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Research Agenda and Evolution of Digital Innovation—Visual Analysis based on CiteSpace

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Abstract: ***Nowadays, the research in the field of digital innovation is relatively rich and deepening, however, there is a lack of a systematic overview of the development and evolutionary trends of digital innovation. This paper uses CiteSpace software and combines bibliometric methods and scientific knowledge mapping to analyze the external characteristics, knowledge structure, hotspots and evolution of the literature on digital innovation, and clarifies the management connotation and research prospects of digital innovation, which has important theoretical significance for understanding the tendencies of global digital innovation. The findings are as follows: (1) The literature of digital innovation is formed with China, the United States and other countries as important power; (2) Hot themes can be summarized as Digital technology empowering industrial intelligence; The effect of corporate digital innovation; The process of corporate digital innovation; Digital innovation promoting economic sustainability; (3) Research of digital innovation initially focuses on the application and development of information technology. With the rise of a new generation of digital intelligence technology, research begins to concern digital technology to promote industrial intelligence; Then research concentrates on the effectiveness and process of enterprise digital innovation; In recent years, the social value of digital innovation has become a hot spot of research.***

Keywords: Digital Innovation, Bibliometrics, Visual analytics, Research hotspots.

1. Introduction

Digital innovation refers to the integration and reorganization of internal digital resources and capabilities based on the application of digital technologies, methods and tools, and the interaction with the internal and external environment to produce new products, services, processes and business models [1]. For example, in business practice, Alibaba is one of the pioneers of digital innovation in China. Alibaba Cloud, as a cloud computing platform, provides powerful data processing capabilities for enterprises. The concept of "new retail" has changed the traditional retail format and greatly improved the service experience of consumers and the operational efficiency of enterprises. It has also promoted the development of fintech through its payment platform Alipay, which has led to the widespread adoption of mobile payments in China. With the deepening of enterprise digital innovation practice, some scholars begin to explore the impact of digital technology on innovation [2]; Since 2010, scholars represented by Yoo et al. [3] explore the complex relationship between digitalization and innovation practice, point out that the implementation of digital innovation by enterprises can bring about changes in organizational strategy, infrastructure, etc., and elevating digital innovation to the level of corporate strategy, which set off a research boom in the field of digital innovation, Subsequently, scholars carry out extensive research on it. Some studies analyze the influence mechanism of enterprises' acceptance of various digital resources [4], Others construct the technology adoption stage model in the process of enterprises' digital innovation [5]; And still others argue that the implementation of digital innovation not only improves the aspects of organizational performance, management capabilities and business models [6], but also optimizes products and services [7], leading to an increase in customer value.

Existing research not only focuses on exploring the impact of digital innovation on enterprises, but also on the role of digital innovation in government governance, urban development, social change and national economy, as well as the application of digital innovation in the global economy, multinational corporations and global value chains. It can be seen that the research field of digital innovation is relatively rich and deepening, but there is a lack of organizing and summarizing a series of veins of research hotspots and themes, development trends and other trends in digital innovation. Therefore, based on the visual analysis of CiteSpace, this paper sorts out and concludes the research agenda and their evolution of digital innovation, which helps to observe the current research situation and knowledge landscape, reveals the future research trends, and has important theoretical significance for insights into the development prospects of global digital innovation.

2. Research Design

2.1 Data Sources

In this paper, the database for literature search is based on the web of science core collection. This article adopts a topic search (TS), i.e. the search mode is set as TS= ("Digital Innovation"), the type of literature is selected as "Article", the language type is set as "English", and the time span is set as all years, i.e. 1993-2023, and a total of 7,736 articles are retrieved. 7,429 articles are obtained by screening out the articles with missing information through the CiteSpace, and This study is developed based on this literature.

2.2 Research Methodology

Bibliometrics is a method of quantitative analysis of literature using mathematical and statistical methods. Based on the quantity and quality indicators of the literature, it can study the influence of the literature and the development trend of the research field through the statistics and analysis of the number, citation, citation frequency, theme, journal, author and other information of the literature. Scientific knowledge graph represents the knowledge and information of related fields in

the form of a graph, and demonstrates the association and attribute information between different subjects through the connection relationship of nodes and boundaries. It is possible to see that these two methods are strongly related and could complement each other, providing a more comprehensive and in-depth research perspective for collating the hot agendas and evolving of digital innovation.

Therefore, this paper adopts the above two methods to conduct a literature metrology and visualization analysis of digital innovation. The research includes the following aspects: Firstly, the research overview of the digital innovation field is combed and summarized. This includes the statistics and analysis of countries, journals, author distribution, and highly cited literature; Secondly, the hot agendas of digital innovation are thoroughly analyzed. It includes keyword co-occurrence, keyword co-occurrence clustering and hotspot analysis; Finally, the evolutionary trends of digital innovation are concluded through the analysis of the timeline graph.

3. Knowledge Landscape of Digital Innovation

3.1 National Distribution of Existing Research Results

Country co-occurrence map shows the cooperation relationship between countries in a macro way, by observing the distribution of countries, it can help scholars and policy makers to learn about the collaboration relationship between countries and also to know the influence of scientific research, knowledge transfer and diffusion of innovations in specific fields of different countries. In this paper, utilizing CiteSpace to set the network node as "country", then obtain the national co-occurrence map of digital innovation. The size of the node indicates the number of papers published by the country; the annual circle of the node represents the number of papers published by the country in different years, it means that the wider the age of a certain year, the more frequent the occurrence of the corresponding year; The connections between nodes reflect the strength of the partnership.

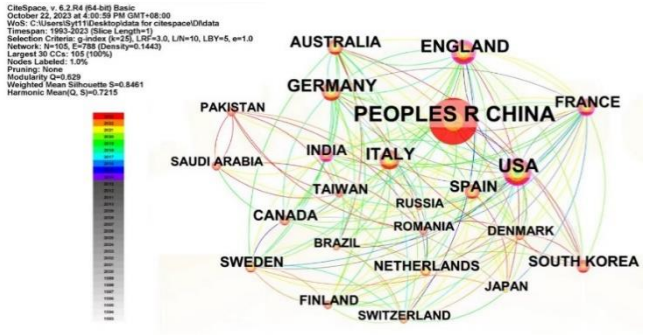

Figure 1: National co-occurrence mapping of digital innovation

As seen within the visualization in Figure 1, the countries with existing research results are mainly distributed in China, the United States, the United Kingdom, Germany, and Italy. European countries like the US and the UK researched digital innovation earlier than Asian countries as China and South Korea; The earliest research of digital innovation originate in 1993 and they become a major power in studying this field by 2021; Since 2022, China becomes an influential force of digital innovation, and the number of publications is far more than that of other countries.

This suggests that the research of digital innovation started from European countries, and the United States and the United Kingdom have long and in-depth research in this field, which has a strong scientific research status; Although China's research of digital innovation began later, it has gradually become the core force through continuous scientific research investment in recent years.

Table 1: Number and Centrality of Publications in Major Countries

Rank	Country	Citation Counts	Centrality	Centrality Ranking
1	China	867	0.02	31
2	USA	373	0.14	4
3	UK	231	0.39	1
4	Germany	203	0.04	17
5	Italy	183	0.05	10
6	Australia	118	0.05	10
7	France	117	0.16	3
8	Spain	115	0.08	6
9	Korea	84	0.00	-
10	India	82	0.17	2

Note: Author collated by CiteSpace results.

The centrality in the country co-occurrence mapping provides a better understanding of international research cooperation patterns. As shown in Table 1, the centrality of the United Kingdom is the highest, indicating that the United Kingdom has more collaboration and intimate contact with other countries; the centrality of India, France and the United States is relatively high, reflecting that the research of these countries in the field of digital innovation also has closer cooperation and sharing with other countries; However, low centrality of China indicates that China's international research cooperation capability is still modest, Although there are more research results in this area, less focus has been placed on inter-country collaboration and exchanges. Therefore, for future research, Chinese scholars should value the significant role of international research cooperation, and enhance partnerships with countries that have powerful scientific research influence, so as to further expand and strengthen the research.

3.2 Journal Distribution of Existing Research Results

The Co-Citation Frequency of a journal can measure the influence and importance of the journal, a higher co-citation frequency indicates that the journal has a greater influence of digital innovation, and the published research results have been widely cited by other scholars; Impact Factor represents the journal's status in academia and the influence of the articles, A higher impact factor implies that the papers published in the journal have a greater influence on the academic community, the papers in the journal are widely cited, and it also reflects that the articles published in the journal have been through a high-level review and screening, so the quality of the articles is higher; Centrality could help to analyze the core journals in the field of digital innovation. The top ten digital innovation co-citation journals are shown in Table 2, based on the compilation of the results of journal co-citation visualization.

Table 2: TOP10 journals cited on digital innovation

Rank	Cited Journal	Frequency	Impact factor	Centrality
1	Journal of Business Research	1019	11.3	0.06
2	Technological Forecasting and Social Change	965	12.0	0.11
3	MIS Quarterly	842	11.8	0.05
4	Sustainability	822	3.9	0.02
5	Research Policy	734	7.2	0.06
6	Strategic Management Journal	658	8.3	0.02
7	Journal of Strategic Information Systems	616	14.7	0.01
8	Journal of Cleaner Production	590	11.1	0.05
9	Academy of Management Review	568	13.9	0.05
10	Organization Science	566	4.1	0.04

Note: Author collated by CiteSpace results

"Journal of Business Research" and "Technological Forecasting and Social Change" have high citation frequency and impact factor, indicating that articles on digital innovation based on these have highly representativeness, influential and academic value, it is also broadly cited and referenced by other articles. "Technological Forecasting and Social Change" has the highest centrality, demonstrating that it is a core journal in the study of digital innovation, and the research findings in this journal have important theoretical value. Both "MIS Quarterly" and "Sustainability" also have high citation frequency. Furthermore, "MIS Quarterly" has high impact factor and centrality, while "Sustainability" is relatively low, it shows that the quality and typicality of the former are superior to those published in the latter.

3.3 Author Distribution of Existing Research Results

By counting the number of times an author has been cited by other scholars, co-citation analysis reveals the scholars who have made great academic contributions and influence in a specific field, which contributes to understand the scholars who have an advanced position in a specific field and to learn more about their research results.

Table 3: Cited Counts and Centrality of digital innovation authors

Rank	Cited Author	Citation Counts	Centrality
1	Nambisan	477	0.22
2	Vial	401	0.04
3	Teece	320	0.07
4	Verhoef	287	0.07
5	Yoo	220	0.03
6	Eisenhardt	219	0.03
7	Bharadwaj	210	0.02
8	Matt	203	0.05
9	Warner	194	0.02
10	Porter	184	0.02

Note: Author collated by CiteSpace results

As shown in Table 3, Nambisan, Vial and Teece have high citation frequency, which demonstrates that their academic achievements have a major impact on the academic community and are widely cited while influencing other aspects of the subject matter. Among them, Nambisan has the highest citation counts and centrality, shows that Nambisan has a senior academic reputation and significant influence in the field of digital innovation, and his research findings and opinions play an important role as a bridge in academic exchanges and collaborations in this field.

Prof. Satish Nambisan's research fields include technological innovation and entrepreneurial strategies, innovation management and develop innovative, digital innovation, etc. In recent years, his research focuses on how to use digital technologies to drive business innovation, transformation or entrepreneurship. As a result, Nambisan's research provides important theoretical and practical guidance for perceiving and applying digital innovation.

3.4 Distribution of Highly Cited Papers with Existing Research Results

Table 4: Top 10 co-cited papers on digital innovation

Rank	Author (Year)	Title	Journal	Citation Counts
1	Vial (2019)	Understanding digital transformation: A review and a research agenda	The journal of strategic information systems	1294
2	Nambisan et al. (2017)	Digital Innovation Management: Reinventing Innovation Management Research In a Digital World	MIS Quarterly	1013
3	Verhoef et al. (2021)	Digital transformation: A multidisciplinary reflection and research agenda	Journal of business research	811
4	Warner & Wäger (2019)	Building dynamic capabilities for digital transformation: An ongoing process of strategic renewal	Long Range Planning	650
5	Nambisan et al. (2019)	The digital transformation of innovation and entrepreneurship: Progress, challenges and key themes	Research policy	638
6	Hinings et al.（2018）	Digital innovation and transformation: An institutional perspective	Information and Organization	420
7	Hanelt et al.（2021）	A systematic review of the literature on digital transformation: Insights and implications for strategy and organizational change	Journal of Management Studies	350
8	Li et al.（2018）	Digital transformation by SME entrepreneurs: A capability perspective	Information Systems Journal	304
9	Matarazzo et al.（2021）	Digital transformation and customer value creation in Made in Italy SMEs: A dynamic capabilities perspective	Journal of Business Research	245
10	Ferreira et al.（2019）	To be or not to be digital, that is the question: Firm innovation and performance	Journal of Business research	216

Note: Author collated by CiteSpace results

The degree of scholars' concern about the journals of digital innovation could be obtained through Table 4, and the high citation counts indicates that the ideas, theories and research contents in the paper have an important impact, which means that the journal has a high significance for reference and learning. Therefore, it has vital thought-provoking and inspirational value to read these highly cited literatures. It not only helps scholars to comprehend the knowledge system and grasp the research dynamics and trends; but also facilitates

scholars to expand and extend their own research of digital innovation.

4. Research Agenda of Digital Innovation

4.1 Keyword Co-occurrence Analysis

In CiteSpace, Keyword co-occurrence analysis reveals themes and tendency in the field of study. By analyzing the co-occurrence of keywords, the relationship between different keywords could be learned. Frequency is the number of times a keyword appears in the literature. The higher the frequency, it means that the keyword could serve as the core concept; Centrality refers to the importance and influence of the keyword in the keyword co-occurrence network. The higher the centrality, the more important status of the keyword in its network, is the focus of research.

Table 5: Keyword Co-occurrence Network Word Frequency Distribution on Digital Innovation

Rank	Keyword	Frequency	Centrality
1	digital transformation	869	0.13
2	technology	406	0.19
3	performance	316	0.14
4	innovation	300	0.07
5	management	284	0.06
6	impact	273	0.07
7	strategy	207	0.07
8	information technology	188	0.04
9	dynamic capability	179	0.05
10	model	148	0.02

Note: Author collated by CiteSpace results

According to Table 5, “digital transformation” “ technology” “performance” “ innovation” “management” “impact” “strategy” “information technology” “dynamic capability” and “model” are the most used keywords by scholars in the field of digital innovation, representing the core research hotspots and content; The centrality of “technology” “performance” and “digital transformation” is much higher than that of the other keywords, which shows that they have an influential position in the keyword network, and many scholars used them as the research priorities. From the perspective of knowledge evolution, the research contents in this field could be broadly classified into three categories: the process of digital innovation, the effect of digital innovation, and digital technology adoption in innovation.

Terms	Strength	Begin	End	Burst period(1993-2023)
digital innovation	6.68	2010	2022	
systems	5.86	2006	2022	
design	5.63	2005	2022	
model	4.90	2005	2022	
knowledge	4.54	2007	2022	
evolution	4.42	2010	2022	
information technology	3.89	2006	2022	
information systems	5.84	2014	2022	
boundary resources	5.15	2015	2022	
industry 4.0	4.02	2017	2022	

Figure 2: National co-occurrence mapping of digital innovation

Keyword emergence is able to analyze rapidly developing and emerging topics in the research field, and then discover new agendas, trends and directions. The strength of the emergent words represents the degree of keyword burst, the higher the intensity, the more likely it is a new research hotspot or tendency. As could be seen from figure 2, from 2005 to 2010, the keywords “design” “model” “system” “knowledge” and “information technology” suddenly appear as research hotspots during this period. It shows that scholars’ research originates from the digital design within organizations, and the research emphasis is on the application of digital technologies, the improvement of business models and the optimization of information systems by enterprises through the acquisition of digital knowledge. For example, some scholars depict that Canon has maintained its international status and core competitiveness in the industry through the enhancement of information technology optimization, pointing out that product innovation based on digital technology could maximize customer value [8].

“Digital innovation” and “evolution” become hot keywords since 2010, many scholars began to explore the complex relationship between digitalization and innovation practices in depth, pointing out that the implementation of digital innovation in enterprises is a long-term change, which not only generates more resources to enterprises, but also changes organizational strategy, infrastructure and other aspects. And raising of digital innovation to the level of corporate strategy. Some scholars concern the mechanism of the role of corporate digital innovation in adjusting the business model from a strategic perspective [9], pointing out that the innovation of the business model requires a comprehensive reconfiguration of the company’s system of activities; Subsequently, scholars divide their studies into two categories, One defines digital innovation as an outcome that could bring many positive impacts and new changes to the organization, such as in the study of reshaping innovation management in the digital world, Some scholars propose digital innovation as the use of digital resources and technologies to make new products [10];The other suppose digital innovation as a process, which is considered to optimize the transformational resources and processes of a company. For example, some studies regard digital innovation as an innovation process that uses digital technology to improve various production activities of a firm [11]; The abrupt word from “information systems” in 2014 to “industry 4.0” in 2017 reflects that the utilization of digital technology is evolving and progressing towards empowering industrial intelligence. With the advancement of the Internet and computing technology, the construction and adoption of information systems become more and more pervasive, and many enterprises use information systems to manage data, optimize business processes, and improve efficiency.

Faced with the intensification of global competition and the promotion of digital transformation, enterprises needed to introduce the concepts and technologies of Industry 4.0 to improve their business operations and performance levels, so as to enhance the core competitiveness , and thus Innovations based on digital technologies are going forward, and the development of new technologies such as the Internet of Things, cloud computing, artificial intelligence, etc. provides the possibility of Industry 4.0, and these technologies make it possible to automate and intellectualize the production process so as to make better production efficiency and product quality.

In summary, these keywords provide certain reference value for understanding and coping with future technological changes; In addition, the research hotspots are able to provide certain enlightenment and pondering for the future

development of the company, which is of practical significance and research value.

4.2 Keyword Co-occurrence Cluster Analysis

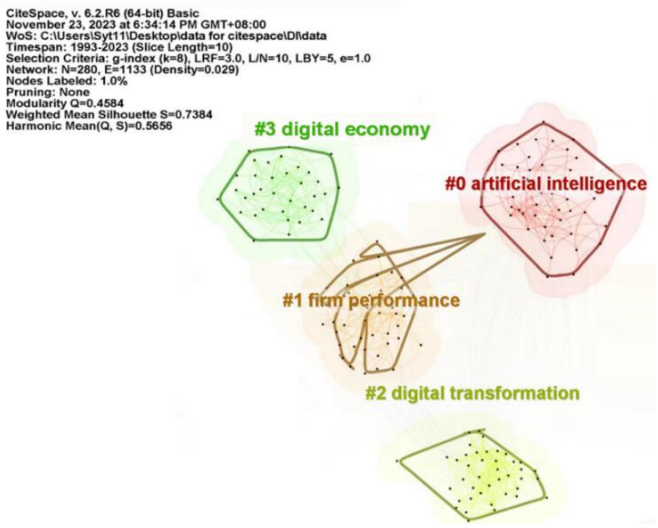

Figure 3: Keyword clustering of digital innovation

Cluster analysis can be divided into different homogeneous groups according to the intensity of association between keywords, which has an aggregation function. The cluster analysis of the digital innovation shows not only the knowledge structure, but also the correlations between and within different agendas. As illustrated in Figure 3, the keyword clusters of digital innovation can be grouped as "artificial intelligence" "firm performance" "digital transformation" and "digital economy".

The "artificial intelligence" cluster reflects the exploration of digital innovation in machine learning, deep learning, natural language processing and other technologies, as well as the analysis of the application of digital technology such as smart manufacturing, automatic driving and smart medical care. From the emergent word analysis, this cluster seems to be a hotspot of digital innovation during the emergent word "Industry 4.0", which reflects the tendency of the application and development of AI technology after 2017.

The "firm performance" cluster points out that through the implementation of digital innovation, enterprises could improve organizational productivity, revenue growth, market share, customer satisfaction and other aspects, reflecting the effectiveness and results of digital innovation; The "digital transformation" cluster suggests that firms need to consider their innovation strategies in terms of technology, organization, and management when undertaking digital transformation. Therefore, these two clusters correspond to the two ways of this field after 2010, either considering digital innovation as a result or as an innovation process.

The "digital economy" cluster is a macroscopic reflection of the exploration of digital innovation on the state, society and market, such as the related sectors based on the innovative application of digital technology to optimize cybersecurity, data protection, green innovation, consumer behavioral analysis and other aspects. As China's economy shifts from a stage of rapid growth to a stage of high-quality development, the digital economy is recognized as a new economic growth point and a key driving force for industrial upgrading; And with science and technology innovation as a national strategy, the government strongly supports and promotes R&D in emerging technology, which provides an enormous amount of resources and technological support for the digital economy; Meanwhile, innovations based on digital technology have given rise to a large number of new industries and business models, bringing great development potential to the market. Therefore, the study of digital innovation under this cluster has strong research value and meaning.

4.3 Hotspot Analysis

Combining the names of the clusters and their members, the cluster contents of digital innovation, i.e., Research agenda can be summarized into four categories: (1) Digital technology empowering industrial intelligence; (2) The effect of corporate digital innovation; (3) The process of corporate digital innovation; (4) Digital innovation promoting economic sustainability. As shown in Table 6.

Table 6: Digital innovation cluster contents, cluster names and cluster members

Cluster Contents	Cluster Names	Cluster Members
Cluster I: Digital technology empowering industrial intelligence	artificial intelligence	industry 4.0; technological change; technological innovation; big data; artificial intelligence; information system; intelligent; smart manufacturing; automation; machine learning; deep learning
Cluster II: The effect of corporate digital innovation	firm performance	organizational performance; financial performance; digital technology; competitive advantage; digital strategy; change management; digital leadership; open innovation; market performance; user experience; customer relationship management
Cluster III: The process of corporate digital innovation	digital transformation	digital innovation; disruptive innovation; dynamic capabilities; business model innovation; service innovation; business strategy; value creation; information systems; digital capability; business ecosystem; blockchain technology
Cluster IV: Digital innovation promoting economic sustainability	digital economy	economic growth; productivity; energy efficiency; digital finance; sustainable development; green innovation; digital inclusion; fintech; green supply chain; smart cities

Note: Author collated by CiteSpace results.

In Cluster I, which takes digital intelligence technology as a research perspective on technological change, technological innovation, and big data analytics, Some scholars argue that AI as an emerging technological field has great potential for development and suggest various ways in which AI can change innovation, it explore the application and impact of artificial intelligence on traditional processes and practices as a technology driver, market pull and new product development facilitator [12]; Other scholars identify the affordability of AI and its practical application in organizations, analyze the mechanisms by which AI capabilities contribute to digital innovation, and emphasize questions about defining boundaries between innovation processes and outcomes [13].

In Cluster II, which focuses on innovation effects as a

research perspective on innovation performance, financial performance, and competitive advantage, some scholars integrate existing digital innovation research results into a technology-driven digital innovation "link" framework that is embedded in the organization and leads to improved business performance. The study presents digital innovation outcomes in three dimensions: technology-driven organizational development, enablers of digital innovation, and governance of digital innovation [14]; And there are also studies based on the "resource-capability-performance" framework which point out that digital innovation orientation has a positive moderating effect on the performance of enterprises in digital transformation; Furthermore, some scholars indicate that higher levels of digital technology adoption by firms are more conducive to the improvement of digital transformation performance [15].

In Cluster III, which adopts the innovation process as a research perspective on dynamic capabilities, business model innovation, and service innovation, A study investigate the relationship between digital innovation and digital transformation based on an institutional perspective, it conclude that digital transformation is a synthesis of multiple digital innovation activities that changes in results, values, and other aspects of the innovation process for the enterprise [16]; Enterprise digital innovation involves new organizational forms, cultures, strategies, infrastructures, etc., and the positive impact of innovation combination and interaction is conducive to enterprise digital transformation. There are also studies based on the "structure-behavior-performance" framework which indicate that the relational and structural embedding of digital technological innovation networks enable corporates to obtain more resources, realize cost reduction and efficiency, and thus promote the digital transformation [17].

In Cluster IV, which regards social value as the research perspective on economic growth rate, energy efficiency, digital finance, and sustainability, Some studies analyze the impact of digital finance on urban CO2 emissions from an innovation perspective, and the studies show that digital finance realizes CO2 emission reduction through the promotion of scientific and technological innovations, which is of great significance to the country's realization of the dual-carbon goal [1]; There are also studies that discover the relationship between demographic dividend, digital innovation, energy intensity and sustainable economic growth, suggesting that the utilization of digital innovation in the energy domain has a beneficial effect on sustainable economic growth [18].

5. Evolutionary Trends in Digital Innovation

5.1 Timeline Graph Analysis

Through the analysis timeline graph, the evolution of each research topic in time series can be observed, which helps to understand the development trajectory and future trends, reveals which keywords have been widely concerned or less researched in a certain period of time, and also demonstrates the correlation and mutual influence between different agenda.

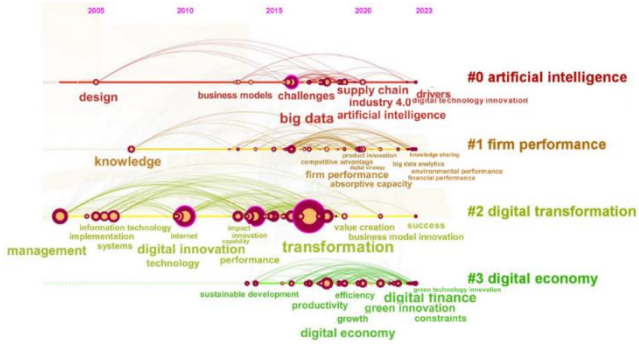

Figure 4: Keyword timeline diagram of digital innovation

From Figure 4, it could be observed that the earliest research on digital innovation in clustering appeared in "digital transformation", and in 2003, "management" as a hot keyword open up scholars to explore digital innovation in enterprise management. At the early stage of digital innovation, the research interval of the four clusters is relatively scattered, and from an overall perspective, the research content mainly focuses on the exploration of innovation in design, knowledge, management, information technology, systems, etc.; The centrality of the keyword "digital innovation" is 0.05, which has a high centrality and could be used as the core concept under this theme. Therefore, since 2010, an increasing number of scholars began to explore digital innovation. As scholars deepen their research, the scope of research is gradually widened, no longer limit to the research of technology-based digital innovation within the enterprise, many studies from different perspectives to analyze it in depth, and then a variety of keywords as a research hotspot appeared in the literature, based on the results of this paper's data acquisition, the clusters formed are called "artificial intelligence" "firm performance" "digital transformation" and "digital economy".

In conclusion, through the horizontal and vertical observation of the timeline chart, it is observed that the research content on the "digital transformation" cluster is more concentrate between 2005-2019, and the keywords contained in this cluster appear as research agenda earlier than other clusters, Meanwhile, the number of keywords appeared more than other clusters. Thus, from the perspective of digital transformation, the research on digital innovation is relatively comprehensive and then the time interval between the following keywords aroused gradually become longer, scholars progressively shift to the research on "enterprise performance" "digital economy" and "artificial intelligence".

In the "artificial intelligence" cluster, "business models" appears as the first keyword, reflects that scholars mainly focus on how to fulfill and motivate digital innovation through new business models in the beginning of AI research, and reveals the application and impact of technological capabilities possessed by enterprises in the business field, especially their innovation and transformation of business models; With the emergence of a new generation of information technologies represented by AI, cloud computing and big data, "challenged" means that scholars perceive and start to study the challenges related to them, such as technical, ethical, legal, and security issues, which need to be fully paid attention to in the process of digital innovation and find corresponding solutions; "big data" shows the great breakthrough of digital technology, reflecting the close

connection between digital innovation and technology. Big data is not only an important driving force to realize the digital transformation and upgrading of enterprises, but also a key tool to solve the "challenges" in the early stage; The continuous maturation of big data technology provides plentiful data resources, powerful computing capability and advanced algorithms for artificial intelligence, which promotes the rapid development and wide application of artificial intelligence technology, and then makes "artificial intelligence" widely studied and used as technical support for optimizing enterprises in commercial practice. The appearance of the keywords "supply chain" and "industry 4.0" indicate that digital technologies such as artificial intelligence and big data began to be applied in more specific areas of enterprises, such as the innovative management of supply chains, which also reflects that the practical adoption of digital innovation was penetrating into all aspects of enterprises and gradually promoting significant changes in industrial production, revealing that digital innovation plays a vital role in industrial development; "drivers" and "digital technology innovation" illustrate scholars' focus on the driving forces behind digital technologies and technological innovation, which suggests that future research will pay more attention to the driving factors of digital technologies and also focus on the practice and application of digital technological innovation.

Table 7: Timeline graph collation and Centrality of digital innovation keywords

Cluster name	Keyword	Time	Centrality
artificial intelligence	business models	2013	0.01
	challenges	2016	0.01
	big data	2016	0.11
	supply chain	2019	0.04
	artificial intelligence	2019	0.05
	industry 4.0	2020	0.02
	drivers	2023	0.01
	digital technology innovation	2023	0.01
firm performance	competitive advantage	2016	0.02
	firm performance	2016	0.05
	absorptive capacity	2017	0.05
	product innovation	2019	0.04
	knowledge sharing	2023	0.01
	environmental performance	2023	0.01
digital transformation	management	2003	0.14
	information technology	2006	0.04
	digital innovation	2010	0.05
	impact	2014	0.07
	transformation	2017	0.01
	value creation	2018	0.02
	business model innovation	2019	0.01
	success	2023	0.01
digital economy	sustainable development	2014	0.01
	productivity	2017	0.02
	efficiency	2019	0.02
	economic growth	2019	0.04
	digital finance	2021	0.03
	green innovation	2022	0.04
	green technology innovation	2023	0.01
	constraints	2023	0.01

Note: Author collated by CiteSpace results

In the "firm performance" cluster, "competitive advantage", as the first keyword studied by scholars, reveals the important role of digital innovation for enterprises to obtain competitive advantage, which is an crucial factor for realizing long-term development and enhancing corporate performance; Later, scholars more profoundly study the impact of digital innovation on corporate performance, the emergence of "firm performance" indicates that an increasing number of scholars are concerned about how to improve the performance of firms through digital innovation, including the promotion of digital innovation on enterprise productivity, cost reduction, quality improvement, etc.; "absorptive capacity" and "product innovation" further explore the impact of digital innovation on enterprise dynamic capabilities and product and service innovation, which are also innovation strategies to improve firm performance, "absorptive capacity" shows that if firms have strong ability to identify, transform, and effectively apply knowledge value, they will be able to make better use of digital innovation to promote corporate performance; "knowledge sharing" and "environmental performance" are the latest research hotspots, "knowledge sharing" indicates that future research will focus increasingly on how firms could improve their innovation capabilities through knowledge sharing. The development of emerging technologies provides more possibilities for knowledge sharing, Consequently, future research may pay more attention to how to use digital technologies to identify, integrate and share knowledge, as well as how to build an intelligent knowledge sharing platform. " environmental performance" indicates that the exploration of the impact of digital innovation on enterprise performance is no longer limit to its operational performance, financial performance, innovation performance, etc., but is broadened to analyze it from the perspective of social sustainable development, Future research may also focus on how to improve the environmental performance of the corporate through the implementation of digital innovation, thereby enhance their social responsibility.

In the "digital transformation" cluster, "management" appears as an early keyword, implying that scholars' initial concern of digital innovation started from the organizational and management perspectives; Subsequently, "information technology" indicates that research began to focus on how to use specific technological tools to manage and optimize organizations, reflecting the core position of information technology in digital transformation, which is the main driving force to promote enterprise transformation, and also the technical means and foundation to realize enterprise digital innovation. The emergence of "digital innovation" as a keyword symbolizes a shift in the core of the research to innovation itself; "impact" and "transformation" suggests that the research began to explore the broader impacts of digital innovation on organizations, industries, and societies, which are not limited to the outcomes of the innovation, but rather the antecedents of digital innovation; The successive appearance of the hot keywords "value creation" and "business model innovation" shows that scholars' research perspectives on digital innovation evolved from innovation output to innovation process, revealing that scholars' research on digital innovation is deepening and diversifying; Digital transformation has generally become a strategic guideline for enterprises to improve their competitive advantages, but many companies have not achieved the expected effect of transformation, and even caused substantial losses; The emergence of "success" as a recent research focus indicates that scholars are focusing more on how to successfully transform enterprises through the implementation of digital innovation. As a result, it is particularly essential to identify the key factors for the success of enterprise digital

transformation, including technology, organizational culture, leadership and market environment, etc. Future research may pay more attention to the strategies for implementing digital transformation, improving the match between inputs and outputs of digital innovations, and ensuring the integration of digital technology and business to improve the effectiveness of transformation.

In the "digital economy" cluster, "sustainable development" as the first keyword under the theme stresses the vital link between digital innovation and sustainable development of the global economy, and scholars began to study how to utilize innovation strategies based on digital technology to deal with issues of environmental and social sustainability, so as to promote sustainable economic growth; The following words "productivity" and "efficiency" attract much attention as key factors in achieving economic growth and continued development; "economic growth" further emphasizes the significant role of digital innovation in promoting the macroeconomy, and research began to analyze how digital innovation could be used as a driving engine to facilitate the prosperity of the overall economy; With the development of financial markets and emerging digital technologies, the occurrence of new financial models of "digital finance" broke the restrictions of traditional financial models, "digital finance" as a research hotspot has important practical significance, which provides a theoretical basis for the advancement of sustainable economic growth; "green innovation" extends the research to how digitalization could foster environmentally friendly innovations and how these innovations help societies achieve the goal of renewable development, showing that studies not only focus on the economic benefits for society, but also explore the sustainability dimensions of greening societies. "green technology innovation" presents a new direction in digital innovation research, underlining the significance of digital innovation in environmental protection, and scholars began to pay attention to how to use digital technology to promote the development of green innovation; "constraints" discusses and analyzes the limitations of technology, human and resource to realize green technology innovation. Future research may focus on how to overcome these limitations and how to better utilize digital technology to promote green innovation and sustainable development, etc. Therefore, an in-depth discussion under this theme can provide firm academic support for the realization of long-term social development.

5.2 Analysis of the Evolutionary Process

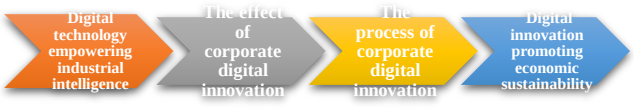

Figure 5: The evolution of digital innovation

Combined with the timeline chart of keywords, it can be concluded that "Information technology" firstly appear in 2006, and scholars started to research the field of digital innovation from the perspective of information technology application and development, For example, some scholars state the degree of Internet innovation adoption in different industries based on the IT innovation adoption perspective [19]; Some depict how to utilize IT to innovate and optimize business processes [20], products [21] and services [22], etc.; With the advent of a new generation of digital technologies represented by cloud computing, big data, and artificial intelligence, this phase was gradually deepening the research on the development and utilization of digital technologies, for example, scholars elaborate on the impact of big data capabilities on process innovation and the conduction process [23].

The subsequent emergence of "big data" and "artificial intelligence" reveal that the rapid development of digital technology has brought great potential for enterprise digital innovation, and has brought about a positive impact on the realization of industrial intelligence. Through continuous in-depth exploration and accumulation of practical experience in this field, scholars began to pay attention to the innovation effectiveness of enterprises based on the use of digital technology, such as the emergence of the keyword "performance" in 2014, which triggered a surge of research on enterprise performance [24], competitive advantage [25], new products [26], or services [27].

Digital innovation can speed up the process of enterprise transformation and improve innovation efficiency while bringing positive innovation benefits to enterprises. The emergence of the keyword "transformation" in 2017 with a high degree of centrality represents that scholars have started to analysis it from a process perspective, for example, scholars find the positive effects of exploitative innovation and exploratory innovation on organizational resilience based on the process of digital transformation [28].

Digital innovation can not only create higher value gains for corporations, but also bring positive impacts on value benefits for society, "sustainable development" and "digital economy" as the research hotspots in 2018 emphasize the significance of digital innovation for economic development, such as the contribution of digital innovation to efficiency [29], economic growth [30], and green innovation [31].

Therefore, following the continuous development and evolution of information technology, informatization (the initial stage of digitization) can better provide technological support for enterprises and bring them remarkable innovation effects, so the research hotspot from the perspective of digital intelligence technology empowerment gradually shift to analysis the effects of digital innovation; Through the accumulation of practice of digital innovation and the continuous improvement of its research methodology, scholars began to study the role of digital innovation in the process of transformation and upgrading of enterprises, which enables an insightful understanding of the nature of digital innovation and the factors affecting it; With the increasing prominence of the significance of digital innovation for economic development, scholars elevated the study of digital innovation to the level of economic sustainability, and analyzed the contribution of digital innovation to social development.

6. Conclusions

Firstly, this paper provides an insight into the dynamics of global research from a macro perspective by revealing the country distribution and literature characterization of digital

innovation. From a general overview, the overall amount of literature about digital innovation shows a growing trend, forming a national layout with China, the United States, the United Kingdom, Germany and Italy as the key power countries. Among them, European countries such as the U.S. and the U.K. start their research earlier, with relevant literature appearing since 1993, and a profound research foundation formed by 2021. Since 2022, the number of publications on its research in China grow rapidly, surpassing the United States and the United Kingdom, and also become an essential research strength in the field of digital innovation. This shows that although China started more recently in digital innovation, it has already achieved more research achievements in this field through its research investment. The UK has the highest centrality in the country co-occurrence mapping, indicating that it has extensive cooperation and close ties with other countries in digital innovation research. India, France and the United States also have high centrality, reflecting that these countries have more active international partnerships and exchanges. However, China's centrality is low, suggesting that China's international research co-operation and sharing capacity in this field needs to be reinforced. Secondly, "Journal of Business Research" and "Technological Forecasting and Social Change" both have high representativeness and influential power in the academic world, and the research findings published by them have great theoretical value, which can be widely cited and learned from.

Secondly, this paper systematically categorizes and analyzes the research hot topics of digital innovation, and deeply analyzes the connotation of these topics and the progress of related research, providing a comprehensive perspective to understand the whole picture of digital innovation. The hot themes of digital innovation can be grouped as follows: Digital technology empowering industrial intelligence; The impact of corporate digital innovation; The process of corporate digital innovation; Digital innovation promotes economic sustainability. The "artificial intelligence" cluster reflects the process of change and evolution of technological innovation, and this category corresponds to the research theme during the emergence of "industry 4.0", demonstrating the tendency of the growth and application of digital innovation in advanced technologies such as artificial intelligence after 2017; The "firm performance" cluster reveals that companies can improve organizational performance, competitive advantage, and revenue growth through implementing digital innovation; The "digital transformation" clustering indicates that enterprises need to consider innovative strategies in technology, process, management, culture, strategy, etc., which are in compliance with their transformation and upgrading, reflecting the process of enterprise digital innovation. These two clusters show the two ways in which scholars delved into the field of digital innovation since 2010, either from an effects perspective or from a transformative process. The emergence of the "digital economy" cluster suggests that the research focus has risen to the macro level, illustrating the impacts of digital innovation on state, society, and market. This cluster is also one of the major research trends for the future, as innovation contributes to the improvement of socio-economic value benefits and the realization of sustainable development.

Finally, this paper demonstrates the evolution of digital innovation. The detailed mapping of the evolutionary vein helps scholars and researchers to understand the changing structure of knowledge in the field and the potential future directions of research. Through a review of the evolution of digital innovation, it is found that research initially focuses on the utilization and the progression of information technology, starting with the emergence of "Information technology" in 2006, scholars discuss the innovative adoption and optimization of information technology in business processes, products and services, and so on; With the continuous penetration of technology and the expansion of applications, research begins to focus on the positive impact of digital innovation on the realization of industrial intelligence; By 2014, the emergence of research hotspots in the "Performance" cluster signal that scholars start to analyze the value benefits of digital innovation for enterprises based on digital technology; Further to 2017, the emergence of "transformation" cluster represents scholars who analyze the positive role of digital innovation in enterprise transformation and the factors affecting enterprise innovation and transformation; The rising keywords "sustainable development" and "digital economy" in 2018 emphasize the importance of digital innovation for economic and social well-being, stressing its contribution to efficiency, economic growth, and green innovation.

To sum up, the research in the field of digital innovation experienced a transition from the perspective based on digital technology to the perspective based on effectiveness and process, and then elevate the level to study of social value, indicating that digital innovation not only contribute to the enhancement of enterprise value creation capacity, but also help to promote long-term sustainable economic development.

7. Discussion

The core of digital innovation involves the research and application of emerging technologies such as big data, artificial intelligence, and cloud computing. Managers need to concern the trend of these technologies, understand how they work, and explore how they can be integrated into the operations and business processes of the enterprise in order to improve efficiency and innovation capabilities; Digital innovation carried out by enterprises involves not only tech-level changes, but also organizational-level changes. This means that companies need to adjust their business processes, organizational structure, corporate strategy, culture, and other aspects in order to adapt to the requirements of the digital era. Managers have a critical role to play in the process of enterprise transformation, and they need to guide and facilitate organizational change and innovation, and actively seek and obtain resources that match their own to ensure that the enterprise can successfully carry out digital transformation and upgrading.

The final goal of digital innovation for an enterprise is to improve performance and achieve long-term growth. Therefore, managers need to set clear objectives and establish an evaluation system to facilitate the assessment of the effectiveness of digital innovation, which includes the evaluation of the enterprise's market performance, financial

performance, innovation performance, etc., so as to ensure that digital innovation will bring real value growth to the company; Digital innovation not only improves the enterprise's value benefits, but also contributes to the improvement of social value. For example, through digital innovation, corporate could improve its environmental performance, thereby contributing to the sustainable growth of the society. Managers need to care about the role of digital innovation in enhancing social value and incorporate this into their corporate social responsibility.

8. Research Prospects

Expanding research agenda in the field of digital innovation and integrating multidisciplinary theoretical perspectives, such as integrating theories from management, sociology and psychology, to provide a more comprehensive theoretical interpretation of digital innovation. Regarding technology-driven aspects, future research could focus on the drivers of digital technology development and how to utilize these drivers to promote technological innovation; Regarding knowledge-sharing aspects, future research could concern how to utilize digital technology for knowledge-sharing in order to improve the innovation capability of enterprises. This includes research on how to use digital technologies to identify, integrate and share knowledge, and how to build intelligent knowledge-sharing platforms to facilitate better utilization of knowledge resources by enterprises; With regard to environmental performance, research could be conducted on how to improve the environmental performance of enterprises through digital innovation in order to enhance corporate social responsibility. This includes research on the role of digital innovation in reducing energy consumption, reducing pollution, improving resource efficiency, etc., and how to transform these results into competitive advantages for enterprises; With respect to successful transformation, future research can pay more attention to the implementation strategy of enterprise digital transformation, how to improve the degree of matching between inputs and outputs of digital innovation, and how to ensure that the integration of digital technology and business improves the effectiveness of transformation; With regard to green technology innovation, it is possible to study how to utilize digital technology to promote the development of green innovation and how to overcome the limitations of realizing green technological innovation, and an intensive discussion of this research theme can provide solid academic support for fulfilling the long-term development of society.

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