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Article

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Mapping the digital landscape: A bibliometric analysis of digital ecosystem research

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ABSTRACT

Digital ecosystems have become a central paradigm for understanding the complex, interconnected networks that characterize the modern digital landscape. However, the rapid growth and interdisciplinary nature of this research present challenges for scholars seeking to grasp its intellectual structure and future trajectory. This study addresses this gap by conducting a comprehensive bibliometric analysis of 1974 publications retrieved from the Scopus database. We map the intellectual structure of the field, identify key research themes, and uncover influential contributors and publications. Our analysis reveals five major thematic clusters: (1) Digital Transformation and Economy, (2) Emerging Technologies and Learning Systems, (3) Foundational Technologies and Semantic Architecture, (4) Human and Social Interaction in Digital Spaces, and (5) Business Strategy and Innovation. Building on this analysis, we outline a detailed agenda for future research, highlighting critical needs in areas such as adaptive governance, social and environmental sustainability, the security of digital infrastructures, and the human-centric application of AI in domains like healthcare. This study provides the first large-scale, holistic overview of digital ecosystem research, offering a robust foundation for future investigations and informing strategic decisions for researchers, practitioners, and policymakers.

1. Introduction

Digital ecosystems have become a cornerstone of the digital transformation, fundamentally reshaping business models, service delivery, and societal interactions (Gawer, 2021; Jacobides et al., 2018). A digital ecosystem refers to a complex network of organizations, individuals, resources, and technologies that interact within a digital environment to achieve common goals or create value (Adner, 2016; Stonig et al., 2022). These dynamic networks, comprising interconnected individuals, organizations, technologies, and processes (Adner, 2016), are not merely collections of digital components but co-evolving entities where participants mutually influence one another (Adner & Lieberman, 2021; Jacobides et al., 2021). The profound importance of this topic lies in its ubiquity; from global e-commerce platforms like Amazon to the integrated smart home devices in our daily lives, digital ecosystems drive modern economic and social activity. They foster innovation by allowing businesses to integrate their offerings and create seamless user experiences, thereby gaining a competitive advantage in the digital economy (Eckhardt et al., 2018; Gawer, 2021; Pussinen et al., 2023).

While the study of digital ecosystems is inherently multidisciplinary, spanning information systems, computer science, economics, and management (Stonig et al., 2022), the resulting research landscape is characterized by its rapid growth, diversity, and fragmentation (Goertler et al., 2025; Miah et al., 2025). This fragmentation presents a significant challenge: understanding the current state, trajectory, and untapped potential of this critical field.

This study directly addresses this challenge by conducting a comprehensive bibliometric analysis of digital ecosystem research. We move beyond simple literature reviews to quantitatively map the intellectual structure, evolution, and emerging trends of this field. While previous studies have examined specific aspects of digital ecosystems (e.g., platform strategies (Jacobides et al., 2021), innovation networks (Zou et al., 2022), or governance challenges (Wareham et al., 2014)), ours is the first to provide a holistic, large-scale bibliometric overview, revealing the interconnectedness of research streams and identifying critical knowledge gaps. This approach allows us to address three pivotal research questions:

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- **RQ1: What are the most influential and productive research constituents (authors, institutions, countries) in digital ecosystem research?** This identifies the key intellectual foundations and driving forces of the field.
- **RQ2: What are the key topics and themes investigated in digital ecosystem research?** This maps the thematic landscape, revealing the evolution of research interests and current trends.
- **RQ3: What are promising, yet under-explored, areas for future research on digital ecosystems?** This identifies critical gaps and emerging trends, providing a roadmap for future scholarly inquiry.

By answering these questions, this study offers several novel contributions. First, it provides a comprehensive, quantitative overview of a rapidly evolving and strategically important research area. Second, it identifies not only established research streams but also emerging trends and unaddressed research needs, offering valuable insights for researchers and practitioners. Third, by revealing the intellectual structure of the field, it fosters a more integrated understanding of digital ecosystems, facilitating collaboration and knowledge building. Finally, our findings serve as a foundation for future research, guiding the development of this crucial field in response to technological advancements and societal needs. The analysis is particularly timely given the accelerating integration of technologies like artificial intelligence, blockchain, and the Internet of Things into digital ecosystems, which presents both new opportunities and challenges (Goertler et al., 2025; Miah et al., 2025).

The remainder of this article is structured as follows: Section 2 reviews the foundational literature on digital ecosystems. Section 3 details the bibliometric methodology and data sources used for this study. Section 4 presents the core findings of the performance analysis, identifying influential contributors and key metrics. Section 5 provides a detailed thematic analysis of the research landscape and outlining a future research agenda. Finally, Section 6 discusses the implications of our findings and concludes by summarizing key insights.

2. Foundations

The concept of ecosystems has become increasingly significant in the context of digital business. Its intellectual roots lie in the idea of “business ecosystems,” pioneered by Moore (1993), who described communities of organizations co-evolving around a new innovation (Moore, 1993). Building on this, a digital ecosystem is now understood as a set of actors interacting around a central digital platform, bound by a web of technological and economic interdependencies (Jacobides et al., 2018). More formally, a digital ecosystem can be defined as the alignment structure of a multilateral set of partners that must interact for a focal value proposition to materialize (Adner, 2016). The defining characteristic that distinguishes an ecosystem from a simple network or market is the presence of non-generic complementarities—that is, the unique and synergistic value that components create only when combined, leading to a value proposition greater than the sum of its parts (Jacobides et al., 2018). Thus, these systems are not merely collections of firms and technologies, but dynamic, co-evolving entities where participants mutually influence one another’s success and the overall direction of innovation (Adner, 2016; Gawer, 2021; Jacobides et al., 2018). Digital ecosystems are characterized by the integration of digital technologies that allow participants to interact seamlessly, expand their technological reach, and provide complementary services (Adner, 2016). These ecosystems typically include a wide array of digital products and services, such as e-commerce platforms, social media networks, cloud computing services, and more (Jacobides et al., 2018). Within these ecosystems, companies and organizations integrate their offerings to create seamless user experiences and expand their market reach (Agarwal & Kapoor, 2023; Amit & Zott, 2015). The interconnected nature of digital ecosystems allows businesses to optimize their operations, drive innovation, and gain a competitive advantage in the digital

economy (Eckhardt et al., 2018; Gawer, 2021; Pussinen et al., 2023). For example, consider the Apple iOS ecosystem. The central actor, Apple, provides the platform (the iPhone and the App Store) and core services (iOS). This platform enables a vast network of other actors—including app developers (technology providers), accessory manufacturers, and end-users (consumers)—to interact, create, and exchange value. A developer creating a successful app adds value not just for themselves but for the entire ecosystem by making the iPhone a more attractive device for consumers. This illustrates how interactions within the ecosystem can create more value than a traditional, linear business model (Adner & Lieberman, 2021; Konopik, 2023).

2.1. Structure and dynamics of digital ecosystems

The structure of digital ecosystems is defined by the interactions between their constituent entities, which include businesses, technology providers, consumers, and regulatory bodies (Adner, 2016; Reischauer et al., 2024). These interactions are often mediated by digital platforms that serve as central hubs within the ecosystem, facilitating communication, transactions, and collaboration among participants (Jacobides et al., 2018). Platforms are the technological frameworks that enable the generation of complementary products and services, enhancing the overall value of the ecosystem (Adner & Lieberman, 2021; Rietveld et al., 2018). The architecture of digital ecosystems is typically modular, allowing for flexibility and scalability as new participants join or as existing participants innovate (Cozzolino & Verona, 2022; Zou et al., 2022). This modularity fosters innovation within the ecosystem, enabling the rapid deployment and integration of new technologies and services (Gawer & Cusumano, 2014). The dynamics of digital ecosystems are driven by the co-evolution of the ecosystem’s participants and the digital platforms that connect them (Adner, 2016; Rietveld et al., 2019). As participants interact and exchange resources within the ecosystem, they co-create value in ways that are often unpredictable and non-linear (Jacobides et al., 2018; Konopik, 2023). For instance, the introduction of a new platform feature can spur the development of complementary services by third-party developers, which in turn enhances the overall value of the ecosystem (Wareham et al., 2014). This co-evolutionary process is a defining characteristic of digital ecosystems, distinguishing them from more traditional, linear business models (Adner & Lieberman, 2021; Konopik, 2023). Moreover, the interconnectedness of digital ecosystems extends beyond technological integration to include a complex web of social, economic, and legal relationships that govern how participants interact and create value. Digital ecosystems often operate under a shared set of standards and protocols that ensure interoperability between different platforms and services (Rietveld et al., 2020). These standards are crucial for maintaining the integrity of the ecosystem and enabling seamless interactions among participants (Koch et al., 2022; Rietveld et al., 2018; Toh & Pyun, 2024). Additionally, the governance structures within digital ecosystems are often decentralized, allowing for greater innovation and flexibility but also introducing challenges related to coordination and trust among participants (Chen, 2023; Li et al., 2024; van Angeren & Karunakaran, 2019). This decentralization is evident in the Android operating system ecosystem, where Google sets the basic standards, but device manufacturers like Samsung and app developers have significant freedom to innovate on top of the platform. This fosters rapid innovation but also creates challenges in ensuring consistent user experience and security across all devices, highlighting the complex governance trade-offs inherent in such systems (Wareham et al., 2014).

The rapid growth, complexity, and interdisciplinary nature of digital ecosystem research make it challenging to gain a comprehensive and cohesive understanding of the field (Goertler et al., 2025; Miah et al., 2025). While individual studies have explored specific aspects of digital ecosystems, and some literature reviews have attempted to synthesize existing knowledge, a large-scale, quantitative analysis of the entire research landscape has been conspicuously lacking.

3. Research method

3.1. Methodological approach

Given the specific objectives of this study – to map the overall structure, evolution, and key trends within the entire digital ecosystem research landscape – a bibliometric analysis was deemed the most appropriate methodological approach. While Systematic Literature Reviews (SLRs) are valuable for in-depth qualitative synthesis of findings on specific, narrowly defined research questions (Petticrew & Roberts, 2008), they are less suited for capturing the breadth and diversity of a large, rapidly evolving, and interdisciplinary field like digital ecosystems. In contrast, bibliometric analysis allows for a quantitative, large-scale assessment of the entire research field, identifying influential publications, authors, institutions, key themes, and emerging trends (Donthu et al., 2021). This “bird’s-eye view” is crucial for understanding the overall structure and trajectory of the field, which is the primary goal of this study.

3.2. Data collection and screening

The initial step involved selecting an appropriate bibliographic database. While Web of Science has historically been a dominant source, Scopus has emerged as a preferred choice for many recent bibliometric analyses due to its broader coverage of journals and conference proceedings, particularly in fields like computer science and information systems (Paul & Criado, 2020). Following the recommendation of Donthu et al. (2021) to avoid data duplication and potential errors associated with merging data from multiple sources, we selected Scopus as the sole data source for this study. Scopus offers a comprehensive and well-structured dataset with broad coverage of journals and conference proceedings, particularly in fields like computer science and information systems, making it suitable for a robust bibliometric analysis. The data collection was conducted on February 10, 2025, and included all publications from the first appearance in 1999 up to the search date. The search string, applied to titles, abstracts, and keywords, was:

TITLE-ABS-KEY(“digital ecosystem” OR “digital-ecosystem”).

This initial search yielded 2831 documents. To ensure the relevance and quality of the dataset, a multi-stage screening process was employed to refine the dataset. Although bibliometric analyses are not SLRs, we adopted the PRISMA (Preferred Reporting Items for Systematic Reviews

and Meta-Analyses) framework to guide our screening process (Page et al., 2021). Using PRISMA enhances the transparency, replicability, and rigor of the selection process, which is a best practice even in quantitative reviews (Donthu et al., 2021). The PRISMA 2020 flow diagram, which displays the number of articles at each stage of the selection, can be seen in Fig. 1.

The screening process involved several sequential exclusion criteria applied via the Scopus search engine: First, we limited the results to peer-reviewed original research and comprehensive syntheses by including only articles (ar), reviews (re), and conference papers (cp). This resulted in the exclusion of 660 documents, such as book chapters, editorials, and notes. Second, only publications in English were included to ensure consistency and accessibility, leading to the exclusion of 153 documents. Third, only documents in their final publication stage were included, excluding articles in press or pre-prints. This step ensures that only validated and complete research is included in the analysis and resulted in the exclusion of 44 documents. After these refinement steps, the final dataset comprised 1974 publications. These publications were exported from Scopus in a CSV (Comma Separated Values) format, including all relevant bibliographic information (authors, titles, abstracts, keywords, affiliations, citations, publication years, etc.) for subsequent bibliometric analysis.

3.3. Data analysis and tool choice

The bibliometric analysis was conducted in two main stages: performance analysis and science mapping (Donthu et al., 2021). To answer our first research question (RQ1) concerning influential research constituents, we performed a performance analysis. This analysis measures the impact and productivity of research constituents, such as researchers, affiliations, and countries, using metrics like the total number of publications, citations, and the h-index (Cobo et al., 2011; Noyons et al., 1999; van Raan, 2005). To account for the academic age of different researchers, we also used the m-index (Hirsch, 2005). For this stage, we utilized the Bibliometrix R-package and its web-based interface, Biblioshiny (Aria & Cuccurullo, 2017), which offers a comprehensive suite of functions for calculating performance metrics. To address our second and third research questions (RQ2 and RQ3) about key topics and future research directions, we conducted a science mapping analysis. Science mapping visually reveals the underlying patterns, intellectual structure, and emerging trends within a field

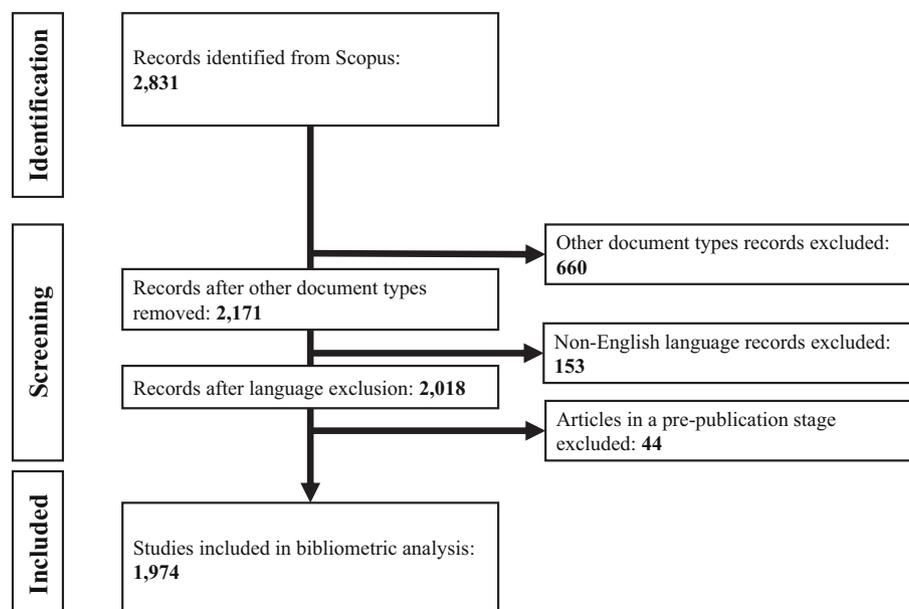


Fig. 1. PRISMA 2020 flow diagram.

through network visualizations. We specifically used keyword co-occurrence analysis, a method that explores the relationships and interconnectedness of keywords to identify thematic clusters and research hotspots (Leung et al., 2017; Tandon et al., 2021; Vallaster et al., 2019). For this visual mapping, we used VOSviewer, a specialized tool for constructing and visualizing bibliometric networks based on co-occurrence data (van Eck & Waltman, 2010).

4. Findings

This chapter provides a comprehensive bibliometric analysis of research within the field of digital ecosystems, focusing on key metrics, performance indicators, influential publications, and international collaborations. By examining the most prominent funding sponsors, key journals, and leading authors, this analysis highlights the driving forces behind scholarly contributions. Additionally, a country-collaboration analysis reveals the global nature of research in this domain, underscoring the importance of international partnerships and the pivotal role of major economies in advancing digital ecosystem studies.

4.1. Overview and key metrics

We start our investigation by giving an overview of the sample and some of its key metrics (see Table 1). In total, 1974 documents dealing with digital ecosystems were identified after the exclusion steps. These documents were published in 1156 different sources and have a mean number of 12.93 citations. The majority of the articles are conference papers (1018), while 895 are journal articles. While the newest articles in our sample were published in early 2025, the oldest articles identified date back to 1999. In this very first publication where the term “digital ecosystem” appears, the authors investigate the ecosystem that is simulated in an entertainment-software called *Creatures*. Cliff and Grand (1999) highlight that the digital ecosystem of *Creatures* might be of interest to artificial life scientists and compare artificial life literature and the technology used in *Creatures*. This early work, along with subsequent papers in the early 2000s (Azuaje, 2001), treated digital ecosystems primarily in the context of artificial life simulations. The focus began to shift towards business and socio-technical systems around 2005, which marked the beginning of the research stream as we understand it today.

Since 1999, 5496 different authors have contributed to digital ecosystem research, which is equal to 0.36 documents per author. 310 of the publications in our sample are single-authored documents, while 1664 publications are written by more than one person, leading to a collaboration index of 3.13 (5496/1664).

In Table 2, we compare different bibliometric studies regarding their

key metrics. With 0.36 documents per author and a single-authored document percentage of 15.7 %, our study aligns closely with the average complexity observed in other fields. This might indicate that research on digital ecosystems is of an average complexity, which nevertheless makes it necessary to collaborate with other researchers.

Fig. 2 illustrates the publication trend in digital ecosystems research over time, starting from the first publication in 1999. After a period of slow growth, a sharp increase in publications is noticeable from 2019 onwards. In 2019, almost twice as many articles were published as in 2018, and these figures continued to rise steadily, with 351 articles published in 2024. For 2025, we extrapolated a total of 407 published articles using linear extrapolation based on the publication growth of the past five years. These findings underscore the substantial growth in research attention dedicated to digital ecosystems in recent years.

Fig. 3 provides a clear visual distribution of publications across various disciplines. It reveals that Computer Science dominates with 30 % of the publications. Engineering and Social Sciences, each at 12 %, underscore the interdisciplinary nature of the field. Business, Management, and Accounting (10 %) further illustrate the integration of economic and organizational perspectives. The “Others” category (10 %) points to a broad range of additional fields contributing to this multifaceted research area.

4.2. Performance analysis and country-collaboration

4.2.1. Funding sponsors

Table 3 provides an overview of the most prominent funding sponsors. The European Commission stands out as the leading sponsor, funding 75 articles, followed closely by the Horizon 2020 Framework Programme with 38 articles. This reflects the European Union’s strong commitment to advancing research in this domain. The National Natural Science Foundation of China is also a major contributor, supporting 29 articles. Russia and the United States follow, with their respective national science foundations funding 20 and 24 articles. These statistics underscore the global nature of research in digital ecosystems.

4.2.2. Influential journals

In terms of publication outlets, the analysis in Table 4 identifies the most influential journals. The IEEE Transactions on Industrial Electronics is particularly noteworthy, with 16 articles and a high h-index of 14, highlighting a strong engineering focus. The Journal of Information Technology is also highly impactful, with a citation count of 1331 from only 8 articles. Conference proceedings, especially from the IEEE-IES Digital Ecosystems and Technologies Conference, are also significant dissemination channels.

4.2.3. Productive authors

Table 5 lists the most productive authors. E. Chang is the most prolific author with 24 articles, followed by M. Takizawa with 22 articles and an h-index of 12. The data suggest that a relatively small group of researchers, often collaborating across institutions, are driving much of the thought leadership in this area. A closer look at their contributions reveals a focus on distinct aspects of the digital ecosystem paradigm. The work co-authored by E. Chang, for instance, often concentrates on the methodical design and application of digital ecosystems in specific domains like healthcare (Hadzic & Chang, 2010). In contrast, M. Takizawa’s co-authored research delves into the fundamental technological infrastructure, addressing challenges such as energy efficiency and power consumption in the server architectures that underpin these ecosystems (Enokido et al., 2014).

4.2.4. Country-collaboration analysis

The country-collaboration map, shown in Fig. 4, highlights the global interconnectedness of research in digital ecosystems. The analysis shows robust collaboration, with notable partnerships between China, the United States, and European Union member states. Chinese

Table 1
Overview of general data and key metrics of our sample.

Metric	Value
Main information	
Timespan of the sample	1999–2025
Sources (Conferences and Journals)	1156
Documents	1974
Average citations per document	12.93
Number of author’s keywords	5725
Document types	
Journal article	895
Conference paper	1018
Review	61
Authors	
Number of different authors	5496
Documents per author	0.36
Authors of single-authored documents	281
Authors of multi-authored documents	5215
Single-authored documents	310
Multi-authored documents	1664
Collaboration index	3.13

Table 2
Comparison of key metrics of different bibliometric studies, based on Brée et al. (2024).

Study	Topic	Documents	Documents per author	CI	Single-authored documents
Secinaro, Brescia, et al., 2021	Data quality	159	0.305	3.60	11.32 %
Secinaro, Dal Mas, et al., 2021	Blockchain in accounting	93	0.443	2.83	29 %
Karger & Kureljusic, 2022	AI for drug discovery	3884	0.322	3.26	6.7 %
Secinaro, Calandra, et al., 2021	Sustainable development	270	0.364	3.09	14.81 %
Jagals et al., 2021	Data governance	780	0.367	3.26	22.18 %
Uluyol et al., 2021	Waqf research	527	0.599	2.53	50 %
Neger & Rosas-Paz, 2022	Fire-Management research	5624	0.43	2.56	13.74 %
Wulfert & Karger, 2022	E-commerce platforms	7463	0.537	1.93	16.58 %
Karger & Kureljusic, 2023	AI for cancer detection	6450	0.27	3.8	3.4 %
Brée et al., 2024	Data ecosystems	840	0.27	4.13	14.52 %
Karger et al., 2024	Blockchain in Smart Cities	797	0.365	2.90	7.65 %
Klimovský et al., 2024	Participatory Budgeting	319	0.478	2.77	34.17 %
Sabherwal & Kaur, 2024	AI for Parkinson detection	1674	0.215	4.73	1.91 %
∑	-	2361.15	0.36	3.15	17.46 %
This Study	Digital Ecosystems	1974	0.36	3.13	15.7 %

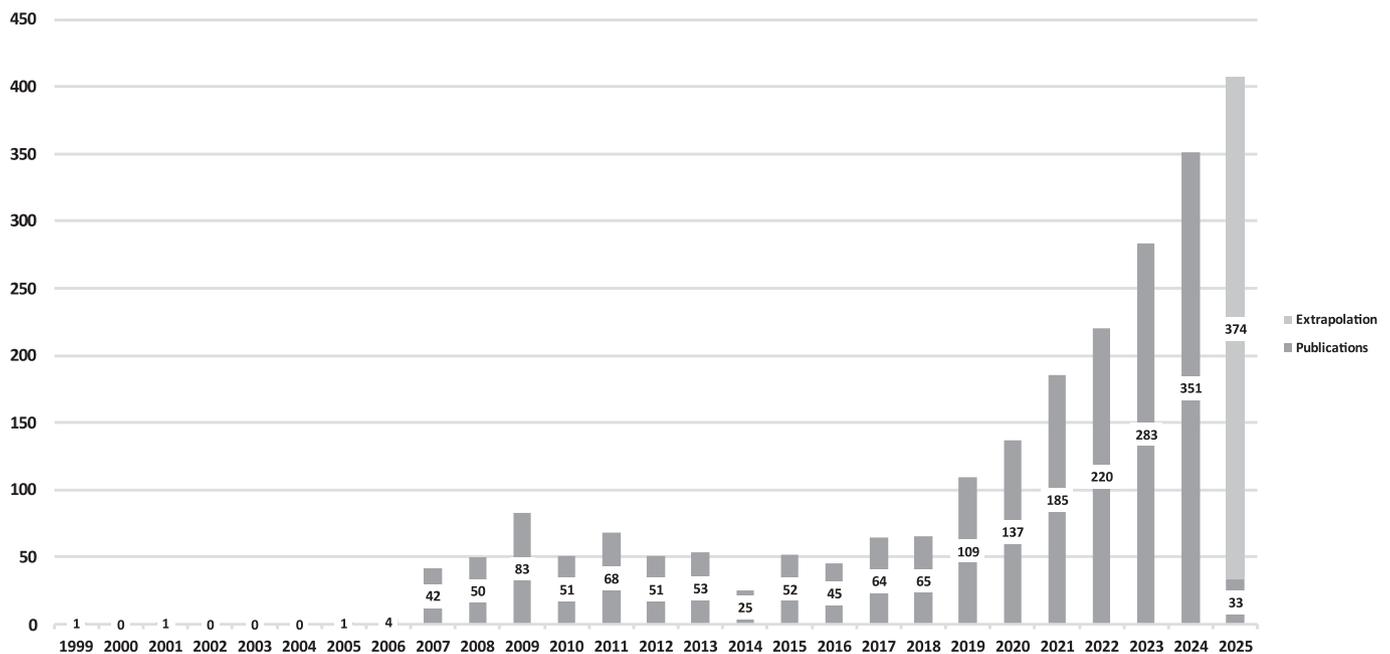


Fig. 2. Annual production of research dealing with digital ecosystems.

institutions are heavily involved in cross-border research, reflecting the country’s strategic interest in advancing its digital capabilities. European countries exhibit a high level of collaboration, driven by the EU’s various funding bodies, while the United States also emerges as a key player in international collaborations.

4.2.5. Author and thematic collaboration networks

To further elaborate on the collaborative structure of the field, we analyzed the collaboration networks between authors. Fig. 5 presents the author collaboration network, showing distinct clusters of authors who frequently publish together. The size of an author’s name corresponds to their productivity. It is evident that many of the most productive authors from Table 5 act as central nodes in these clusters, such as Chang, E. (yellow cluster), Takizawa, M. and Enokido, T. (purple cluster), and Krause, P. J. (red cluster). This visualization highlights the existence of several influential and interconnected research groups that are driving the discourse in the field of digital ecosystems.

Fig. 6 illustrates the evolution of key research themes over time, with the position and size of the circles indicating the recency and frequency of a topic. The chart shows a clear chronological progression. Foundational topics such as knowledge management, interoperability, and embedded systems were prominent in the earlier years of the analysis

period (around 2018). Subsequently, a significant wave of interest emerged around 2020 in topics like the internet of things, innovation, and information management. Most recently, the research focus has shifted towards cutting-edge themes, with edge computing, cybersecurity, machine-learning, and block-chain appearing as the most current trend topics. This trend analysis visually demonstrates the maturation of the field and its increasing focus on new technologies and applications, which reinforces the sharp increase in publications observed since 2019.

The performance and country-collaboration analyses reveal that digital ecosystems research is a highly collaborative, globally dispersed field with significant contributions from Europe, Asia, and North America. The field benefits from substantial support from major funding bodies, and its knowledge base is largely shaped by a small number of highly productive researchers and influential journals. These findings highlight the importance of international cooperation and sustained funding in driving forward research in this dynamic and rapidly evolving field.

5. Thematic analysis

The thematic analysis of digital ecosystems research provides a comprehensive understanding of the intellectual landscape, highlighting

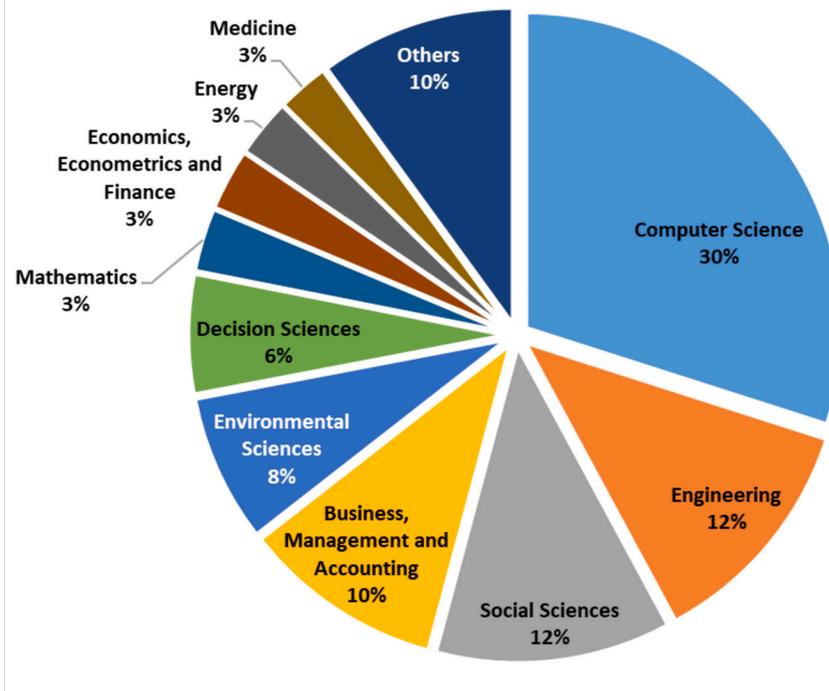


Fig. 3. Distribution of publications across disciplines.

Table 3
Overview of the most appearing funding sponsors.

No	Funding sponsor	Country/Region	Articles
01	European Commission	European Union	75
02	Horizon 2020 Framework Programme	European Union	38
03	National Natural Science Foundation of China	China	29
04	European Regional Development Fund	European Union	27
05	National Science Foundation	United States	24
06	Russian Foundation for Basic Research	Russia	20
07	Bundesministerium für Bildung und Forschung	Germany	16
08	Ministry of Science and Technology of the People's Republic of China	China	15
09	Russian Science Foundation	Russia	13
10	Engineering and Physical Sciences Research Council	United Kingdom	11

the key themes, trends, and areas of focus within this evolving field. By utilizing bibliometric tools such as keyword co-occurrence analysis and thematic clustering, this section aims to map the central themes and emerging topics in digital ecosystem research, contributing to the broader understanding of this multidisciplinary domain.

To visualize the thematic structure and key research areas within the digital ecosystem literature, we constructed a keyword co-occurrence network (Fig. 7). This network represents the relationships between keywords assigned to the publications in our dataset, providing insights into the conceptual connections and dominant themes (van Eck & Waltman, 2010). In a keyword co-occurrence network, nodes represent keywords, and links between nodes indicate that the keywords appear together in the same publication. The size of a node typically reflects the frequency of the keyword's occurrence, while the thickness of a link represents the strength of the co-occurrence relationship. The colors represent clusters of closely related keywords, identified through a

Table 4
Overview of the 15 most influential journals.

No	Outlet	Citations	Articles	h-index	m-index
01	Journal of Information Technology	1331	8	6	0.5
02	Small Business Economics	882	4	4	0.5
03	IEEE Transactions on Industrial Electronics	728	16	14	1
04	Nucleic Acids Research	621	1	1	0.25
05	Research Policy	536	1	1	0.143
06	Computers in Human Behavior	494	2	2	0.182
07	New Political Economy	445	2	2	0.25
08	International Journal of Entrepreneurial Behavior and Research	441	1	1	0.167
09	Proceedings of the 2007 Inaugural IEEE-IES Digital Ecosystems and Technologies Conference, DEST 2007	377	28	9	0.50
10	Technological Forecasting and Social Change	322	9	7	0.583
11	2009 3rd IEEE International Conference on Digital Ecosystems and Technologies, DEST '09	311	42	8	0.50
12	Journal of Business Research	306	6	5	1
13	MIT Sloan Management Review	287	3	2	0.200
14	Journal of Telemedicine and Telecare	268	1	1	0.333
15	International Journal of Environmental Research and Public Health	260	7	5	0.833

clustering algorithm (Blondel et al., 2008).

The thematic analysis in this study was conducted using VOSviewer, a powerful tool for constructing and visualizing bibliometric networks. The analysis focused on author-provided keywords. Of the 1974

Table 5
Overview of most productive authors.

No	Author	Articles	Citations	h-index	m-index
01	E. Chang	24	386	10	0,556
02	M. Takizawa	22	509	12	0,857
03	S. L. Nimmagadda	22	137	5	0,333
04	T. Enokido	21	493	12	0,857
05	P. J. Krause	19	179	9	0,500
06	F. K. Hussain	18	233	9	0,5
07	A. Aikebaier	16	343	10	0,714
08	T. Reiners	15	101	4	0,25
09	H. Dong	14	204	8	0,444
10	S. Moschoyiannis	11	103	6	0,333

documents in our final dataset, 1715 contained author keywords, which formed the basis for this analysis. The remaining documents did not include keywords and were therefore excluded from the co-occurrence network. The co-occurrence network of these keywords was constructed to identify clusters of related terms, which were then analyzed to determine the key themes within the research. The minimum threshold for a keyword to be included in the analysis was set at 20 occurrences, ensuring that the map represents the most significant and frequent research topics.

5.1. Key themes in digital ecosystem research

In this section, we explore the key thematic clusters identified through a detailed examination of the current research landscape in digital ecosystems. The thematic analysis uncovers distinct clusters of research focus, each representing a critical domain within the broader digital ecosystem field, as shown in Fig. 7. These clusters not only highlight the diversity of topics being explored but also reveal the interconnectedness of various themes, pointing to the complex and multifaceted nature of digital ecosystems. The thematic clusters identified include: Digital Transformation and Economy (red cluster), Emerging Technologies and Learning Systems (green cluster), Foundational Technologies and Semantic Architecture (blue cluster), Human and Social Interaction in Digital Spaces (purple cluster), and Business

Strategy and Innovation (yellow cluster).

5.2. Digital transformation and economy (red cluster)

The first major cluster centers on the intersection of digital transformation and the economy, encompassing topics such as digital economy, digital transformation, big data, digital technologies, software design, and business models. This cluster underscores the profound impact of digital technologies on economic structures and business strategies. The digital transformation of industries is not merely a shift in technological tools but a comprehensive change in how businesses operate, innovate, and compete. (Cennamo et al., 2020; Ishfaq et al., 2022; Zutshi et al., 2021) Research in this cluster focuses on how digital transformation drives economic growth, reshapes industries, and leads to the emergence of new business models. The advent of big data and digital technologies has enabled companies to innovate rapidly, optimize their operations, and deliver enhanced value to customers. However, this transformation also brings challenges, including the need for new governance structures, the management of digital platforms, and the integration of digital services into traditional business models (Brunetti et al., 2020; Cennamo et al., 2020; Sahut et al., 2021; Zutshi et al., 2021). Moreover, the economic implications of digital ecosystems are profound, influencing competition, market dynamics, and the development of digital economies. Scholars within this cluster explore the ways in which digital transformation impacts economic growth, the role of digital platforms in fostering or hindering competition, and the strategies businesses must adopt to thrive in a rapidly changing digital landscape (Brunetti et al., 2020; Cennamo et al., 2020; Kopalle et al., 2020).

5.3. Emerging technologies and learning systems (green cluster)

The second thematic cluster focuses on the integration of emerging technologies into various sectors, with a particular emphasis on learning systems and smart cities. Key topics within this cluster include the Internet of Things (IoT), artificial intelligence (AI), machine learning, data analytics, smart cities, and e-learning. This cluster reflects the

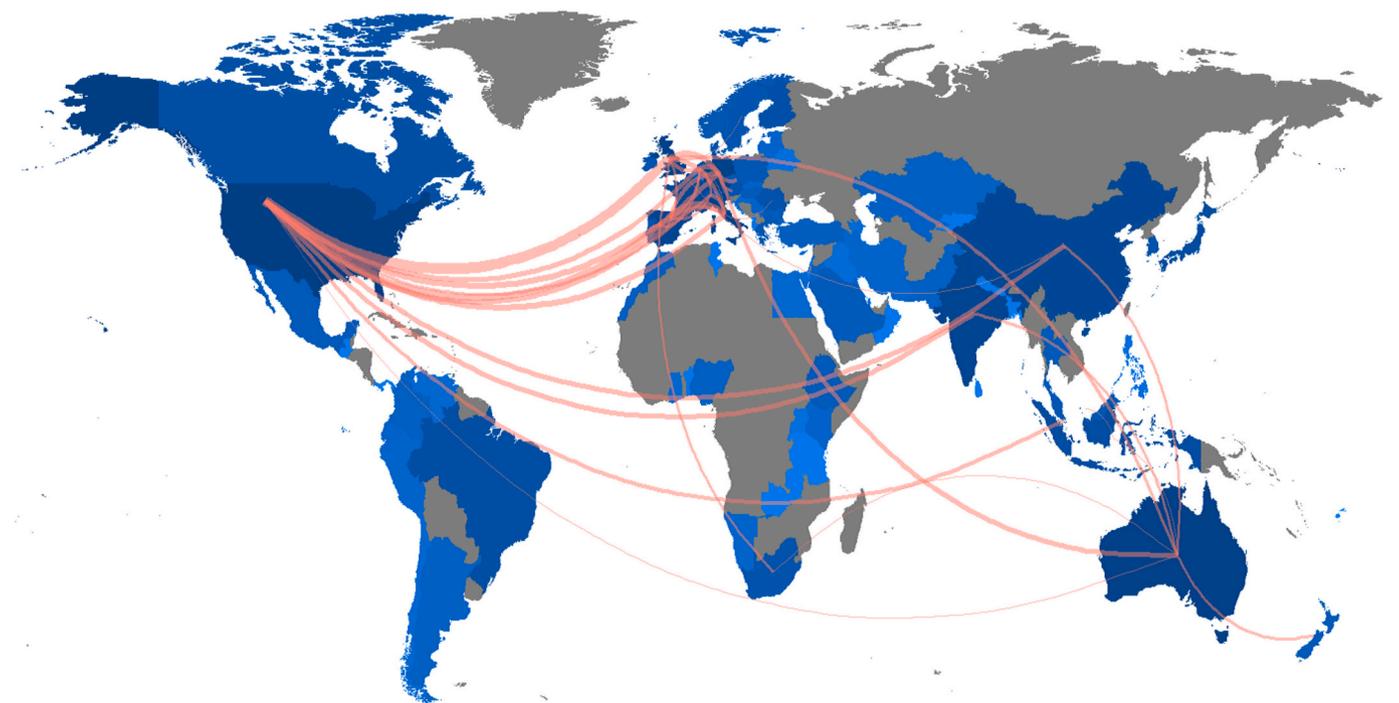


Fig. 4. Country-collaboration map (created with biblioshiny, minimum number of collaborations: 5).

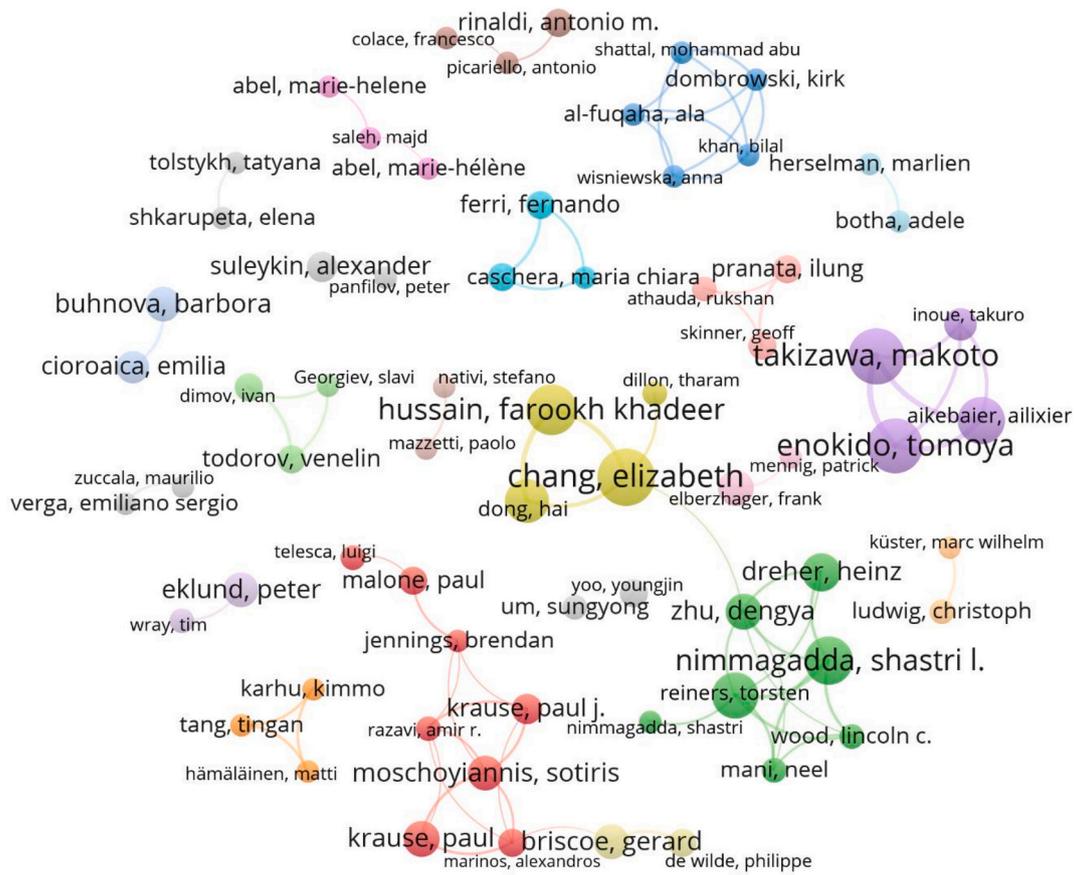


Fig. 5. Author Collaboration Network (created with Biblioshiny, minimum number of collaborations: 3).

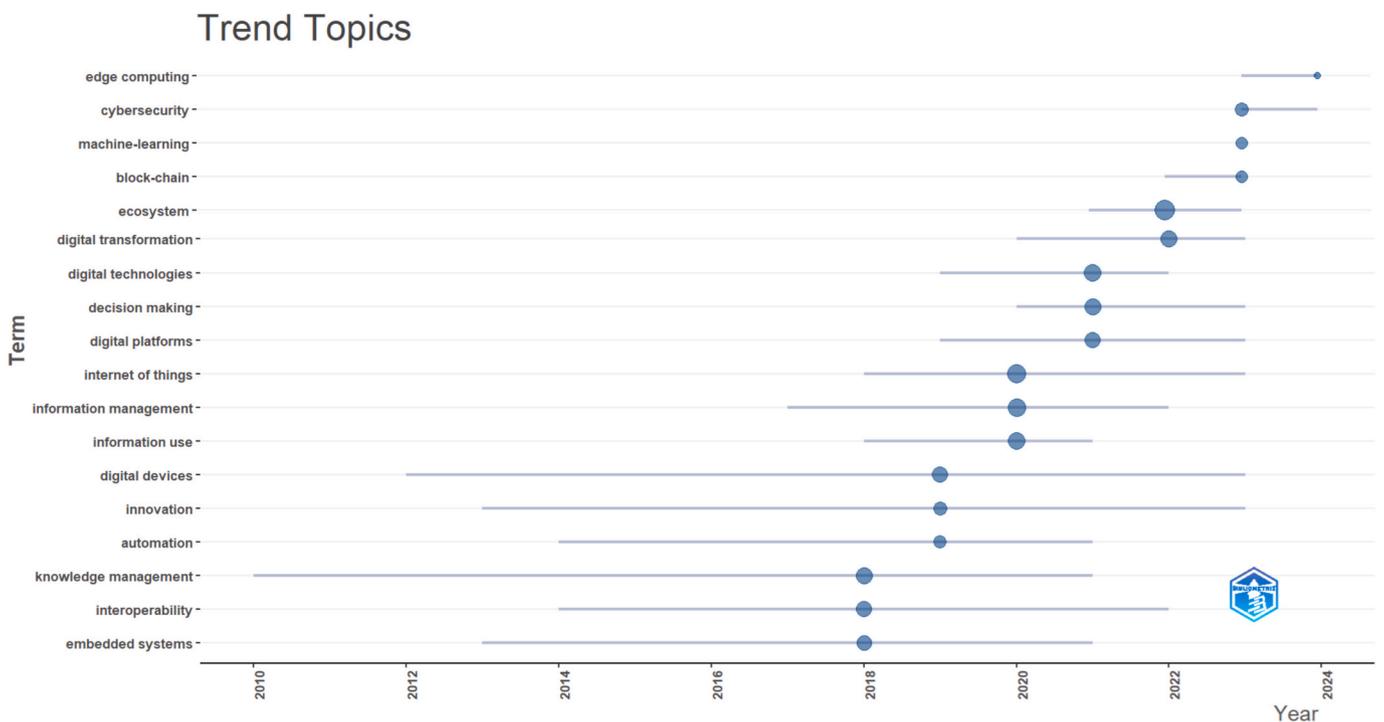


Fig. 6. Thematic Evolution of Digital Ecosystem Topics (created with Biblioshiny).

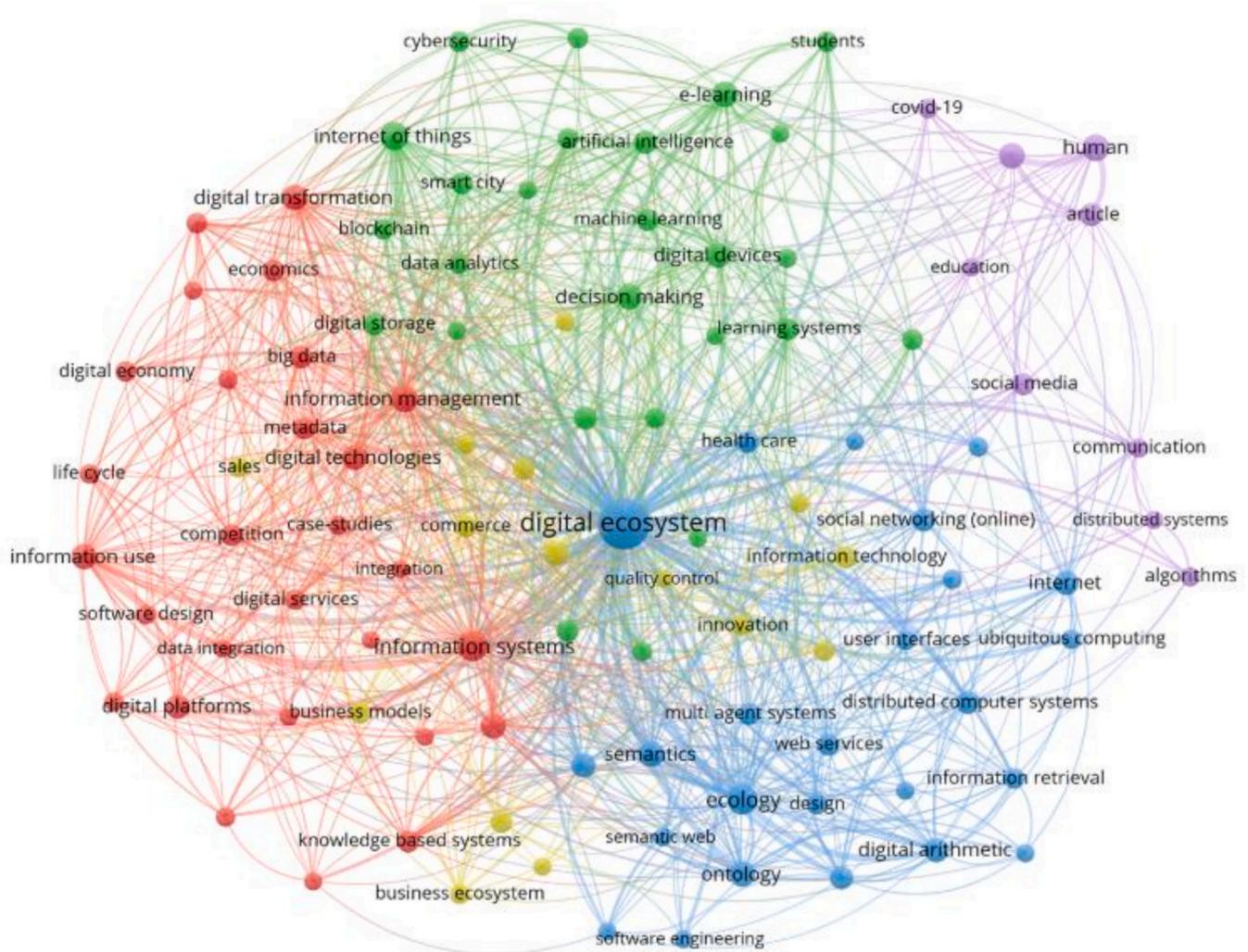


Fig. 7. Keyword Co-occurrence network of index keywords (created with VOSviewer, minimum number of occurrences: 20).

growing importance of AI and IoT in transforming traditional systems and processes (Del Río Castro et al., 2021; Morgan-Thomas et al., 2020; Nambisan & Baron, 2021). The research here delves into how these emerging technologies are applied to enhance decision-making, optimize operations, and create more efficient learning environments. AI and machine learning are increasingly being used to analyze vast amounts of data, leading to more informed and effective decision-making processes in both urban and educational settings. The concept of smart cities, driven by IoT and AI, exemplifies the potential of these technologies to create more sustainable, efficient, and responsive urban environments (Del Río Castro et al., 2021; Ishfaq et al., 2022; Morgan-Thomas et al., 2020). In the realm of education, e-learning platforms powered by AI and machine learning are revolutionizing the way knowledge is delivered and consumed. These platforms offer personalized learning experiences, adapt to the needs of individual learners, and provide real-time feedback, making education more accessible and effective. This cluster underscores the critical role of emerging technologies in shaping the future of learning and urban development (Barykin et al., 2021; Brunetti et al., 2020; de Las Heras-Pedrosa et al., 2020).

5.4. Foundational technologies and semantic architecture (blue cluster)

The blue cluster represents the technological and conceptual backbone of digital ecosystem research, focusing on the core computer

science principles required to build such complex systems. Key themes encompass “software engineering,” “ontology,” “semantics,” “multi-agent systems,” “web services,” and “distributed computer systems.” This cluster addresses the fundamental architectural challenges of creating environments where diverse and autonomous digital entities can interact meaningfully and efficiently. It forms the foundational layer that enables the higher-level economic and social applications seen in other clusters (Dong et al., 2011; Hadzic & Chang, 2010). Research within this cluster delves into the creation of intelligent and interoperable systems. Scholars explore how “semantic technologies,” such as the “semantic web” and formal “ontologies,” can overcome challenges in “information retrieval” and data integration, allowing different components of the ecosystem to “understand” each other (Davis et al., 2021). This is crucial for enabling the seamless function of “web services” and ensuring that information flows correctly across “distributed computer systems.” The focus on “multi-agent systems” reflects the need to manage the dynamic and decentralized nature of these ecosystems, where autonomous agents must coordinate their actions to achieve collective goals (Hadzic & Chang, 2010). Moreover, this cluster strongly emphasizes the concept of “ecology design,” suggesting a move away from rigid, centrally controlled systems towards more adaptive, resilient, and self-organizing digital environments that mimic principles from natural ecosystems (Barykin et al., 2020). The goal is to engineer systems that can evolve and sustain themselves over time. This foundational work on architecture and intelligence is ultimately aimed at

improving the end-user experience through better “user interfaces” and enabling “ubiquitous computing,” where the underlying complexity of the ecosystem is hidden from the user, creating a seamless and intuitive interaction (Nativi et al., 2021).

5.5. Human and social interaction in digital spaces (purple cluster)

The fourth thematic cluster focuses on the social and human aspects of digital ecosystems, with key themes including human interaction, social media, communication, education, and social networking (online). This cluster is particularly relevant in the context of the COVID-19 pandemic, which has accelerated the shift towards online communication and education (Thomas et al., 2022). Research in this cluster explores how digital platforms and ecosystems are transforming the way people interact, communicate, and learn. Social media platforms have become central to human interaction, influencing social dynamics, cultural norms, and even political processes. The cluster also examines the impact of digital ecosystems on education, particularly the shift to online learning and the challenges and opportunities this presents (Morgan-Thomas et al., 2020; Nambisan & Baron, 2021). The social implications of digital ecosystems are vast, ranging from the effects of social media on mental health to the role of online platforms in facilitating or hindering democratic processes. This cluster highlights the need for a deeper understanding of the human and social dimensions of digital ecosystems, particularly in light of the rapid changes brought about by digital transformation (Mihelj & Jiménez-Martínez, 2021; Morgan-Thomas et al., 2020).

5.6. Business strategy and innovation (yellow cluster)

The yellow cluster forms the strategic and commercial core of the research landscape, centered prominently around the main keyword “digital ecosystem”. This cluster bridges technological possibilities with market-oriented applications, focusing on keywords such as “commerce”, “innovation”, “quality control”, and “decision making”. It represents the managerial perspective, examining how digital ecosystems are leveraged to create business value, enhance operational efficiency, and foster competitive advantages. The inclusion of “case studies” further highlights the applied and empirical nature of the research within this thematic area. Research in this cluster investigates the mechanisms through which innovation is managed and commercialized within complex digital networks. Scholars explore how effective “decision making” processes, often supported by data analytics from the green cluster, lead to improved “quality control” and service delivery. This theme is not abstract; it is concerned with the tangible outcomes of digital strategies, analyzing how concepts like “commerce” are reshaped through digital platforms and how continuous “innovation” becomes a critical survival factor for firms operating within these ecosystems (Barykin et al., 2020; Kopalle et al., 2020; Teubner & Stockhinger, 2020). Furthermore, the central position of this cluster in Fig. 7 underscores its integrative function. It draws heavily from the economic principles of the red cluster, the emerging technologies of the green cluster (like “health care” applications), and the technical foundations of the blue cluster (like “multi-agent systems”). This cluster is where theoretical models and technological tools are translated into actionable business strategies and measurable commercial success. It addresses the “so what?” question of digital ecosystems: how they can be effectively designed, managed, and governed to achieve specific organizational and economic goals (Brunetti et al., 2020; Las Heras-Pedrosa et al., 2020; Thomas et al., 2022).

The thematic clusters identified in this analysis provide a comprehensive overview of the current research landscape in digital ecosystems. Each cluster represents a distinct but interconnected domain of inquiry, highlighting the multifaceted nature of digital ecosystems and the diverse challenges and opportunities they present. By understanding these clusters, researchers can better navigate the complex terrain of

digital ecosystems, contributing to the continued evolution and sustainability of these vital systems.

5.7. Detailed justification of implications for future research based on thematic clusters

The thematic clusters identified in the previous analysis not only provide a comprehensive overview of current research trends within digital ecosystems but also highlight critical areas where future research is urgently needed. Each cluster represents a domain with significant implications for the continued evolution of digital ecosystems. By delving into these implications, researchers can address emerging challenges and leverage new opportunities, ultimately contributing to the sustainable development and growth of digital ecosystems. To identify the most pressing research areas, we analyzed the twenty most-cited studies in the field published within the last four years. This approach is a well-established method for identifying influential research and emerging trends (Aksnes et al., 2019; Bornmann & Daniel, 2008). Highly-cited articles are often considered to have set the agenda for subsequent research, shaping the direction of scholarly inquiry. Therefore, examining these works provides valuable insights into the areas that are currently attracting significant attention and are likely to remain important in the near future. Table 6 presents these twenty influential studies, aligned with key Areas of Future Research Directions. The areas identified are directly derived from the themes and challenges highlighted in these works. The high citation counts underscore the importance of these topics, demonstrating their influence on both academic discourse and practical applications. This alignment justifies the prioritization of these areas as central to future research efforts.

By examining these studies, we were able to pinpoint gaps in current knowledge. We have divided these gaps into the following five areas of future research directions:

6. Area of future research directions

6.1. Digital transformation and economy: Addressing governance and sustainability challenges

The cluster focused on digital transformation and the economy reveals a complex interplay between technological advancements and economic structures. As digital technologies continue to reshape industries, there is a growing need for research that examines the governance and sustainability of these ecosystems.

- Governance Models:** With digital platforms playing a central role in the economy, research must urgently explore governance models that ensure fair competition and prevent monopolistic behaviors. The work by Sahut et al. (2021), which provides a micro-level perspective on how digital entrepreneurs create value, highlights that this phenomenon not only drives innovation but also concentrates power, creating an immediate need for new governance. This is echoed by studies focusing on the strategic challenges of transformation. For instance, Brunetti et al. (2020) use a multi-stakeholder approach to identify systemic challenges, while Kopalle et al. (2020) offer a specific framework for how legacy firms can adapt. Both underscore the practical governance gaps firms face. Similarly, Cennamo et al. (2020), in their work on the scope of digital transformation, emphasize that new modalities of value co-generation demand new governance mechanisms. Future research should therefore build on comprehensive strategic reviews, like the one by Teubner and Stockhinger (2020) on the evolution of IS strategy in the digital age, to investigate adaptive regulatory frameworks. A key question is how governance can address disruptive technologies. The study by Zutshi et al. (2021), which systematically reviews the value propositions of blockchain, points to its potential for creating radical new forms of decentralized,

Table 6

The twenty most frequently cited studies aligned with the Areas of Future Research Directions.

No	Name (Author and Title)	Area of Future Research Directions	Citations
1	Davis et al., 2021 - Comparative Toxicogenomics Database (CTD): Update 2021	5.2	634
2	Thomas et al., 2022 - Building on the momentum: Sustaining telehealth beyond COVID-19	1.2, 4.2	271
3	Del Río Castro et al. 2021 - Unleashing the convergence amid digitalization and sustainability towards pursuing the Sustainable Development Goals (SDGs): A holistic review	1.2, 2.1, 2.2, 5.2	263
4	Sahut et al., 2021 - The age of digital entrepreneurship	1.1, 3.2	203
5	Baskerville et al., 2020 - Digital first: The ontological reversal and new challenges for information systems research	3.2, 4.1	193
6	Brunetti et al., 2020 - Digital transformation challenges: strategies emerging from a multi-stakeholder approach	1.1, 2.1, 2.2, 3.2	184
7	Nambisan & Baron, 2021 - On the costs of digital entrepreneurship: Role conflict, stress, and venture performance in digital platform-based ecosystems	2.1, 3.2, 4.1	137
8	Morgan-Thomas et al., 2020 - Digital ecosystem and consumer engagement: A socio-technical perspective	2.2, 3.2, 4.1	113
9	Kopalle et al., 2020 - How legacy firms can embrace the digital ecosystem via digital customer orientation	1.1, 2.2, 3.2	109
10	Cennamo et al., 2020 - Managing Digital Transformation: Scope of Transformation and Modalities of Value Co-Generation and Delivery	1.1, 3.2	98
11	Las Heras-Pedrosa et al. 2020 - Sentiment analysis and emotion understanding during the COVID-19 pandemic in Spain and its impact on digital ecosystems	2.1, 4.1, 5.2	95
12	Nativi et al., 2021 - Digital ecosystems for developing digital twins of the earth: The destination earth case	1.1, 2.1, 5.1	86
13	Barykin et al., 2020 - Economics of digital ecosystems	2.1, 3.2, 5.1	75
14	Barykin et al., 2021 - Developing the physical distribution digital twin model within the trade network	2.1, 3.1, 5.1	73
15	Mihelj und Jimenez 2021 - Digital nationalism: Understanding the role of digital media in the rise of 'new' nationalism	1.1, 4.1	69
16	Baggio et al., 2020 - Smart tourism destinations: a critical reflection	3.1, 5.1	65
17	Ishfaq et al., 2022 - Digital supply chains in omnichannel retail: A conceptual framework	1.2, 2.1, 3.2	64
18	D'Urban Jackson et al. 2020 - Three-dimensional digital mapping of ecosystems: A new era in spatial ecology	5.1	63
19	Zutshi et al., 2021 - The value proposition of blockchain technologies and its impact on Digital Platforms	1.1, 2.1, 3.2	61
20	Teubner and Stockinger 2020 - Literature review: Understanding information systems strategy in the digital age	1.1, 3.2	61

participative governance, a concept existing models are unprepared for. Furthermore, the analysis of “digital nationalism” by [Mihelj and Jiménez-Martínez \(2021\)](#) demonstrates that governance is not purely economic, but must also account for the complex ways digital ecosystems shape national identity and geopolitics. Finally, even

large-scale scientific initiatives, like the “Digital Twins of the Earth” proposed by [Nativi et al. \(2021\)](#), require a “metasystemic” governance level to manage vast, interconnected data ecosystems for the public good—a challenge that far exceeds traditional corporate governance.

- **Sustainability:** The sustainability of digital ecosystems, encompassing both environmental and social dimensions, is another critical research area. A strong foundation for this inquiry is provided by the holistic review from [Del Río Castro et al. \(2021\)](#), which systematically explores the nexus between digitalization and the Sustainable Development Goals (SDGs). Building on this, future research could apply sustainability criteria to specific ecosystem contexts. For example, the conceptual framework for digital supply chains developed by [Ishfaq et al. \(2022\)](#), while focused on operational structure, provides an ideal basis for subsequent research on optimizing these systems for lower environmental impact. On the social front, the work by [Thomas et al. \(2022\)](#), which identifies key requirements for sustaining telehealth services post-pandemic, directly highlights the need for research into socially sustainable digital health ecosystems that ensure long-term accessibility and equity.

6.2. Emerging technologies and learning systems: Enhancing AI integration and E-learning effectiveness

The integration of emerging technologies like AI and IoT presents numerous opportunities, but these technologies also introduce new challenges that warrant further exploration.

- **AI and Decision-Making:** Future research must focus on how AI can be better integrated into decision-making processes, particularly concerning its ethical implications. The general challenges of digital transformation, identified through the multi-stakeholder approach of [Brunetti et al. \(2020\)](#), become more acute with AI, demanding new frameworks for transparency and fairness. This is especially true at the intersection of AI and sustainability, where the holistic review by [Del Río Castro et al. \(2021\)](#) identifies significant opportunities but also ethical caveats that require further investigation. A concrete application area is the development of digital twins. The work by [Nativi et al. \(2021\)](#), proposing digital twins of the Earth, and by [Barykin et al. \(2021\)](#), who model physical distribution twins, both rely heavily on AI. Future studies should therefore scrutinize the autonomous decision-making role of AI within these complex models. This also applies to other advanced technological integrations, such as the AI-driven supply chains envisioned in the framework by [Ishfaq et al. \(2022\)](#) or the new governance forms enabled by blockchain, as reviewed by [Zutshi et al. \(2021\)](#). Finally, research should address the human and social dimensions of AI-driven ecosystems. Studies like that of [de Las Heras-Pedrosa et al. \(2020\)](#), which uses AI-powered sentiment analysis to understand emotional responses during crises, show how AI can generate insights into human behavior. A vital future path would be to explore the opposite: how AI can be designed to actively mitigate human costs, such as the role conflict and stress faced by digital entrepreneurs identified by [Nambisan and Baron \(2021\)](#). This moves beyond AI for efficiency to AI for human well-being.
- **E-Learning and Personalization:** The rise of e-learning platforms powered by AI offers a rich area for future research on personalization. Scholars should explore how to optimize these technologies, and frameworks from commercial contexts can provide a useful starting point. For instance, the socio-technical perspective on consumer engagement from [Morgan-Thomas et al. \(2020\)](#) or the “digital customer orientation” for legacy firms proposed by [Kopalle et al. \(2020\)](#) could be adapted into a “learner orientation” to create more effective personalized learning experiences. Beyond personalization, research must address accessibility and equity. The multi-stakeholder analysis by [Brunetti et al. \(2020\)](#), which explicitly

includes the education industry, highlights the systemic challenges involved. Furthermore, ensuring equitable access to e-learning aligns directly with the broader sustainability goals reviewed by [Del Río Castro et al. \(2021\)](#), framing the digital divide as a key sustainability issue for future research.

6.3. Information systems and technology integration: fostering interoperability and innovation

As digital ecosystems become more complex, ensuring that different systems can communicate and work together seamlessly is essential for their success.

- **Interoperability Standards:** Future research should focus on the development of interoperability standards, which are crucial for seamless integration. At a technical level, the work by [Barykin et al. \(2021\)](#), which develops a specific mathematical model for a digital twin, implicitly highlights this need; for such specialized models to be effective, they require data and model interoperability to connect with the broader ecosystem. At a destination level, the critical reflection on smart tourism by [Baggio et al. \(2020\)](#) provides a direct warning: their analysis shows that even advanced digital tools fail if the underlying organizational and operational processes are not integrated. This demonstrates that a lack of interoperability can undermine the entire “smart” proposition, preventing the creation of a seamless experience.
- **Innovation Ecosystems:** Future studies should examine how digital ecosystems can be structured to support and orchestrate innovation. This requires a new strategic mindset, as the foundational work by [Baskerville et al. \(2020\)](#) on the “digital first” ontological reversal posits a fundamental shift in how reality is constructed, setting new challenges for IS research. To navigate this, firms need updated strategic frameworks. The literature review on IS strategy by [Teubner and Stockhinger \(2020\)](#) and the work by [Cennamo et al. \(2020\)](#) on managing the scope of transformation both provide a high-level understanding of this new strategic landscape. At a practical level, the multi-stakeholder approach of [Brunetti et al. \(2020\)](#) demonstrates that fostering innovation is a systemic challenge that requires coordinated action. Research must also delve into the specific roles of different actors. For instance, while the micro-level perspective of [Sahut et al. \(2021\)](#) frames the new “age of digital entrepreneurship,” the study by [Nambisan and Baron \(2021\)](#) on the costs of these new roles reveals the significant stress entrepreneurs face, creating a need to balance opportunities with well-being. Similarly, research must consider how established players adapt, as shown in the framework by [Kopalle et al. \(2020\)](#) for legacy firms adopting a digital customer orientation. A truly holistic understanding of innovation also requires integrating the socio-technical perspective on consumer engagement from [Morgan-Thomas et al. \(2020\)](#) and the foundational economic principles of collaboration proposed by [Barykin et al. \(2020\)](#). Orchestrating these diverse actors and principles to foster sustainable innovation is the core challenge, whether in specific applications like the digital supply chains conceptualized by [Ishfaq et al. \(2022\)](#) or when integrating new paradigms like the value propositions of blockchain identified by [Zutshi et al. \(2021\)](#).

6.4. Human and social interaction in digital spaces: navigating the social and ethical implications

As digital platforms become increasingly central to daily life, understanding their social and ethical implications is crucial.

- **Social Media and Mental Health:** The impact of social media on mental health requires urgent research attention. The “digital first” paradigm proposed by [Baskerville et al. \(2020\)](#) provides the foundational argument for this urgency, as it posits a fundamental

reshaping of human experience. The personal costs of this new reality are empirically demonstrated in studies like that of [Nambisan and Baron \(2021\)](#), whose work quantifies the role conflict and stress faced by digital entrepreneurs. To study these phenomena systematically, future research can employ the socio-technical perspective offered by [Morgan-Thomas et al. \(2020\)](#) as a theoretical lens, and practical methods like the large-scale sentiment and emotion analysis used by [Las Heras-Pedrosa et al. \(2020\)](#) during the COVID-19 pandemic. Finally, the work on “digital nationalism” by [Mihelj and Jiménez-Martínez \(2021\)](#) serves as a crucial reminder that these platforms have profound societal and psychological impacts beyond individual well-being, which must be understood to foster positive social interactions.

- **Online Education and Equity:** The shift towards online education, accelerated by the COVID-19 pandemic, requires research focused on designing digital ecosystems that ensure equitable access. Instructive lessons can be drawn from other essential service sectors. For example, the work by [Thomas et al. \(2022\)](#), which specifically investigates the requirements for sustaining telehealth post-pandemic, provides a powerful parallel. Their findings on the challenges of maintaining momentum and ensuring equitable access to a critical digital service can directly inform future studies on how digital tools can bridge educational gaps for all students.

6.5. Ecology and semantics in digital ecosystems: building sustainable and intelligent systems

The ecology and semantics cluster highlights the growing importance of sustainability and semantic technologies in the design of digital ecosystems.

- **Sustainable Digital Systems:** Research should explore how ecological principles can be applied to enhance the sustainability of digital ecosystems. The work on creating digital twins of the Earth by [Nativi et al. \(2021\)](#) is a prime example of using digital ecosystems for environmental monitoring. The call for three-dimensional digital mapping of ecosystems by [D’Urban Jackson et al. \(2020\)](#) points to a new era in spatial ecology enabled by digital tools. At a more applied level, critical reflections on “smart tourism” by [Baggio et al. \(2020\)](#) question the actual sustainability of such destinations, while the economic models of [Barykin et al. \(2020\)](#) provide frameworks for analyzing resource distribution, which is key to sustainability.
- **Semantic Technologies:** The use of semantic technologies is crucial for improving knowledge management and enabling intelligence within digital ecosystems. A prime example of a large-scale application is the Comparative Toxicogenomics Database detailed by [Davis et al. \(2021\)](#), which functions as a massive, semantic knowledge base essential for scientific progress. At a more applied level, the study by [Del Río Castro et al. \(2021\)](#) demonstrates the power of specific semantic techniques like sentiment analysis to generate real-time insights from unstructured data during crises. The broader need for these technologies is emphasized by the holistic review of [Del Río Castro et al. \(2021\)](#), which makes clear that tackling complex challenges like the SDGs relies on semantic approaches to organize and link disparate data. Future research should therefore focus on how these technologies can be more deeply integrated to enhance the overall intelligence and adaptability of digital ecosystems.

7. Discussion and conclusion

This final chapter synthesizes the findings of our bibliometric analysis. We begin with a new discussion section that critically reflects on the broader implications of our results. This is followed by a summary of the findings structured around our research questions, an overview of the study’s limitations, and a concluding statement on the contribution and future of digital ecosystem research.

8. Discussion

Beyond simply mapping the landscape, our findings spark a deeper conversation about the nature and trajectory of digital ecosystems. We identified a clear shift in research from purely technical or simulated ecosystems to complex socio-technical systems with profound economic and social consequences. Several implications of this evolution warrant further discussion.

The Paradox of Value Creation and Capture Our thematic analysis highlights a strong focus on “business models” and “digital transformation.” While the literature celebrates the immense value created through ecosystem interactions, it is less clear on how this value is distributed. The dynamics of platforms often lead to a “winner-take-all” scenario, raising critical questions about fairness and sustainability that our proposed future research on governance must address. The goal of an ecosystem is to bring actors together to co-create value; however, future work must more critically examine whether these systems lead to equitable value capture for all participants or primarily benefit the platform orchestrator.

Human Interaction and Organizational Learning at the Core A key insight from our analysis is the centrality of the “Human and Social Interaction” cluster. While we touch upon this in our future research agenda, its broader implication is that digital ecosystems are fundamentally learning systems. They are not just technological infrastructures but social structures where knowledge is created, shared, and applied, which in turn fuels innovation. For example, user feedback on social media directly influences product development, and developers learn from each other in app store environments. This continuous, distributed organizational learning is a key catalyst for the resilience and adaptability of these ecosystems. Future research should therefore not only focus on e-learning platforms but on the mechanisms of organizational learning that are embedded within all digital ecosystems, as this is crucial for navigating the transition towards greater sustainability and social responsibility.

Navigating the Challenges: From Fragmentation to Integration Our analysis confirmed that the research field is fragmented. This fragmentation mirrors the complexity of the ecosystems themselves. The primary challenge and opportunity for the field is integration. Our identification of five distinct thematic clusters is a step towards creating a more unified map. The most significant future contributions will likely come from research that bridges these clusters—for instance, by examining how “Emerging Technologies” (Cluster 2) like AI can be governed to enhance “Human and Social Interaction” (Cluster 4) in an ethical manner, or how principles of “Ecology” (Cluster 5) can inform sustainable “Digital Economies” (Cluster 1).

8.1. Summary of findings

Our study provides a comprehensive analysis of the current state and evolution of digital ecosystem research, addressing three central research questions to better understand the field’s intellectual structure, thematic focus, and future directions.

RQ1: What are the most influential and productive research constituents in digital ecosystem research? Research in digital ecosystems is primarily driven by significant funding from European and Asian institutions. The European Commission is the most prominent sponsor, funding 75 articles, highlighting the European Union’s strong commitment to this field. Other key contributors include the Horizon 2020 Framework Programme, the European Regional Development Fund, and the National Natural Science Foundation of China. Influential journals such as the IEEE Transactions on Industrial Electronics and the Journal of Information Technology play a critical role in disseminating research. Prolific authors like E. Chang and M. Takizawa have significantly shaped the field with numerous articles and high citation counts. The research landscape is characterized by strong global collaborations, particularly between China, the United States, and European Union

member states, underscoring the interconnectedness of digital ecosystem research.

RQ2: What are the key topics and themes investigated in digital ecosystem research? Digital ecosystem research encompasses five prominent clusters of themes. The first, Digital Transformation and Economy, focuses on how technologies like big data reshape economic structures and business models. The second, Emerging Technologies and Learning Systems, explores the integration of AI, IoT, and machine learning into sectors like smart cities and e-learning. The third cluster, Foundational Technologies and Semantic Architecture, examines the core computer science principles needed to build these systems. The fourth cluster, Human and Social Interaction in Digital Spaces, delves into the social aspects of digital platforms, particularly relevant in the post-pandemic era. Finally, the Business Strategy and Innovation cluster represents the managerial and commercial core, focusing on how ecosystems create business value.

RQ3: What are promising areas for future research on digital ecosystems? Promising areas for future research span multiple domains. In Digital Transformation and the Economy, research is needed on governance models for digital platforms to ensure fair competition and on the environmental sustainability of digital technologies. For Emerging Technologies, future work should focus on the ethical integration of AI in decision-making and on enhancing personalized e-learning while addressing the digital divide. In Information Systems, developing interoperability standards and understanding how ecosystems can foster innovation are critical. For Human and Social Interaction, the impact of social media on mental health is an area requiring urgent attention. Our analysis also reveals that specific application domains, particularly healthcare, have become prominent fields for digital ecosystem research. These so-called “Digital Health Ecosystems” represent a critical area of study, focusing on challenges that range from systematic design methodologies to semantic service discovery, thereby creating significant societal impact (Dong et al., 2011; Hadzic & Chang, 2010). Additionally, two other critical areas for future research emerge from our analysis. First, the increasing importance of sustainability suggests a need for more research into “Green Digital Ecosystems.” As exemplified by foundational work on energy-efficient infrastructure (Enokido et al., 2014), future studies could explore how to design and manage digital ecosystems to minimize their environmental footprint. Second, as these ecosystems become more pervasive, ensuring their security and resilience is paramount. The appearance of keywords like “cybersecurity” and “blockchain” signals a nascent but vital research stream focused on trust, data integrity, and defense mechanisms against systemic risks. Finally, in Ecology and Semantics, research is needed on designing more energy-efficient digital systems and improving knowledge management through advanced semantic technologies.

8.2. Limitations

Our study, along with the bibliometric approach we employed, is subject to some limitations. Firstly, as recommended by Donthu et al. (2021), we relied solely on the Scopus database for our data collection. While Scopus is a comprehensive source, this choice inherently restricts our coverage. Our reliance on a single database means that publications indexed exclusively in other databases (e.g., Web of Science) are not included, representing a potential scope limitation.

Additionally, our sample was limited to journal articles, conference proceedings, and reviews. We excluded other publication types, such as book chapters, editorials, grey literature, and practitioner reports, which could have provided additional insights. Non-English and non-finalized articles were also excluded from our dataset, potentially omitting relevant contributions. Our focus on scientific literature means that our study primarily reflects the current state of academic research, while practical developments remain outside the scope of this work. Finally, it is important to acknowledge that bibliometric analysis, though effective for quantitatively assessing large volumes of literature, cannot substitute

for qualitative research methods and is inherently limited to presenting a snapshot of a rapidly evolving field.

9. Conclusion

Our study offers a comprehensive overview of the current state and evolution of digital ecosystem research, emphasizing the field's intellectual structure, thematic focus, and future directions. We identified the most influential research constituents, highlighting the significant role of European and Asian funding institutions, key journals, and prolific authors in driving the field forward. The strong global collaborations underscore the multidisciplinary and interconnected nature of this research area.

The thematic analysis revealed that digital ecosystem research spans diverse areas, from the technical and economic to the social and ecological. Looking ahead, our study identifies several promising avenues for future research, including the governance of digital platforms, the sustainability of digital ecosystems, the ethical integration of emerging technologies, and the impact of digital ecosystems on human well-being. Addressing these challenges will require continued interdisciplinary collaboration and a focus on developing sustainable, transparent, and inclusive digital ecosystems. By advancing research in these areas, scholars can contribute to the development of digital ecosystems that are not only technologically advanced but also socially responsible and environmentally sustainable.

CRediT authorship contribution statement

Arne Jeppe: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Project administration, Methodology, Investigation, Data curation, Conceptualization. **Tim Bree:** Writing – review & editing, Writing – original draft, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Erik Karger:** Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Methodology, Formal analysis, Data curation, Conceptualization. **Heike Proff:** Writing – review & editing. **Frederik Ahlemann:** Writing – review & editing.

Declaration of competing interest

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

Data availability

No data was used for the research described in the article.

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