subcommunities in Pajek for conducting a deeper study on representative topics. Moreover, STATA is employed to plot the themes and keywords versus average year.

2.2. Data Sets

The aim of our study was to search articles that contain both topics: digital transformation and innovation. Among the various existing bibliographic databases, we tended to obtain the data for our study from the Web of Science (WoS) database, which has consistently formatted citation information for their papers and is widely used in many bibliometric studies [56–60]. The search was made on 23 January 2022. In our study, a structured search for topic search query (TS, including title, abstract, and keywords) was conducted on the WoS. Therefore, the query strings used are the following: TS = (”digital transformation and innovation” OR ”digital innovation” OR ”digitization innovation” OR ”digitalization innovation”). Article language was limited to English, document type was limited to journal articles, and Web of Science categories covered business, management, and economics fields. This study carefully examined whether the papers are related to digital transformation and innovation. As a result, a total of 2489 papers, published from 1994 to 2021, were obtained for the next stage analysis (please see Figure 1).

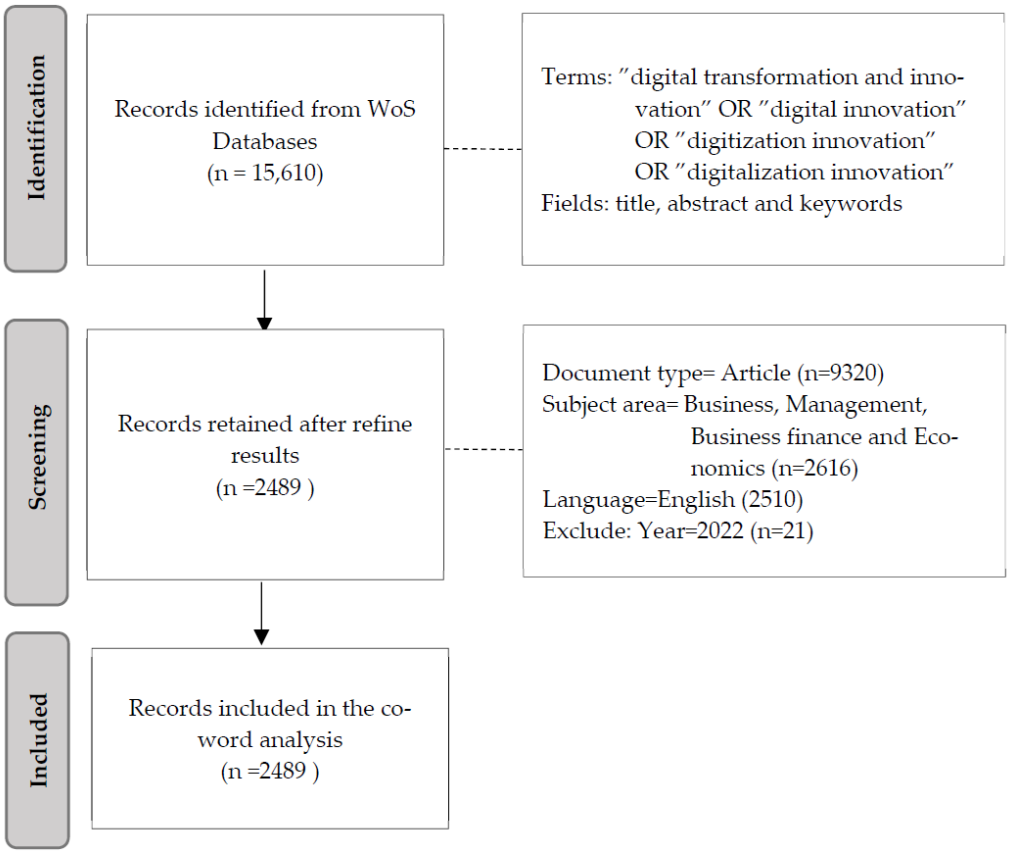

Figure 1. Process of data collection.

3. Results Analysis

3.1. Scientific Output

Figure 2 shows the evolution of the papers and journals on the study of digital transformation and innovation per year from 1994 to 2021. The publications present a relatively stable trend before 1999 and between 2000 and 2011, and the highest number of papers is only 21 published in 2009. Throughout 2012–2021, and especially in the recent past five years, the number of papers increased significantly and accounts for 93.21% of all publications, suggesting that the topic of digital transformation and innovation gradually became the interest of scholars. Moreover, the number of journals also revealed a similar evolution process.

As far as the journal is concerned, the results show that 535 journals are responsible for the 2489 papers. Table 1 lists the journals with twenty or more papers published on the topic of digital transformation and innovation from 1994 to 2021. Note that a large part of the papers were published in Technological Forecasting and Social Change (149 papers, 5.99%). This journal is followed by the Journal of Business Research (99 papers, 3.98%). The rest of the papers were published in 523 other journals. Results also indicate the special preference for this topic among the journals mostly from technology and innovation management, information systems and information management, and general management and business.

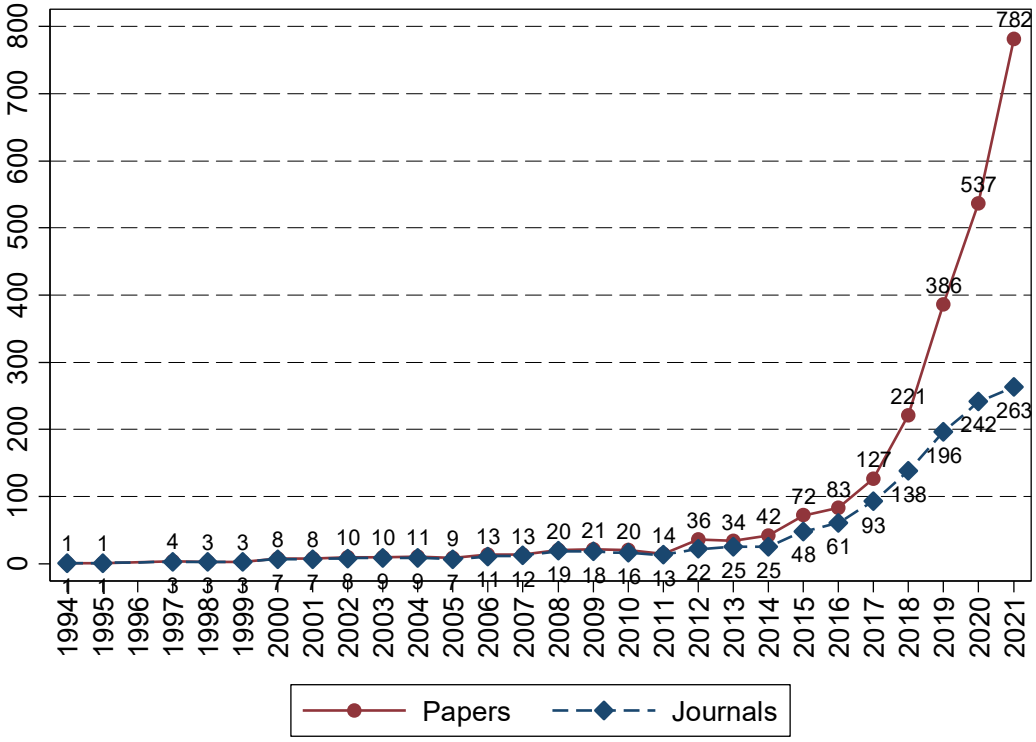

Figure 2. Frequency distribution of papers and journals analyzed by year of publication.

Table 1. Journals with twenty or more papers from 1994 to 2021.

Journals	No. of Papers	%
Technological Forecasting and Social Change	149	5.99
Journal of Business Research	99	3.98
Technology Innovation Management Review	43	1.73
Research Policy	40	1.61
IEEE Transactions on Engineering Management	39	1.57
MIS Quarterly	36	1.45
International Journal of Innovation and Technology Management	35	1.41
Industrial Marketing Management	34	1.37
Technology Analysis Strategic Management	34	1.37
Journal of Product Innovation Management	33	1.33
Technovation	29	1.17
Organization Science	27	1.08
Information Systems Research	25	1.00
Journal of Information Technology	24	0.96
Information Management	23	0.92
Journal of Manufacturing Technology Management	23	0.92
California Management Review	22	0.88
Creativity and Innovation Management	22	0.88
International Journal of Technology Management	22	0.88
Management Decision	22	0.88
—	—	—
Total	2489	100%

As far as authorship is concerned, the results show that 5562 authors are responsible for the 2489 papers. Table 2 gives the information of the fourteen authors with 10 or more papers published on the topic of digital transformation and innovation from 1994 to 2021. Professor Vinit Parida, from Lulea University of Technology, is the most prolific, with 28 papers devoted mostly to entrepreneurship and innovation, focusing on digital innovation, servitization, business model innovation, and others. In the second and third place are Sascha Kraus and Daniel Trabucchi, with 14 papers; they are from Free University of Bozen-

Bolzano and Politecnico di Milano, respectively. Sascha Kraus' main research areas are strategy, entrepreneurship, and innovation, while Daniel Trabucchi's main research field is digital two-sided platforms. Furthermore, David Sjodin and Marko Kohtamaki are usually co-authors with Vinit Parida, and their research fields are mainly in digital innovation, servitization, digital servitization, and value co-creation. In addition, Tommaso Buganza and Daniel Trabucchi, both from Politecnico di Milano, also published 12 papers together.

Table 2. Authors with ten or more papers from 1994 to 2021.

Authors	Current Affiliation	No. of Papers
Parida, Vinit	Lulea University of Technology (Sweden)	28
Kraus, Sascha	Free University of Bozen-Bolzano (Italy)	14
Trabucchi, Daniel	Politecnico di Milano (Italy)	14
Buganza, Tommaso	Politecnico di Milano (Italy)	12
Dong JQ	University of Dublin (Ireland)	11
Henfridsson, Ola	University of Miami (USA)	11
Nambisan, Satish	Case Western Reserve University (USA)	11
Sjodin, David	Lulea University of Technology (Sweden)	11
Del Giudice, Manlio	University of Rome (Italy)	10
Dell'Era, Claudio	Politecnico di Milano (Italy)	10

3.2. Keywords Analysis

Given that the data were downloaded from the Web of Science, papers contain two types of keywords: author-provided keywords (DE) and Keywords Plus (ID). Having initially obtained a total of 6775 author-provided keywords and 2995 Keywords Plus, we then screened them to detect and eliminate duplications. Prior to the analysis, a normalization process was carried out while keeping keywords' meaning unchanged, where: (1) the plural and singular forms of the keywords (e.g., "consumer" and "consumers") were joined, and (2) the acronyms (such as "ICT" and "information and/or communication technology", or "industry 4.0" and "fourth industrial revolution", or "research-and-development" and "R&D", or "innovation diffusion" and "diffusion of innovation") were also joined, and (3) the words in British vs. American English (e.g., "organization" vs. "organisation" and "analyse" vs. "analyze") were also joined. Finally, a subset of 7949 keywords was obtained.

According to the word frequency distribution, we find that the cumulative frequency of 12,204 keywords is less than 10 and only 122 keywords are more than 30. Moreover, there are 2381 keywords with a frequency between 11 and 20, and 1535 keywords with a frequency between 21 and 29. The keywords with a high frequency indicate that there are many scholars that pay attention to them. According to the power law distribution of keywords, we selected the top 122 keywords with a frequency greater than or equal to 30 (see Table 3). The cumulative proportion of these top keywords accounts for about 42% of the total number of keywords, so these keywords may reveal hotspots on digital transformation and innovation from 1994 to 2021.

Table 3. Keywords with thirty or more occurrences from 1994 to 2021.

Keyword	N	Keyword	N	Keyword	N
Innovation	1096	Challenge	92	Exploration	46
Technology	413	Product	92	Community	45
Performance	318	Digital Platform	88	Supply Chain (SC)	45
Strategy	281	Market	88	Blockchain	44
Management	261	Business Model Innovation (BMI)	84	Productivity	44
Digitalization	244	Research and Development (RD)	81	Dominant Logic (DL)	43
Impact	229	Growth	78	User Acceptance (UA)	43
Model	226	Absorptive Capacity (AC)	77	Resource-based View (RBV)	42
Digital Transformation (DTF)	224	Social Media (SM)	77	Behavior	40

Table 3. *Cont.*

Keyword	N	Keyword	N	Keyword	N
Information Technology (IT)	220	ICT	74	Infrastructure	40
System	220	Artificial Intelligence (AI)	71	Start-up (SU)	40
Knowledge	208	Competitive Advantage (CA)	70	Digital Divide (DD)	39
Business Model (BM)	196	Evolution	66	Innovation Management (IM)	39
Firm	170	Co-creation (CC)	65	Sharing Economy (SE)	39
Digital Innovation (DI)	168	Governance	65	Technological Change (TC)	38
Capability	167	Collaboration	64	Trust	38
Dynamic Capability (DC)	151	Diffusion	64	Consumer	37
Perspective	150	Knowledge Management (KM)	64	Digital	37
Entrepreneurship	147	Service	64	Experience	37
Network	142	Determinant	62	COVID-19	36
Big Data (BD)	133	Technological Innovation (TI)	61	Digital Servitization (DS)	36
Framework	132	Product Development (PD)	59	Product Innovation (PI)	36
Adoption	130	Creation	58	Acceptance	34
Business	127	Dynamics	58	Disruptive Innovation (DI)	34
Internet	127	Integration	58	Engagement	34
Industry 4.0	126	Digital Economy (DE)	57	Boundary Resource (BR)	33
Digitization	121	Policy	56	Consumption	33
Competition	120	Servitization	56	Creativity	33
Information	120	Sustainability	56	Fintech	33
Future	118	Implementation	54	Success	33
Organization	116	Antecedent	53	Environment	32
Design	114	E-commerce (EC)	53	Science	32
Value Creation (VC)	108	Opportunity	53	China	31
Open Innovation (OI)	105	Case Study (CS)	52	City	31
Digital Technology (DT)	104	Service Innovation (SI)	52	Communication	31
SME	103	Information System (IS)	51	Market Orientation (MO)	31
Ecosystem	102	Value Co-creation (VCC)	50	Economics	30
Platform	97	Digital Entrepreneurship (DES)	49	Exploitation	30
Industry	95	Internet of Things (IOT)	49	Smart	30
Firm Performance (FP)	94	Work	48	Supply Chain Management (SCM)	30
Transformation	93	Architecture	46		

According to the statistic results of Table 3, "Innovation" ranks top one, and it is followed by "Technology", "Performance", "Strategy", "Management", and other topics. The top 122 keywords cover many areas, such as different kinds of new generation technologies (e.g., "big data", "artificial intelligence", "internet of things", "social media", and "blockchain"), innovation activities (e.g., "open innovation", "business model innovation", "technological innovation", "product innovation", and "service innovation"), management functions (e.g., "strategy", "knowledge management", "supply chain management"), mainstream theory and method (e.g., "dynamic capability", "absorptive capacity", "resource-base view", and "case study"), groups (e.g., "firm", "organization", "SME", and "consumer"), and so forth. These abundant keywords further illustrate the complexity of this research field. These broad top keywords illustrate an interconnection between research on digital transformation and innovation and the specific aspects of digital and innovation, as well as other issues of management and economics deriving from these practices. It further shows that this research field is extensive and needs multidisciplinary scholars to give full play to their great potential.

Based on the keyword frequency distribution, we can perform further keyword co-occurrence frequency analysis. According to the method of matching the keyword of Bibexcel software, we pair the keyword by co-occurrence. Analyzing the distribution of keyword pairing frequency, we find that the frequency of 4707 keyword pairs is less than 10, and only 13 keyword pairs have more than 10 frequencies. Moreover, the cumulative frequency of 857 keyword pairs that appeared more than 10 times is about 54.67%, which are significantly important research points. Table 4 further shows the first 20 keyword

co-occurrence pairs in frequency. From Table 4, we can see that keyword co-occurrence pairs are regular, which effectively shows the interrelatedness of the keywords and reveals the conceptual structure of the research field.

Table 4. The first 20 keyword co-occurrence pairs in frequency.

Keyword Co-Occurrence Pairs (1–10)	Frequency	Keyword Co-Occurrence Pairs (11–20)	Frequency
Innovation-technology	210	Business model-innovation	107
Innovation-strategy	172	Innovation-knowledge	106
Innovation-performance	163	Firm-innovation	100
Impact-innovation	127	Capability-innovation	89
Innovation-model	120	Innovation-perspective	80
Digitalization-innovation	119	Innovation-network	79
Innovation-management	118	Entrepreneurship-innovation	75
Innovation-system	113	Business-innovation	72
Digital transformation-innovation	111	Dynamic capability-innovation	70
Information technology-innovation	111	Competition-innovation	69

3.3. Research Themes Analysis

To reveal the potential research themes in digital transformation and innovation from 1994 to 2021, VOSviewer and Pajek software with the Kamada–Kawai algorithm were used to analyze the top keywords co-occurrence matrix obtained by the Bibexcel software. The Kamada–Kawai algorithm is a graphic rendering algorithm based on the spring system, which can minimize the gross energy in the whole system [61]. We adopted the Kamada–Kawai algorithm realized by Pajek to divide the final keyword co-occurrence relations into different clusters, and VOSviewer was then employed to visualize these clusters. The clustering results of top keywords are shown in Figure 3, and the research themes and the keywords contained therein are shown in Table 5.

Table 5. Clusters and topics.

Cluster	Number of Keywords	Keywords
1 Diffusion and adoption of technology and innovation	37	acceptance, adoption, behavior, co-creation, communication, community, consumer, consumption, creativity, design, determinant, diffusion, digital divide, digital, dominant logic, e-commerce, engagement, environment, experience, impact, information system, information, innovation, model, network, opportunity, organization, perspective, service innovation, service, sharing economy, social media, technology, trust, user acceptance, value co-creation, work
2 Digital innovation management	26	absorptive capacity, antecedent, business, capability, case study, collaboration, competitive advantage, digital innovation, dynamic capability, exploitation, exploration, firm performance, information technology, innovation management, integration, knowledge management, management, market orientation, open innovation, performance, product development, product innovation, research and development, resource-based view, small and medium-sized enterprise, technological innovation
3 Digital transformation management	24	artificial intelligence, big data, blockchain, business model innovation, business model, challenge, Covid-19, digital servitization, digital transformation, digitalization, digitization, framework, future, implementation, industry 4.0, internet of things, internet, product, servitization, smart, supply chain management, supply chain, sustainability, transformation

Table 5. *Cont.*

Cluster	Number of Keywords	Keywords
4 Digital platform and ecosystem	21	architecture, boundary resource, China, competition, digital platform, disruptive innovation, dynamics, economics, ecosystem, evolution, fintech, governance, industry, infrastructure, market, platform, science, strategy, system, technological change, value creation
5 Digital entrepreneurship and economy	14	city, creation, digital economy, digital entrepreneurship, digital technology, entrepreneurship, firm, growth, information and communication technology, knowledge, policy, productivity, start-up, success

Figure 3 shows a grouping around five clusters, represented by red, green, blue, yellow, and purple, respectively. Each cluster represents a research theme of subfield in digital transformation and innovation field. Clusters are labeled according to the respective keyword name of the dominant node. By analyzing the core keywords, this study selected representative literature and presented research fields of different clusters.

The first cluster contains 37 keywords constituting about 30.3% of the co-word network, and comprises studies on diffusion and adoption of technology and innovation. In the digital age, the effect of the adoption of various technologies on innovation activities is a typical topic of concern for scholars. Some scholars paid attention to the characteristics and logic perspective of service innovation in the digital age and the process model of digital service innovation [62–66]. Some studies argued the role of social media in facilitating knowledge flow to promote innovation activities [67–69]. Other studies stated the role of user communities in managing the interaction between firms and their communities to support and improve innovation [70,71]. Furthermore, the research on innovation diffusion and adoption became a hot topic. The studies analyzed the change law and mode at different levels [72–74]. More representative studies focused on the influencing factors of innovation diffusion and adoption at the subject level of individual [75], organization [76–79], and country [80,81], respectively, and the comprehensive analysis of multiple factors [82–85].

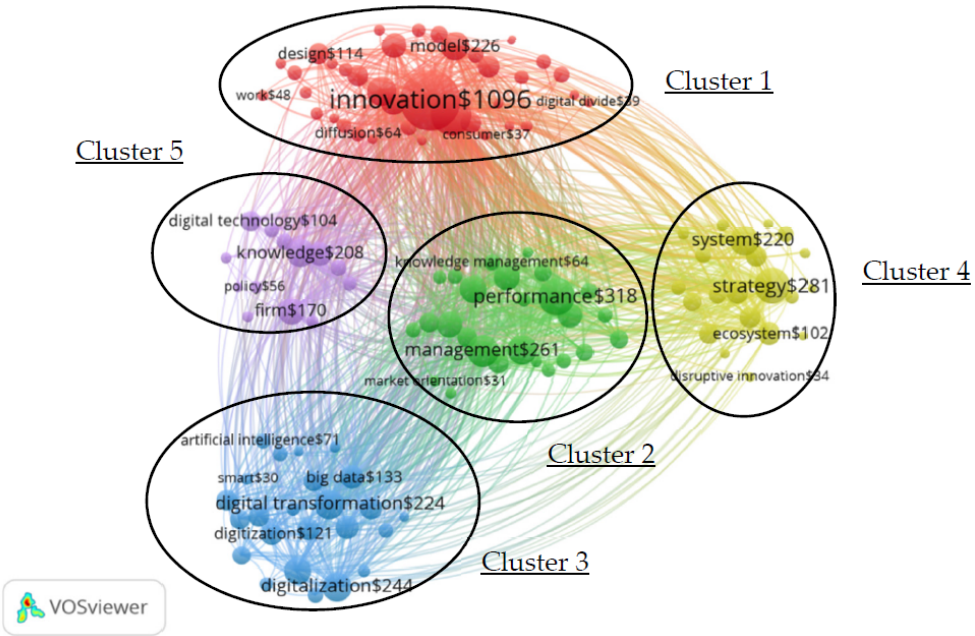

Figure 3. Clusters of keywords identified in the digital transformation and innovation research.

The second cluster contains 26 keywords constituting about 21.3% of the co-word network, and deals with studies on digital innovation management. Information technology has a positive effect on innovation activities by shifting innovation process and

outcome [86,87], enhancing innovation capability [88,89], improving innovation efficiency and performance [90–92], etc. At the same time, the emergence of digital innovation also attracted the attention of scholars. The studies conceptualized and proposed the framework [93–96], addressed the effect [97], and examined the influencing factors, such as capability and knowledge [98–102]. Furthermore, as a new innovation paradigm, the research on open innovation in the digital age also has certain significance, including the process mechanism and influencing factors [103–105].

The third cluster contains 24 keywords, constituting about 19.7% of the co-word network, and includes studies on digital transformation management. The academic researchers paid more attention to the digital transformation and resultant business model innovation. The most cited articles associated with digital transformation identified different strategies and stages [106,107], analyzed the effect [108], and explored the influencing factors [109,110]. Other works associated to the digital transformation of business models proposed the definition and framework [111,112], and examined the effect [113,114]. Meanwhile, digitization and servitization are viewed as the most typical transformation trends in industrial firms. The studies examined the relationship between digitalization and servitization and their effect on performance [115–117], described the types and processes of digital servitization [118–120], and explored the relationship between digital servitization and business model innovation [121,122]. What is more, as a new level of organization, the rise of Industry 4.0 is due to significant development of the advanced technologies [123], so as to run the firms' business process by adopting digital technologies [124]. The studies explored how the firms employ the various technologies to reinvent their business model [125–128] and improve the innovation process [129–131].

The fourth cluster contains 21 keywords, constituting about 17.2% of the co-word network, and relates to studies on digital platforms and ecosystems. As important organizational forms, platforms and systems play a significant role in promoting innovation activities and increasing value creation in the digital age. Previous studies discussed the role of the digital platform from the engineering perspective, economic perspective, and organizational perspective [132]. The engineering perspective views digital platforms as technological architectures [133–135], the economic perspective regards digital platforms as markets that facilitate efficient interactions of transaction subjects [136–138], and the organizational perspective emphasizes digital platforms as technological mechanisms and social arrangements [139–141]. Meanwhile, with regard to the systems and ecosystems based on value creation networks in the digital age, the studies analyzed how the firms cultivate their innovation capability [142,143] and management innovation tensions [144]. Furthermore, based on the inter-organizational perspectives on ecosystems, the digital platforms can promote the autonomous agents of ecosystems to interaction [145], and the relevant studies also analyze how the platform firms enhance the innovation capability and promote an innovation process to create and capture value [146–149].

The fifth cluster contains 14 keywords, constituting about 11.5% of the co-word network, and explores studies on digital entrepreneurship and economy. As a result of the multiple instances of the integration of technology and entrepreneurship, technology entrepreneurship in the digital era attracted the attention of scholars. The articles proposed the definition and the framework of digital entrepreneurship [150,151]. Other works also focused primarily on the effects of digital technologies on the entrepreneurial process [152–155]. Meanwhile, digital technology also plays an important role in promoting economic growth and enhancing productivity and economic competitiveness [156–159].

3.4. Thematic Network and Strategic Diagram Analysis

Table 6 shows the network characteristics of the five clusters. The density and clustering coefficients of all the five clusters are higher than that of the global network, suggesting that the clusters have stronger internal relationships and represent different research fields. Furthermore, as shown in Figure 3, the topics in Cluster 1, Cluster 2, Cluster 3, and Cluster 4 tend to associate with other clusters, which suggests that these clusters are not independent

research fields. So Cluster 1 has many associations with Cluster 2, Cluster 2 has many associations with Cluster 1 and Cluster 3, Cluster 3 has many associations with Cluster 1 and Cluster 2, and Cluster 4 has many associations with Cluster 1, Cluster 2, and Cluster 3. In contrast, Cluster 5 has more links with other clusters and mostly collaborates with topics within itself.

Table 6. Associations and network indicators of the five clusters.

Cluster	Links between or within the Clusters					Degree Centralization	Closeness Centralization	Betweenness Centralization	Density	Clustering Coefficient
	C1	C2	C3	C4	C5					
C1	3794	4362	3652	3160	1992	0.1889	0.4514	0.0067	0.4107	0.427
C2	4362	2379	2863	1927	1418	0.0500	0.4904	0.0030	0.4769	0.478
C3	3652	2863	1938	1716	999	0.0870	0.5009	0.0027	0.4601	0.465
C4	3160	1927	1716	1150	866	0.1947	0.5738	0.0119	0.4119	0.433
C5	1992	1418	999	866	374	0.1410	0.4941	0.0088	0.4396	0.451
Global network						0.2504	0.4984	0.0021	0.3768	0.409

To describe the development status of the five clusters, we built two types of strategic diagrams, which are shown in Figures 4 and 5, respectively. In Figure 4, the area of the graph is proportional to the number of papers associated with each theme; while in Figure 5, the area of the graph is proportional to the number of citations of the papers associated with each theme.

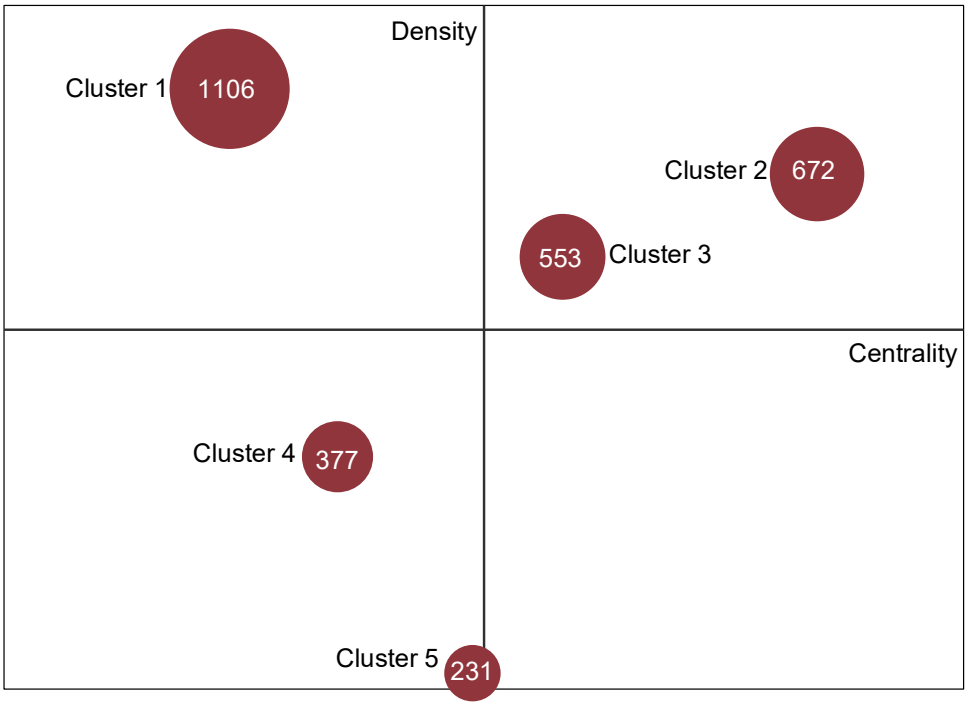

Figure 4. Strategic diagram based on number of papers published.

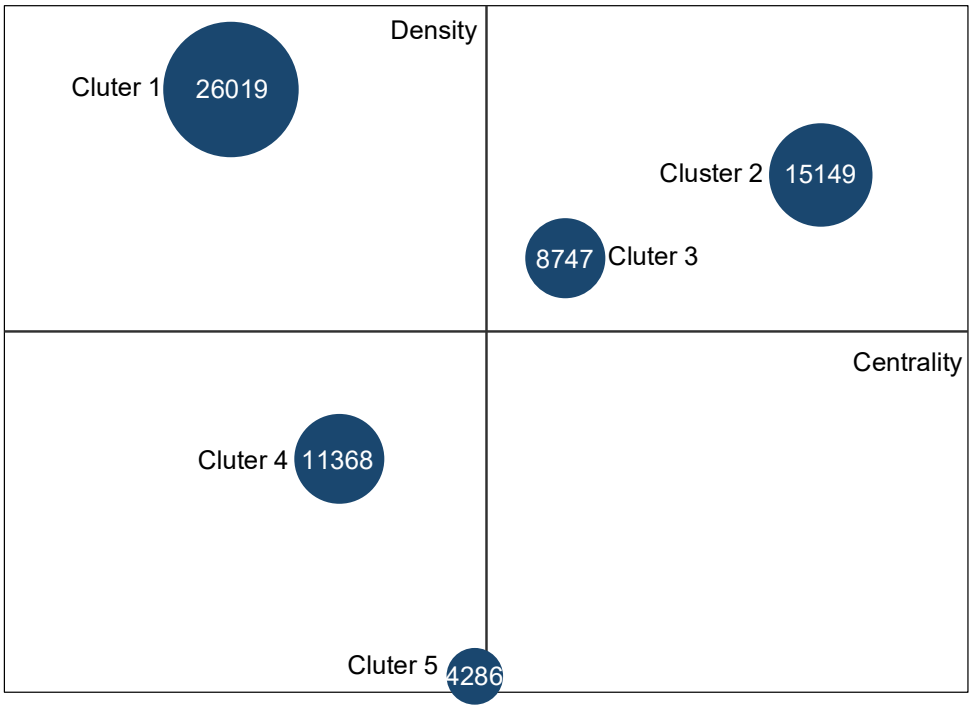

Figure 5. Strategic diagram based on number of times the papers was cited.

As shown in Figures 4 and 5, Cluster 2 and Cluster 3 are located in the first quadrant, with both relatively high density and centrality, showing that these clusters not only have strong internal interactions, but also externally collaborate with other clusters. Thus, compared with the other clusters, research in Cluster 2 and Cluster 3 are the dominant subfields of digital transformation and innovation. Actually, the research on transformation and digital innovation in these two clusters not only involves the traditional themes in the field of technological innovation management and information systems, but also represents the achievements of many interdisciplinary fields.

With low centrality and high density, Cluster 1 is located in the second quadrant, showing that this cluster has strong cohesion and maturity, but few associations with the other clusters. This is because studies centered on innovation and technology could be seen as a part of the field of technology and innovation management, and mostly associated with those topics in Cluster 2 and Cluster 3. Meanwhile, for Cluster 1, it deals with the research on the diffusion and adoption behavior of individuals and organizations, involving psychology, management, and other multidisciplinary fields, and has a relatively mature self-development and seldom associates with topics in the other clusters.

In contrast, Cluster 4 and Cluster 5 are in the third quadrant, with relatively low density and centrality, indicating that these two clusters loosely interact with their internal topics and have few relationships with the other clusters. The reason may be that, as a context, Cluster 4 and Cluster 5 contain the complex topics, which are mostly related to emerging technologies, economic development, science policy, and technological change, and involve content at macro and micro levels and contexts that distract scholars from interdisciplinary fields. Consequently, these topics in two clusters are unstable and heterogeneous, resulting in less contacts and smaller scales.

3.5. Performance Analysis

In previous studies on co-word analysis, scholars put forward the concepts of "frontier of relevance" or "influence zone" to identify the most cited keywords, and their impact was measured by the number of papers in which they appear [160,161]. These keywords are considered to be well developed and important for the construction of related fields. To identify the frontier of relevance, this study compared the number of papers with

the average times cited, as shown in Figures 6 and 7, and also depicts these results for each cluster.

Whether keywords can become a more extensive "stream of research" depends on whether they are located in the upper right-hand corner of the figure. The analysis of streams of research (see Figure 6) reveals that "innovation", "technology", "information technology (IT)", and "model" represent a stream of research, but the number of citations is still quite low. The clustering results (see Figure 3) show that "information technology (IT)" and other three keywords belong to different clusters. The former belongs to Cluster 2, which involves the research of innovation management, while the latter belongs to Cluster 1, which involves the research of innovation diffusion and adoption. Meanwhile, Figure 6 also shows that "architecture", "technological change (TC)", and "environment" have relatively high citation counts, yet the impact is still fairly low. These keywords belong to Cluster 1 (innovation, technology, and adoption) and Cluster 4 (system, value creation, and platform), which extend the boundaries of important and related fields (see Figure 6).

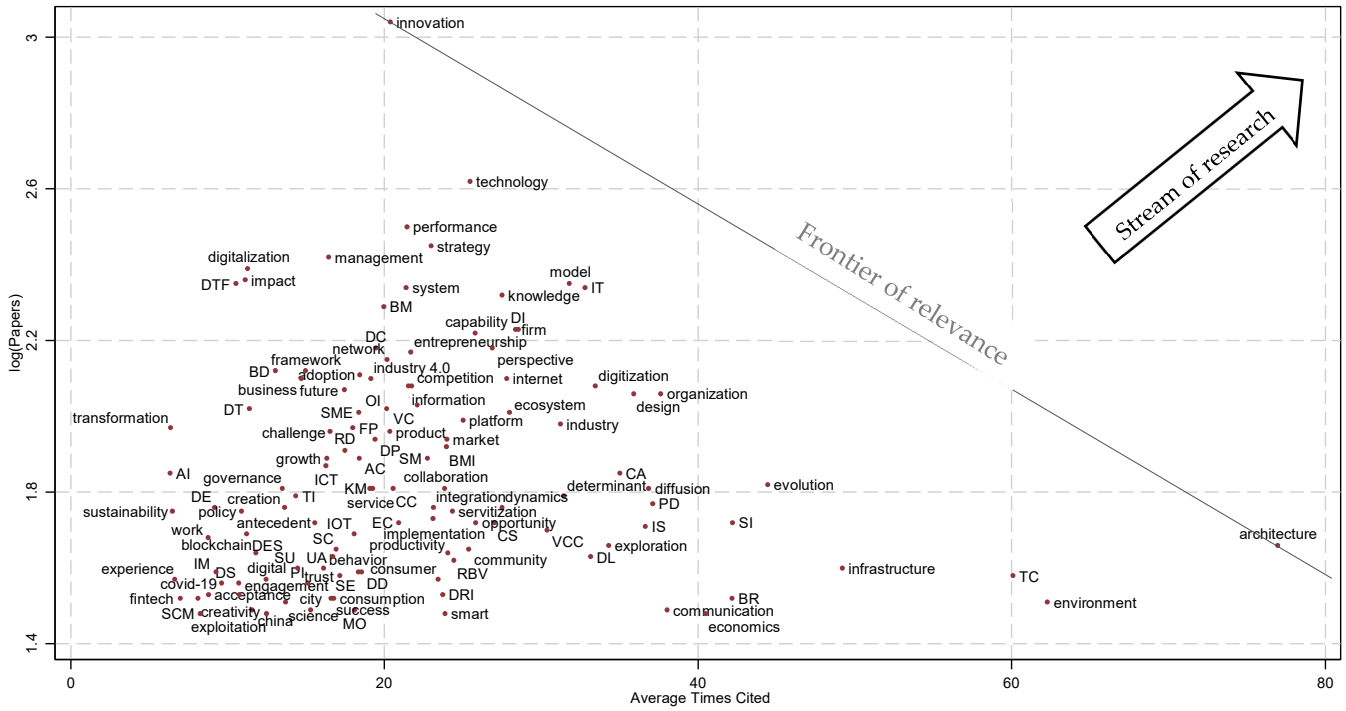

Figure 6. Analysis of streams of research on the most prominent keywords.

Furthermore, according to Figure 7, Cluster 1 and Cluster 2 are potentially important streams of digital transformation and innovation research, as they are trending toward the top right of the graph. Figure 6 also shows that Cluster 5 (entrepreneurship and digital technology) never reached the high level of relevance in academic research that the other clusters have, according to citations.

This study gives a more complete map of the most recent keywords and the relative relevance, which is measured by calculating the ratio between the number of times a keyword is cited and the number of papers including the keyword by average year (see Figures 8 and 9). This analysis can depict how different keywords impact the research field and how they evolved, which is a longitudinal analysis of the most important themes.

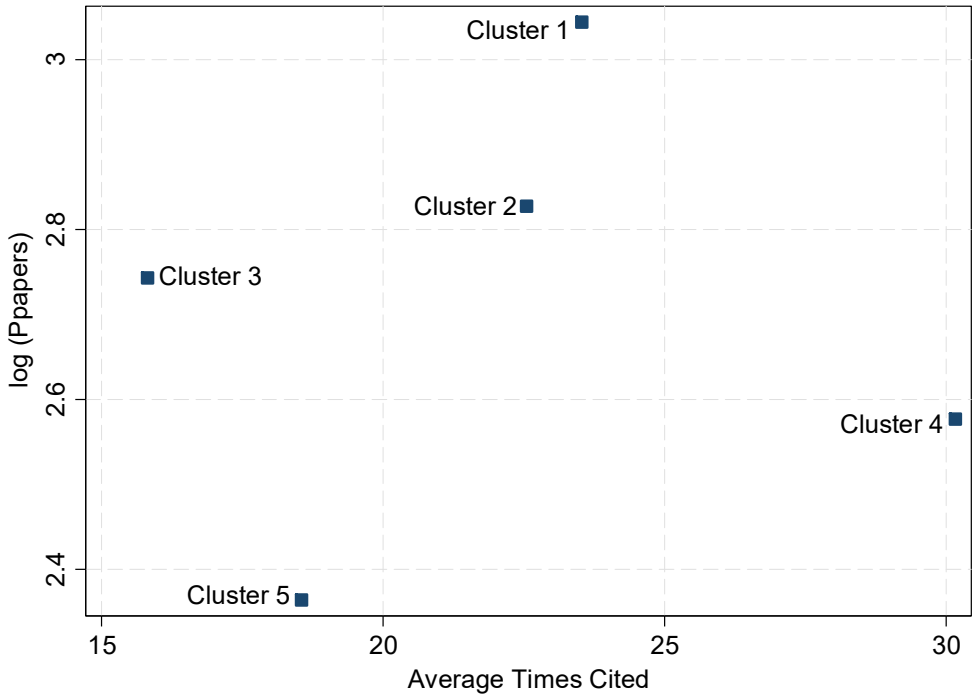

Figure 7. Analysis of streams of research on the most prominent clusters.

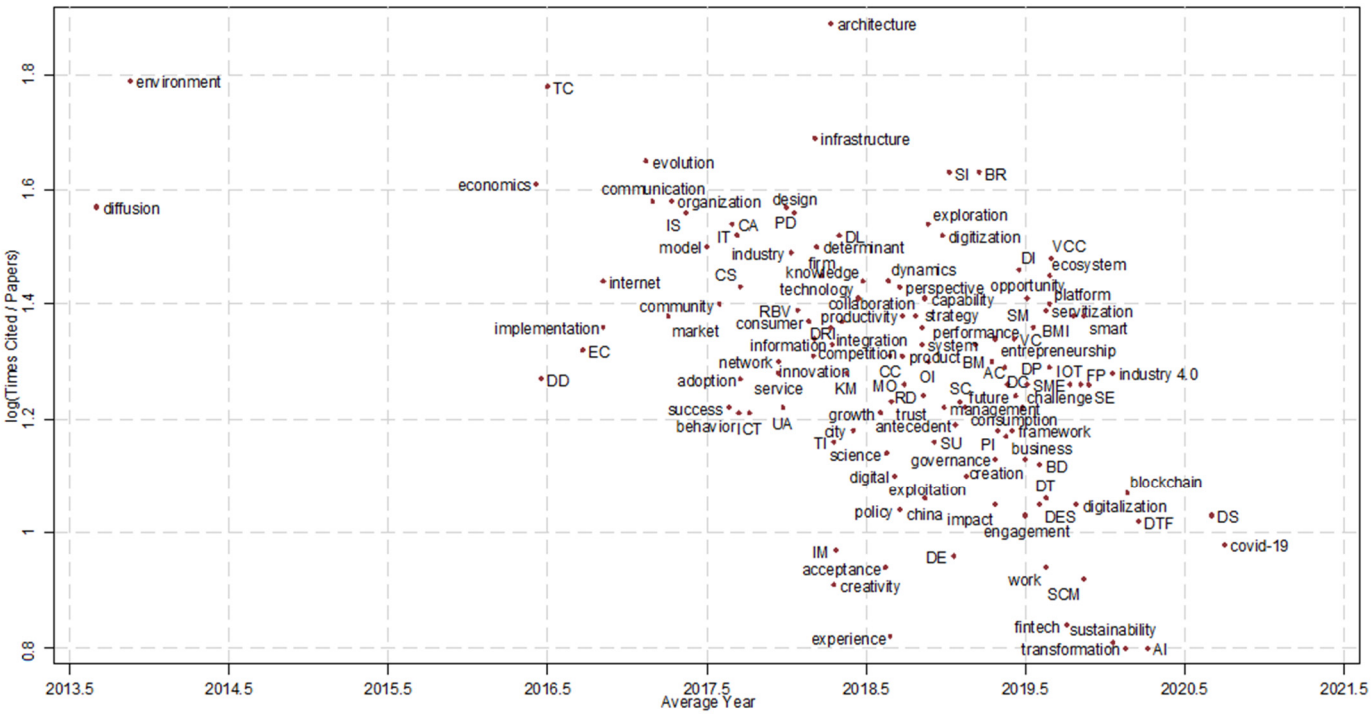

Figure 8. Longitudinal analysis of the most significant keywords.

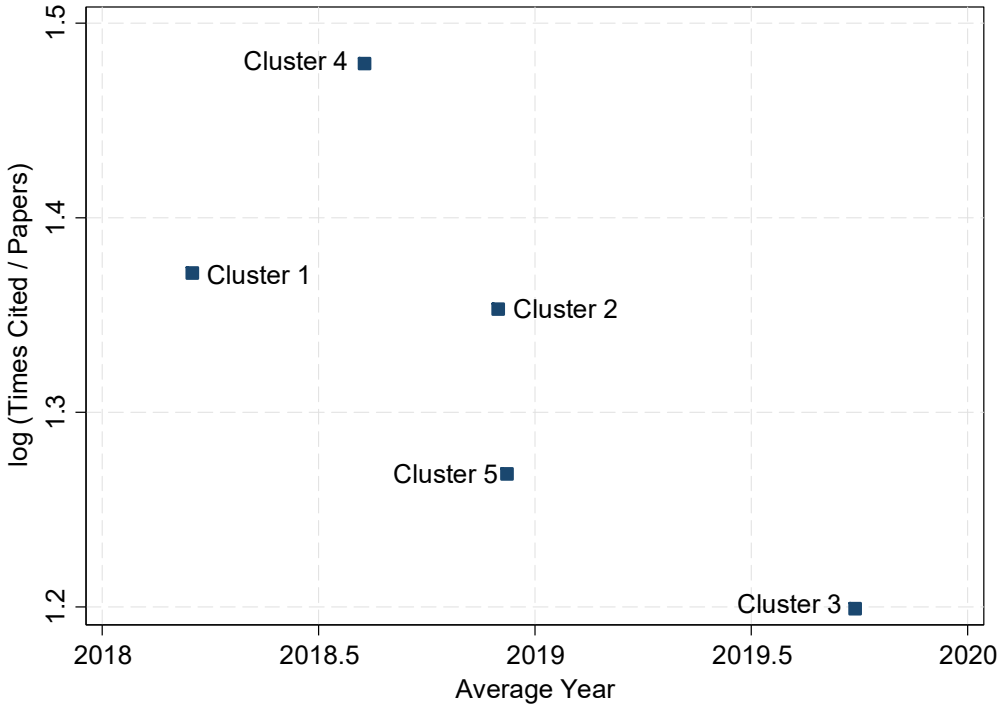

Figure 9. Longitudinal analysis of the most significant clusters.

The closer a keyword is to the upper right corner of the map, the greater its influence on the research field and the more likely it is to be a future development direction. According to the results of Figure 8, it was found that keywords such as "architecture", "infrastructure", "boundary resource (BR)","service innovation (SI)","exploration", "digitization", "digital innovation (DGI)", "value co-creation (VCC)", and "ecosystem" have—and will continue to have—a strong impact on digital transformation and innovation research. These keywords belong to Cluster 2, Cluster 3, and Cluster 4. Meanwhile, other keywords, such as "Covid-19", "SCM", "fintech", "sustainability", and "transformation", belonging to Cluster 3 and Cluster 4, recently attracted the scholars' attention, but their impact is still very poor. In addition, keywords such as "diffusion" and "environment", belonging to Cluster 1, have high relative relevance, but they are historically frequently discussed themes.

Furthermore, it can be seen from the results of Figure 9 that the themes pertaining to Cluster 2 and Cluster 4 reach a relatively high level of impact within the present research field, but a smaller future impact in terms of research direction is identified for Cluster 1 and Cluster 3.

4. Conclusions, Limitations and Future Research

4.1. Conclusions and Discussion

On the basis of analyzing literature in the WoS database, this study identified the structure of current themes and predicted emerging trends in the research on digital transformation and innovation. The following sections will discuss the conclusions drawn from our study.

One initial conclusion from the distribution of the scientific output shows that digital transformation and innovation is increasingly attracting the academic interest of scholars from many countries and different fields. Although the research on digital transformation and innovation started in 1994, sufficient attention was not to paid to the many papers published until 2015. It is noteworthy that some universities from the USA and Europe emerged as strong contributors over the past decades. However, no institutions from developing countries are found in the top contributing list, suggesting potential opportunities. Analyzing the journal content and author background, it is clear that they are primarily oriented towards broad knowledge fields from technology and innovation management,

information system and information management, and other forms of general management and business.

Second, the research on digital transformation and innovation means a challenge to the scholars and emphasizes the need for more advanced analyses of interdisciplinary areas. According to the description of the keywords and their frequency, most of the literature in this field is related to various digital technologies and innovation management-specific topics. Furthermore, much of the literature in this field is also related to other management-specific topics, such as supply chain management, knowledge management, performance, as well as other theories and methods and other research fields, such as economics, policy, psychological, and behavior issues.

Furthermore, five clusters of frequent themes were extracted from the global thematic network. These are: (1) diffusion and adoption of innovation and technology; (2) digital innovation management; (3) digital transformation management; (4) digital platform and ecosystem; and (5) digital entrepreneurship and economy. Diffusion and adoption of innovation and technology were a hot theme for many years. Based on the uniqueness of digital technologies, the process mode, influencing factors, and implementation results of their diffusion and adoption were discussed. The theoretical framework of digital innovation management was preliminarily built. As a new paradigm, internal process mechanisms, antecedents, and consequences of digital innovation were studied. In addition, some classical theories, such as dynamic capability, resource-based theory, and dual theory, were also integrated into the research system of digital innovation management. In view of the series of changes involved in digital transformation, the research from the perspective of operation management, business model, and business model innovation were explored. The relationship between digital transformation and other transformation modes, such as servitization, were also discussed. From the engineering perspective, economic perspective, and organizational perspective, the characteristics, functions, and governance mechanisms of the digital platform and ecosystem were further studied. Meanwhile, based on several theories and methods, such as strategy management, system analysis, and the roles of platforms and ecosystems in creating and capturing value and promoting innovation activities were emphasized. Thanks to the integration of various digital technologies, the research on the identification of entrepreneurial opportunities, the reconstruction of entrepreneurial processes, and the growth of entrepreneurial enterprises were further improved.

This leads to a third conclusion on the development status and evolving nature of different research themes of digital transformation and innovation. In particular, according to the results of the strategic diagram, the research of digital innovation management and digital transformation management are the mainstream of research due to recent frequent discussions and their strong relevance with other topics. The research on the digital platform and ecosystem, and digital entrepreneurship will have strong development potential over upcoming years. The research of diffusion and adoption of technology and innovation has a relatively mature self-development field. Furthermore, the analysis of streams and the performance of research of digital transformation and innovation also show similar results.

4.2. Theoretical Contributions

For the scholars, we contend that the research results enrich the existing body of research on digital transformation and innovation as separate fields. From the theoretical perspective, in recent decades, the innovation management discipline constitutes a general theme that runs through other topics. Thus, a major contribution of the present study is to analyze the role of digital transformation in contributing to the development of the innovation management discipline as a whole. Based on our findings, we suggest that in the processes of digital transformation, various digital technologies and their combinations can be a trigger or an enabler to affect the innovation processes and outcomes. The emergence of digital transformation not only supports the development of innovation activities, but it also changed the logic of innovation management, which led to some

new innovation research trends—"digital innovation" or "digital entrepreneurship"—that evolved way beyond traditional innovation management. These findings are consistent with the previous research considering the roles of digital technologies as the operand and operant resource [162,163]. Another important contribution made by this study is the innovation perspective it offers of the knowledge of digital transformation research. From the technical level, digital transformation is triggered and shaped by the extensive application of various digital technologies [164], which requires exploring how to accelerate the rapid diffusion and adoption of digital technologies from the perspective of innovation diffusion and adoption. From the management level, digital transformation can lead to a series of organizational structure and form changes [165], which also require examination and responses from the perspective of management innovation and business model innovation.

4.3. Practical Implications

From a practical point of view, several suggestions may be beneficial for the managers and governments in dealing with a wide range of issues regarding digital transformation and innovation. Managers should be familiar with the use of various digital technologies and overcome the barriers of application to maximize the potential of the technologies. Managers need to optimize the internal resources and capabilities, and to reorganize the organizational structure and governance mechanisms, which improve digital innovation and entrepreneurship processes and increase performance. Furthermore, managers need to be cognizant of the possibility of employees' stress emanating from uncertainty of the digital era, and should communicate more frequently with employees and provide them with adequate culture and structure support to minimize related negative impacts. The results of our study also have implications for governments. Governments should strengthen managers' awareness of digital economy change and increase their ability to build development targets of digital transformation. Governments should establish educational institutions and training projects to solve talent shortages. Furthermore, governments need to provide and improve policy systems to support and promote digital transformation and innovation activities.

4.4. Limitations and Future Research

We acknowledge that this study has some limitations. First, one particular limitation is the database used by the study. The study mainly analyzed the keywords from the WoS database, which includes limited journals. Therefore, the research results may lead to a deviation from the entire digital transformation and innovation field. Thus, future research can further extend the data from other databases (such as Scopus) to obtain a more exhaustive understanding of the digital transformation and innovation field. Moreover, some types of literature, such as conference proceedings and review, were not included in our study, which could be considered in the future. Second, a further limitation comes from the characteristics of the method applied. Co-word analysis focused on the structure and links among the keywords and made little effort to deeply analyze the reasons behind the phenomenon. Thus, future research can employ the systematic approach to identify major themes and to discern key relationships. Furthermore, considering the interdisciplinary characteristics of this field, other bibliometric methods (such as a co-citation analysis) can be applied to explore the integration of knowledge from various disciplines in the future.

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