

Conceptualizing and defining digital innovation ecosystems: A systematic literature review

Research Article

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Abstract: Digital transformation gives rise to enhanced innovation, changes in the digital landscape, and elevated stakeholder interconnectedness, so the phenomenon of digital innovation ecosystems (DIEs) arises. DIEs give new opportunities but, at the same time, pose new challenges related to the interaction between citizens, communities, organizations, and territories in the rapidly changing environment. The DIE concept has been explored in the scientific literature, though it remains a topic of partial debate. Hence, the main objective of this research is to provide a full-fledged definition of the term DIE, its core components, and a conceptual framework of the studied phenomenon. The research adopts a systematic literature review of scholarly studies. Additionally, we use a latent semantic analysis to complement the results, particularly to provide statistical validation for the theorized DIE framework. The outcomes of this research may inspire further academic research and discussion, fostering a deeper understanding of the topic, while helping business and political decision-makers assess and enhance the development level of their respective DIEs.

Keywords: *Digital innovation ecosystems • Digital innovation • Systematic literature review • Latent semantic analysis*

1. Introduction

The digital transformation has strongly affected markets, customers, and firms, and favored the diffusion of innovation in the last few decades (Huru et al., 2021; Verhoef et al., 2021; Yoo et al., 2010). As a result, the limits and the barriers among the economic actors have fallen, new products and services have been introduced, and there are now more efficient ways to do business (Schwertner, 2017). The coronavirus disease 2019 (COVID-19) pandemic, causing severe repercussions, has however become an impetus for the development of the digital economy; digital technologies played a crucial role in connecting business to consumers during the COVID-19 pandemic (Dumitra et al., 2022). In this new dynamic context, the innovations are increasingly the result of a network that could present the form of an “ecosystem” (Kolloch & Dellermann, 2018) and less and less the direct consequences of the actions of a single entrepreneur (Hagedoorn, 1996); these fundamental changes pose new

challenges to the stakeholders involved in innovation processes (Adner & Kapoor, 2010).

As a consequence of shifts in economic and social spheres in recent decades (Shepherd, 2004), the concept of innovation ecosystems has emerged (Adner, 2006; Basole, 2009; Iansiti & Levien, 2004). An innovation ecosystem is described as a novel approach to innovation-related value-creating interactions among different actors (Adner & Kapoor, 2010; Dodgson et al., 2014; Granstrand & Holgersson, 2020). With the development of digital technologies and changes in economic and social conditions, innovation ecosystems have become more complex and hence new types of ecosystems have emerged (Al-Sulaiti et al., 2023; Gu et al., 2021). Digital transformation stimulates significant changes in the cooperation between companies, governments, and society (Mai et al., 2024; Nambisan et al., 2019), with digital companies emerging and looking for new approaches to collaboration and value-creation (Amit & Han, 2017; Ghezzi et al., 2022; Gregori & Holzmann, 2020). Digital innovation ecosystems (DIEs), as one of the innovation ecosystem types, being an inevitable part of the innovation context, lack a “coherent” and shared theoretical framework

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to consolidate diverse managerial and scientific perspectives (Wang, 2019).

The present research aims to answer the following question: “*What are the latest advancements in academic literature regarding the discussion on DIES?*” Accordingly, this study seeks to systematically review the scientific literature, gather and share evidence on the definitions and core components of DIES, and propose further conceptualization. Although DIES have been previously studied, and high-quality thorough research has been conducted on the topic, to the authors’ knowledge, no prior systematic summary of the ongoing debate has been presented. Moreover, with the increasing digitalization and ongoing digital transformation shifts, the authors anticipate a growing interest in this type of ecosystem. Therefore, the evidence gathered and the proposed framework could provide researchers with a foundation for future studies on the topic.

The article is structured as follows: Section 2 outlines the research methodology applied, detailing the step-by-step approach and introducing the research questions. Section 3 presents the findings of the study, including a latent semantic analysis (LSA) to complement the results. Finally, in Section 4, concluding remarks on the study are provided.

2. Research methodology

A systematic literature review (SLR) was chosen as an evidence-based approach for the present research (Tranfield et al., 2003); this approach has previously claimed its efficiency in managerial studies (Dall-Orsoletta et al., 2022; Savastano et al., 2019; van der Poll, 2022). The present study follows a six-step review process (Durach et al., 2017). The SLR process started with the definition of the research questions and the identification of the keyword combinations. The authors aimed to explore the vast variety of scholarly studies where the DIES were discussed. To achieve this scope, the keyword combination “digital innovation ecosystem*” was selected, with a wildcard (*) applied to encompass the scientific articles where the keyword combination was used in the plural form. The present research aims to gather evidence on the current state-of-the-art academic literature concerning the discussion on DIES. Through an SLR, this study intends to provide evidence on various aspects including *system levels, definitions, and dimensions of DIES* as discussed in academic literature. The literature that didn’t cover these issues was excluded from the sample. This evidence will

Type of inclusion criteria	Characteristic of inclusion criteria
Document type	Articles and research papers
Time period	Until December 2023
Language	English
Geography	Worldwide
Databases	Scopus, WOS, Google Scholar

Table 1. Inclusion criteria and their characteristics.

Source: Authors’ contribution.

be crucial for further conceptualization of DIES. As the second step of the research, the authors formulated the inclusion criteria for potentially relevant literature selection. The summary of the inclusion criteria and their characteristics is presented in Table 1.

In the third step of the research, potentially relevant literature was collected. The relevant literature retrieval was conducted using the default search field TITLE-ABS-KEY in Scopus, the Topic field in WOS, and the specified keyword combination in the search box of Google Scholar. The articles retrieved from Google Scholar were further checked by the authors for being peer-reviewed in order to guarantee the academic quality of the studies included in the present study.

Relevant literature was selected in the next (fourth) step of the research. Identification, screening, and inclusion steps of the literature selection process were reported using the PRISMA 2000 approach (Page et al., 2021); PRISMA 2000 represents a rigorous approach to literature selection (Moroianu et al., 2023). As a result, 43 documents were included in the review. Figure 1 represents the PRISMA flow diagram, illustrating the logical stages of the pertinent literature selection. At the identification stage of the research, the authors applied the inclusion criteria to identify relevant studies. At this stage, only duplicate articles were removed by common consent to maintain the broadest possible sample. During the screening stage, the authors reviewed and discussed the abstracts of the studies gathered in the identification phase. Studies that met the exclusion criteria were not included in the sample. After a full-text review, the authors reached a consensus to exclude certain articles that did not align with the exclusion criteria.

In the fifth step, a content analysis was conducted on the documents included in the review. The categories applied in the analysis included the study’s purpose, DIE application level, specific industry, sector, company, definition of DIE, scope of DIE creation, DIE components, and its relation to other types of innovation ecosystems.

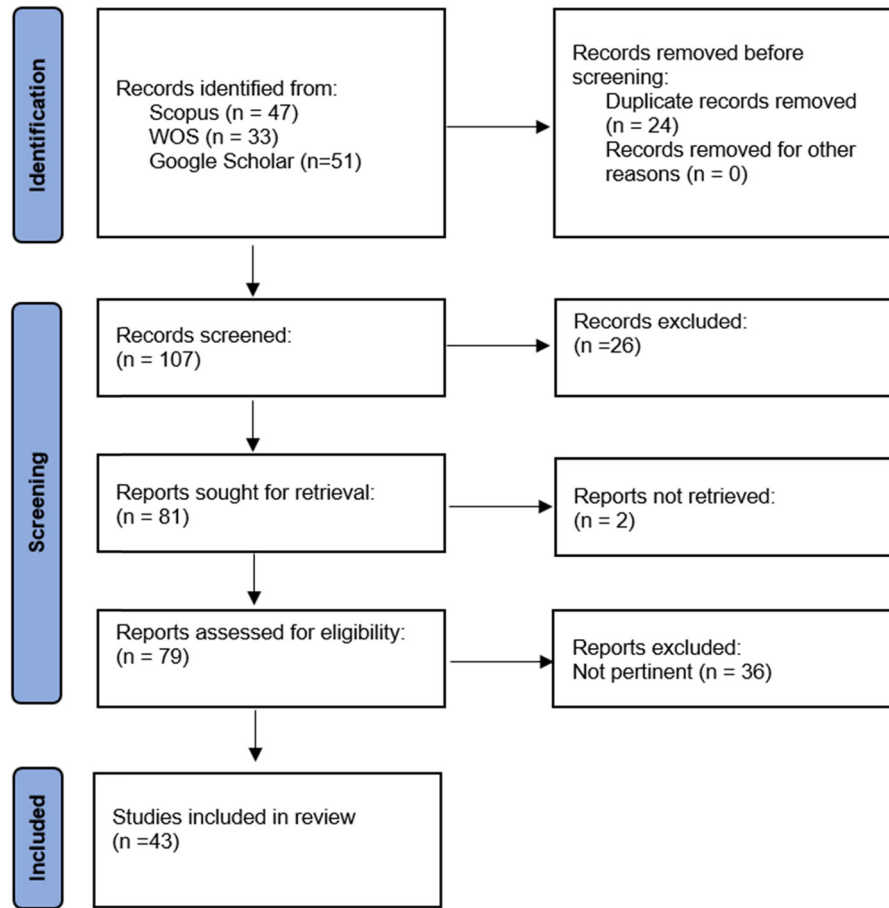


Figure 1. PRISMA 2020 flow diagram of the literature selection stages.

Source: Authors' elaboration based on Page et al., 2021.

Finally, in the sixth step, a descriptive analysis of the insights from the gathered academic literature was provided and discussed. Additionally, an LSA of the included articles was performed to (1) understand less obvious connections between different emerging themes and topics and (2) detect possible research gaps and avenues for future research. The findings of the review are presented in the next paragraph.

3. Results and discussion

3.1 Characteristics of the studied literature

As noted in the previous section, we selected 43 articles from a total of 131 retrieved across three databases for

our research. Figure 2 illustrates the distribution of the included literature by year of publication. The first mention of DIE dates back to 2011, but research on the topic has been growing since 2018, peaking in 2023. This pattern suggests that DIE is only beginning to gain major attention in scientific discourse, even though the studied literature shows in-depth research on this topic.

Figure 3 shows the distribution of studies by country. As can be seen from the graph, China is the leader in DIE research, and the USA, Germany, Brazil, Indonesia, and the UK are following. Other EU countries represented in the scientific literature are Austria, Finland, France, Italy, Latvia, Poland, Slovenia, Spain, Sweden, and the Netherlands. In total, the countries of the EU contribute to roughly half of the studies.

The distribution of articles in Table 2 is heterogeneous; the articles are nearly evenly divided between sources and publication types – journal articles and conference proceedings. However, in 2022 and 2023, we observe a

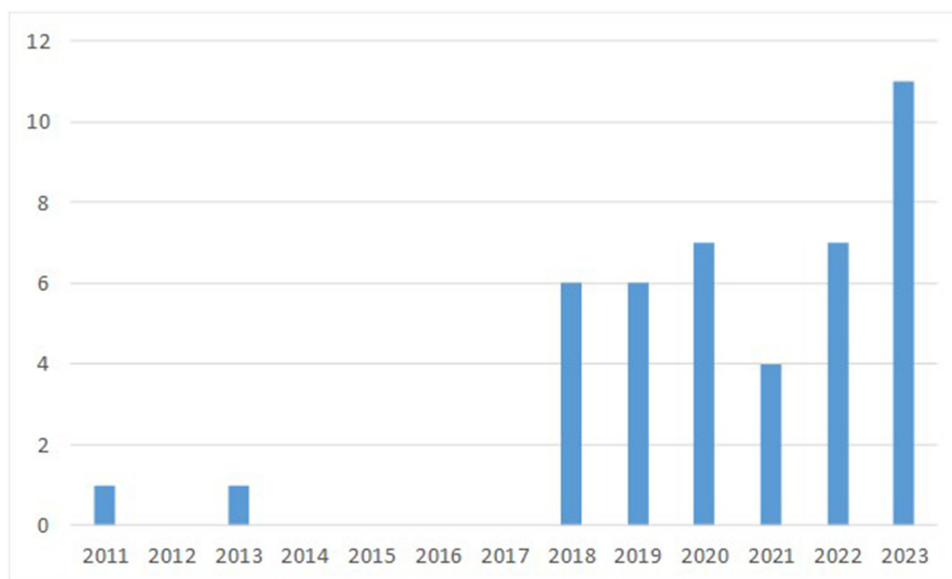


Figure 2. Distribution of the articles by years of publication.

Source: Authors' contribution.

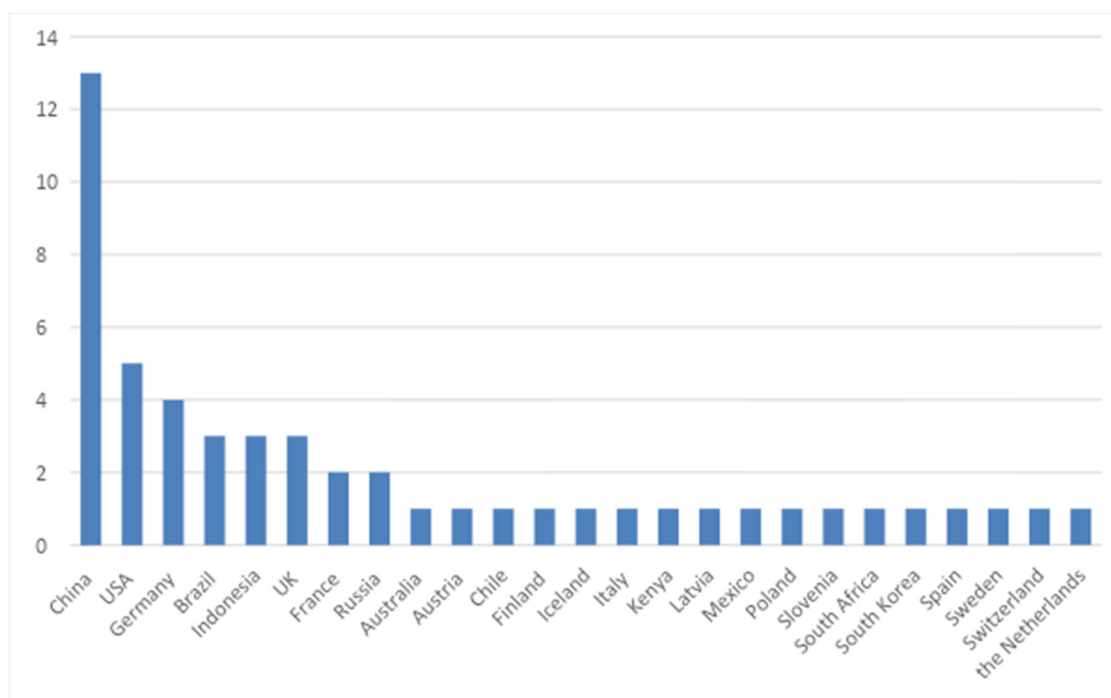


Figure 3. Distribution of the articles by country.

Source: Authors' contribution.

noticeable increase in topical studies within the same journals. The authors suggest that this trend may indicate the gradual integration of the DIE phenomenon into scientific discourse in recent years.

3.2 Definitions of the DIEs

The literature offers several DIE definitions, as shown in Table 3. According to the evidence gathered, a DIE is

Journal	'11	'12	'13	'14	'15	'16	'17	'18	'19	'20	'21	'22	'23	Tot.	%
Advances in Intelligent Systems and Computing										1				1	2.3
Agricultural Systems													1	1	2.3
Business Process Management Journal													1	1	2.3
Frontiers in Psychology												1		1	2.3
IEEE Access												2		2	4.6
IEEE Transactions on Engineering Management										1				1	2.3
Information and Organization												1		1	2.3
Intereconomics								1						1	2.3
International Journal for Innovation Education and Research							1							1	2.3
International Journal of E-Entrepreneurship and Innovation													1	1	2.3
International Journal of Information Management							1							1	2.3
Journal of Cleaner Production									1					1	2.3
Journal of Electronics and Information Science									1					1	2.3
Journal of Strategic Information Systems							1							1	2.3
KYBERNETES														1	2.3
Managerial and Decision Economics													1	1	2.3
MIS Quarterly: Management Information Systems										1				2	4.6
PLOS ONE													1	1	2.3
Project Management Journal								1						1	2.3
Research Policy									1					1	2.3
Review of Integrative Business and Economics Research											2			2	4.6
Sensors									1					1	2.3
Studies of Transition States and Societies									1					1	2.3
Sustainability													3	3	7
Technological Forecasting and Social Change							1							1	2.3
Technology Analysis & Strategic Management									1					1	2.3
Conference proceedings															%
2023 IST-Africa Conference (IST-Africa)	'11	'12	'13	'14	'15	'16	'17	'18	'19	'20	'21	'22	'23	1	2.3
22nd Pacific Asia Conference on Information Systems								1						1	2.3
27th European Conference on Information Systems									1					1	2.3
31st International Business Information Management Association Conference								1						1	2.3
								1						1	2.3

(Continued)

Table 2: Continued

Journal	'11	'12	'13	'14	'15	'16	'17	'18	'19	'20	'21	'22	'23	Tot.	%
40th R&D Management Conference "R&Designing Innovation: Transformational Challenges for Organizations and Society"			1											1	2.3
8th International Conference on P2P, Parallel, Grid, Cloud and Internet Computing											1			1	2.3
Hawaii International Conference on System Sciences (HICSS)									1					1	2.3
International Congress and Conferences on Computational Design and Engineering												1		1	2.3
Lecture Notes on Data Engineering and Communications Technologies														1	2.3
Portland International Center for Management of Engineering and Technology	1													1	2.3
Russian Conference on Digital Economy and Knowledge Management										1				1	2.3
Working Conference on Virtual Enterprises											1			1	2.3
Total	1	1	1					6	6	7	4	7	11	43	100

Table 2. Distribution of selected articles by source and publication year.

Source: Authors' contribution.

Paper	Definition of DIE
Kolloch and Dellermann (2018)	"an innovation ecosystem as a social technological system (actor network) consisting of two inseparable parts: a social system (human actor network) and a technological system (non-human actor network)"
Suseno et al. (2018)	"digital innovation ecosystem models the interactions and relationships between organisations and stakeholders, in creating new products and services using digital technologies in order to create value"
Wang (2018)	"a special type of sociotechnical system"
Chae (2019)	"a complex arrangement of technologies, methodologies, concepts, business application areas, organizations, and institutional contexts"; "a network of heterogeneous social and technical elements, which co-evolve over time"
Beltagui et al. (2020)	"digital innovation ecosystems account for industry-spanning co-operative and competitive dynamics among firms related to innovations that combine physical and digital elements"
Cvar et al. (2020)	"a complex system of various actors having different roles, interacting in mutual interdependence, constantly learning how to interact effectively"
Wang (2019)	"as a special type of sociotechnical systems, <i>a digital innovation ecosystem is a dynamic collective of interdependent actors and the resources they draw on to innovate with digital technology</i> "
Xu (2020)	"a complex network of collaborative and competitive relationships among individuals, organizations and digital technologies that jointly create value for innovation"
Wang (2021)	"a loosely coupled set of autonomous actors (people and organizations who interact without hierarchical fiat) involved in the development and implementation of innovations enabled by digital technologies"
Li et al. (2022)	"a complex economic structure in which organizations and individuals interact with each other". "The digital innovation ecosystem not only introduces data as a factor of production, but also enhances the connections between subjects, promotes synergy among elements, and finally causes changes in the system logic"
Ji et al. (2023)	"loosely interconnected networks formed by firms and other innovation agents"
Liu et al. (2023a)	"a complex system of symbiotic competition and collaborative evolution comprising several interconnected, interacting and proactive digital innovation subjects. It has a complex internal network, communicating the interaction between subjects, and its development is driven by the knowledge-sharing and cooperation needs between subjects"

Table 3. DIE definitions in the literature.

Source: Authors' contribution.

frequently described as complex, indicating that it embraces numerous interconnected stakeholders (Chae, 2019; Cvar et al., 2020; Li et al., 2022; Liu et al., 2023a; Xu, 2020). The scholars emphasize the presence of the combination of social and technical aspects within the DIE, suggesting that DIEs do not just involve joint technology exploitation but also social interactions between stakeholders in the ecosystem (Kolloch & Dellermann, 2018; Wang, 2018, 2019). Some scholars stress that DIEs have loosely coupled architecture (Ji et al., 2023; Wang, 2021). The primary goal of a DIE is to foster innovation, leading to the development of novel products and services and value creation using digital technologies, as an integral part of the DIE (Suseno et al., 2018; Wang, 2019; Xu, 2020). The scholars stress the presence of technological (digital) and social/physical mutually interdependent and interconnected components (Beltagui et al., 2020; Chae, 2019; Kolloch & Dellermann, 2018; Xu, 2020); the components of the DIE constantly co-evolve, enhancing

interaction capabilities (Chae, 2019; Cvar et al., 2020; Liu et al., 2023a). The dynamic nature of the DIE makes it resilient and adaptable to changing environments (Wang, 2019). Some definitions presented in the research stress the presence of competition in the DIEs (Beltagui et al., 2020; Liu et al., 2023a; Xu, 2020). Taking into consideration all the above, the authors propose the following DIE definition, based on the definitions presented in Table 3: DIE is an ecosystem that integrates technological aspects and unites various actors who continuously co-evolve, cooperate, compete, and leverage digital technologies to generate value.

3.3 Characteristics of the DIEs

In order to categorize the studies under investigation, the system-level approach by Vanhamaki et al. (2019) was applied; this research introduced the system-level

approach to the circular economy and described the actors on macro, meso, and micro levels. The authors of the study brought this model to the research on DIE, dividing the studied literature by system levels to which the DIE was applied. Some of the research studied the universal nature of DIE applicable in all the levels, so we introduced the fourth group named “Meta level.” The results of the distribution are presented in Table 4.

3.3.1 Macro level DIEs

Misséri (2013) claims that DIEs promote local innovation by supporting the evolution of DIEs stakeholders and representing a source of knowledge; the author also highlights five major components of DIEs – innovation platforms, web 3.0 technologies, innovative services for customers, knowledge production and analysis, and a user-centered and customized environment. At the same time, Mutegi et al. (2023) state that local characteristics of the territory, such as social and economic issues, influence the DIEs’ development representing both challenges and opportunities for the ecosystems.

The SLR reveals the discussion on the role of the DIE stakeholders in the ecosystem development and successful functioning. Therefore, Baumane-Vitolina and Dudek (2020) claim that the DIE performance is possible, thanks to digital platforms as a meeting point between customers, producers, and suppliers. However, according to Purbasari et al. (2022a), the DIE stakeholders have different influences on innovation processes inside the ecosystem, so start-ups and customers have a higher influence on digital innovation processes than suppliers and investors. Further research by Purbasari et al. (2022b) claims the need for more collaboration between stakeholders inside the DIE and results in the development of a DIE framework for digital start-ups (Purbasari et al., 2023). The research of Cvar et al. (2020) identifies DIEs as a multilevel framework of structures, strategies, tools, and people; active participation of different stakeholders in the DIE leads to the creation of DIE built with the respect of public values.

Several scholars provide other insights on the nature of the DIE based on their case studies. Pistorio et al. (2018) stress the key role of governmental organizations and targeted policies in the development of DIEs. Whyte (2019) analyzes the DIE development as a result of joint industry/government initiatives; the research reveals that DIEs influence the process of strategies’ adoption by industrial stakeholders. The study by Filatova et al. (2020) identifies three core digital elements of the DIE – digital infrastructure, tools, and competencies. Ruohomaa et al. (2020) argue that DIEs deliver innovation resulting in the development of new

System level	Meta level	Papers	System level	Actors	Papers
		Vasin et al. (2018); Wang (2018); Wang (2019); Nepelski (2019); Wang (2019); Xu (2020); Wang (2020); Kewen and Junji (2022); Kindermann et al. (2022); Liu et al. (2023a); Liu et al. (2023b)	Macro level	Supranational organizations, Nations, cities, regions	Misséri (2013); Pistorio et al. (2018); Whyte (2019); Baumane-Vitolina and Dudek (2020); Cvar et al. (2020); Filatova et al. (2020); Ruohomaa et al. (2020); Maurer, (2021); Purbasari et al. (2022a); Purbasari et al. (2022b); Chen and Cai (2023); Mutegi et al. (2023); Purbasari et al. (2023)
			Meso level	Local ecosystems, industrial networks	Kolloch and Dellermann (2018); Gorecky et al. (2019); Beltagui et al. (2020); Cui et al. (2022); Li et al. (2022); Liao et al. (2023); Wolfert et al. (2023); Wu and Negassi (2023); Xu et al. (2023)
			Micro level	Companies, consumers	Rao and Jimenez (2011); Suseno et al. (2018); Rocha et al. (2018); Rocha et al. (2019); Yin et al. (2020); Raabe et al. (2021); Rocha et al. (2021); Zou et al. (2022); Ji et al. (2023); Li and Liu (2023)

Table 4. Distribution of the literature by system levels.

Source: Authors’ contribution.

business models. Maurer (2021) claims that digital innovation hubs should become an important component for DIES acting as the provider of expertise, services, and facilities for the DIES' stakeholders. Chen and Cai (2023) stress the importance of resilience improvement as one of the key prerequisites for the development of regional DIES. Rocha et al. (2021) investigate how R&D collaborations with scientific and business partners contribute to the digital transformation of manufacturers in Brazil; the authors state that such incentives as the promotion of technological innovation in the private sector have the potential to establish a DIE to foster the country's industrial competitiveness.

3.3.2 Meso level DIES

Kolloch and Dellermann (2018) analyze the interaction between technological and social components of the DIE; the authors identify DIE as an actor-network with human (organizational) and non-human (technological) actors. Gorecky et al. (2019) focused their research on the technological advancements and adoption of Industry 4.0 technologies for DIE development; in their research, the authors outline the acceleration of Industry 4.0 as the main DIE objective. Beltagui et al. (2020) investigate the mechanisms of disruptive innovations, in particular 3D printing, in the DIES; the authors claim that the ecosystems should support the development of disruptive technologies by implementing the latter within the ecosystem.

The discussion of value creation, composition, and sharing in the DIES are among the topics actively discussed by the authors. Li et al. (2022) and Wu and Negassi (2023) consider DIE as a value-creating ecosystem, the latter claim that value-creation within DIE becomes possible due to "internal self-construction and external cooperation." Xu et al. (2023) stress the importance of decentralized innovation for value creation in the ecosystem. Ji et al. (2023) also stress the role of transversality in value creation claiming that in the DIES it is possible by breaking industry, regional, and enterprise boundaries. Cui et al. (2022) analyze the value composition of the DIE as a process of resource sharing and cooperation among the stakeholders for common benefits. Liao et al. (2023) and Wolfert et al. (2023) state that value creation and distribution are at the core of DIES, and this process involves the development and application of digital technologies.

3.3.3 Micro level DIES

The research of Rocha et al. (2018, 2019) considers DIES as a collaboration platform that supports the development, dissemination, and commercialization of digital solutions.

Raabe et al. (2021) stress the key role of digital technologies in DIE that facilitate the resolution of challenges that businesses face. Li and Liu (2023) state that DIES favor better decision-making in the companies that lead to higher efficiency and enterprises' further smart development. Zou et al. (2022) consider DIES as the providers of resources and information that promote knowledge and technological innovation; the latter can also lead to the DIE's development in order to foster industrial competitiveness (Rocha et al., 2021). Suseno et al. (2018) explored value creation processes in DIES as the result of collaboration between a company's consumers and professional stakeholders; indeed, active engagement of customers favors innovation creation and hence creates a more viable DIE (Rao & Jimenez, 2011). Also, Suseno et al. (2018) support the idea of fluid DIE boundaries. Yin et al. (2020) define the components of DIE – cyberspace, social, and physical spaces.

3.3.4 Meta level DIES

Vasin et al. (2018) name the unhindered cooperation among the ecosystem participants as a key characteristic of the DIES. Nepelski (2019) also stresses the collaborative nature of the DIE; the scholar claims that the DIE consists of physical and technological layers, where the technological layer includes software producers and platforms. Wang (2018) offers a multilevel ecological model of a DIE, the author states that digital technologies, knowledge, and innovation are the main DIE components, and the DIE boundaries are fluid. The research of Chae (2019) supports the idea of the DIE boundaries' fluidity and that DIES emerge at the intersection between social and technical dimensions. Continuous innovation and collaboration, information and knowledge sharing, and value co-creation are among the benefits of DIES' deployment (Liu et al., 2023a, b); DIES favor enterprise innovation and competition (Xu, 2020). Wang (2019) maps the key attributes of the ecosystems which include the number of actors, the characteristics of the groups they form, the frequency of actor entry and exit within an ecosystem, cooperation among actors, and the resilience to disruptions. Wang (2021) highlights the importance of the correlation between information capacity and information needs within the ecosystem; the author emphasizes the role of digital technologies in narrowing this gap. The paper of Kewen and Junji (2022) discusses the DIE governance, according to the scholars the government supports and fosters innovation within the ecosystem through the implementation of specific goal-oriented policies. Kindermann et al. (2022) address issues related to the DIES' orchestration, mapping out

challenges and potential solutions; the scholars emphasize the key role of orchestrators in driving positive changes.

3.4 DIEs integrative conceptualization

Some authors reflect on the interrelation between DIEs and other innovation ecosystems. Beltagui *et al.* (2020), Kolloch and Dellermann (2018), and Pistorio *et al.* (2018) claim that DIEs are synonymous with innovation ecosystems. Wang (2018) argues that many innovation ecosystems are DIEs, while Baumane-Vitoliņa and Dudek (2020) state that DIEs are one of the types of innovation ecosystems. Since there is no unanimous consent on the nature of the DIE, we need to proceed with its integrative conceptualization. As a consequence of the in-depth study of the literature corpus, DIE definitions (Table 3), and DIE system levels (Table 4), we revealed several patterns that help to shape the DIEs' conceptualization. Regardless of the system level at which the DIE has been considered, there is a clear tendency to mention technology as a meta-factor for the existence of the DIE. In addition, the general trend is the interconnection between the physical and social components of the ecosystem, as it was discussed above; the institutional landscape also has an important role in the functioning of the DIE. Figure 4 represents the DIE conceptual framework and the four main components of the DIEs. These components are as follows:

1. *technology* – this component comprises technological advancements in general (all the authors emphasize the importance of this component for the successful existence of the DIE), as well as digital solutions such as digital platforms (Baumane-Vitoliņa & Dudek, 2020; Misséri, 2013; Nepelski, 2019; Pistorio *et al.*, 2018; Rao & Jimenez, 2011; Wang, 2018, 2019), that enable actors of the ecosystem to connect with each other, cooperate, sometimes compete, deliver value to others, exchange knowledge and experience.
2. *institutional landscape* that implies institutional arrangements, policies, and regulations, local administrations that operate in the geography of the DIE allocation and creates a fruitful environment to shape the activity of DIEs (Chae, 2019; Kewen & Junji, 2022; Nepelski, 2019; Pistorio *et al.*, 2018; Vasin *et al.*, 2018; Whyte, 2019);
3. *physical environment* in terms of infrastructure and tangible assets used by the actors and stakeholders (regardless of the system level of DIE) to develop and implement innovations (Beltagui *et al.*, 2020; Gorecky *et al.*, 2019; Nepelski, 2019; Whyte, 2019; Yin *et al.*, 2020);
4. *social environment* that includes actors and stakeholders of the DIEs, organizations, and human capital. Since any ecosystem inherently includes its participants, who generate value within it, all authors, to some extent, discuss the role and position of stakeholders and actors in the DIE. However, some scholars emphasize this concept as a fully-fledged component of the DIE (Chae, 2019; Kolloch & Dellermann, 2018;

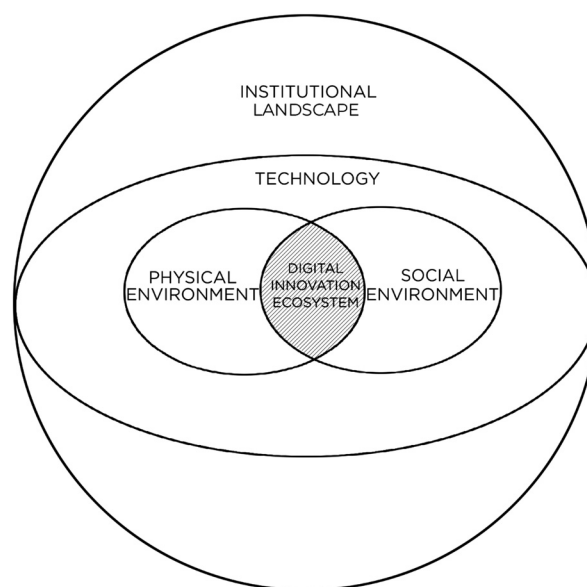


Figure 4. DIE conceptual framework.

Source: Authors' contribution.

Rao & Jimenez, 2011; Wang, 2018, 2019, 2021; Yin et al., 2020).

We believe all ecosystem components are equally important for the successful functioning of the ecosystem and exist autonomously, but at the same time, they are in interaction with each other. At the same time, the technology and institutional landscape components are meta elements as they serve as the foundation for the creation, existence, and development of the other two components (Physical environment and Social environment). Technologies and the institutional landscape create conditions for the interaction of the physical (Physical environment) and the social component (Social environment) and favor the emergence of other DIEs in the intersection of these fields.

3.5 LSA: Validation of DIE conceptual framework

To further validate the DIE conceptual framework and, therefore, to grant our results additional methodological robustness, we looked beyond the results of the qualitative investigation and coding and performed an LSA of the 43 retrieved papers. Essentially, here, we treat LSA as a form of quantitative triangulation to our qualitatively derived taxonomy and a way to further validate qualitatively derived results in a more neutral way that is less prone to the subjectivity of a researcher.

LSA is a well-established natural language processing technique based on the distributional hypothesis, assuming that words that are similar in meaning (i.e., have high semantic similarity) occur in semantically similar documents (Evangelopoulos, 2013). In essence, it treats words as variables, while the frequency of a specific word in a document constitutes a particular observation for a given variable. The resulting table is called the document-term matrix (DTM) and it is typically first pre-processed to account for different documents' lengths. After that, a singular value decomposition (SVD) is applied to the DTM, identically to how a principal component analysis is performed to reduce the number of dimensions in a dataset.

Hence, the initial space of variables is reduced to a lower number of principal components (or dimensions/eigenvectors) that jointly summarize the textual corpus in fewer dimensions while retaining the initial variance of the DTM. Particularly, the importance of components is captured in descending order, starting from the most relevant dimension in terms of percentage of captured variance, and then followed by the series of orthogonal dimensions (therefore, uncorrelated) with diminishing contributions to the total variance. In this manner, a

complex semantic space can be represented as a series of orthogonal dimensions in which terms that frequently co-occur are close to each other. Respectively, those documents that are overall similar, will tend to cluster.

The main reason we opted for LSA instead of more complex natural language processing techniques is that, unlike those, LSA is entirely deterministic and is not veiled behind the "black box" of weights and biases resulting from the machine learning processes. Hence, the process is replicable and leads to identical results each time SVD is applied. Moreover, LSA is a well-established and validated technique with a long "pedigree" in computational linguistics.

To begin with, we uploaded the documents to qualitative data analysis software (MAXQDA, release 22.6.1) and calculated the absolute frequencies of all words across the 43 papers. English language lemmatization was also performed to account for different spellings, plurals, and words with identical semantic roots (e.g., *systems* and *systems* are counted as one token). We have also applied a stop word list containing 412 auxiliary words used in English (e.g., *a*, *above*, *about*, and *accordingly*) to exclude terms that carry no particular semantic meaning from the initial frequency count.

Overall, 20,567 unique words were identified (type-token ratio = 0.0585). The contributing researchers have then separately assessed the respective absolute frequency table and selected all the nouns, verbs, and adjectives deemed directly or indirectly related to the topic of DIE. To increase the inter-rate reliability of the results, we compared the respective lists and collegially decided on the words to include in the final analysis of semantic relatedness. In total, 48 words were selected. According to LSA scholars (Landauer et al. 1998), while around 300 dimensions are optimal for moderate-size document collection (hundreds of thousands of documents), for a smaller-size textual corpus, like in our case, around 50 dimensions are sufficient.

Figure 5 shows all the words included in the analysis, with the size of words linearly proportional to their absolute frequency across papers.

To account for the different lengths of the analyzed papers, we transformed all the absolute frequencies into relative ones by dividing (for each of the 43 papers) the absolute frequency of every keyword (Figure 6) in a paper by the sum of absolute frequencies of all the keywords selected for that paper. We then imported the obtained DTM into RStudio and performed a principal component analysis on the matrix.

Out of 48 initial variables, PCA extracted 40 uncorrelated components (dimensions). In order to understand which principal components are important for the



Figure 5. The most frequent words related to the topic of DIE.

Source: Authors' contribution.

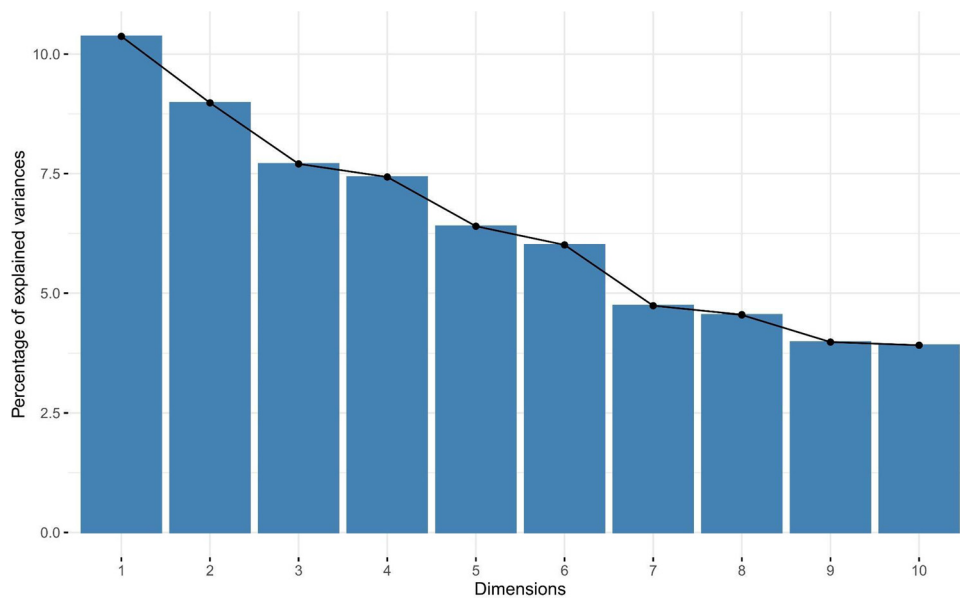


Figure 6. Scree plot. The ten most contributing principal components.

Source: Authors' contribution.

interpretation, it is customary to rely on the scree plot (Figure 6) reporting the contribution of the individual components to the overall variance. In particular, Figure 6 shows the first ten components' contributions. Given a relatively gradual decrease in variance explained and, hence, the difficulty in interpreting principal components beyond the second one, only the first two dimensions

(accounting for roughly 20% of explained semantic variability of the analyzed papers) were analyzed in-depth.

Figure 7 shows the correlation of the variables (keywords) with the two most contributing PCA dimensions. As such, it can be understood as a summary representation of the semantic space of the 43 papers included in the review. Accordingly, terms that are close to each other (i.e., when

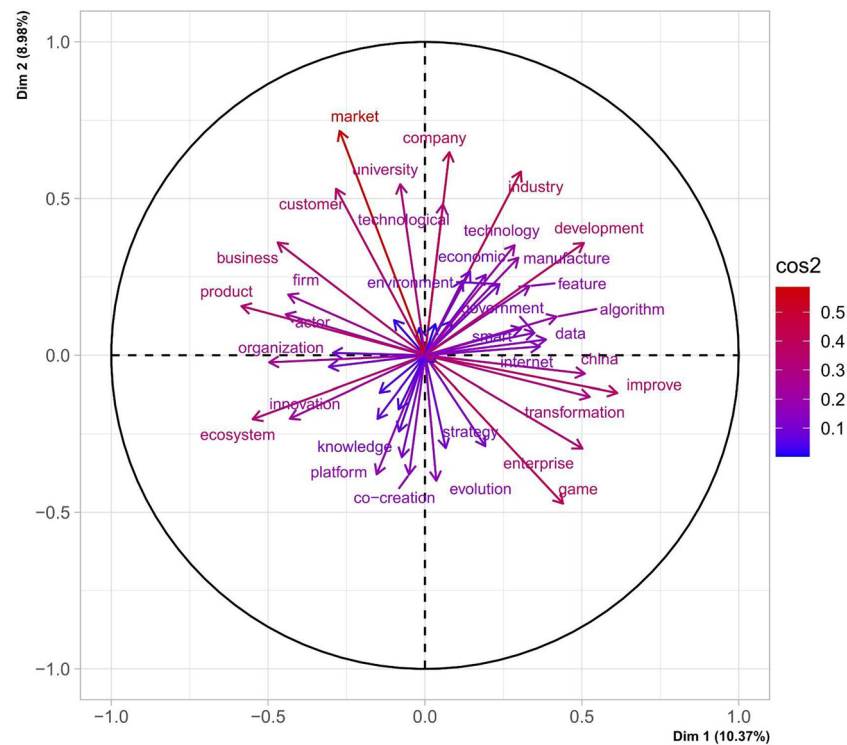


Figure 7. PCA. The correlation of active variables with the first two dimensions. Note: $\cos^2$ denotes the quality of the representation of variables on the axes. For better presentational clarity, only variables with $\cos^2 > 0.1$ are reported.

Source: Authors' contribution.

the angle between vectors is small and the length of vectors is similar) are more likely to appear together in a document.

The horizontal dimension, which is also the most important in terms of the overall contribution to the construction of the PCA plane, seems to highlight the crucial conceptual distinction between papers primarily focused on technology-related themes and topics in the north-east and south-east parts of the plane (e.g., *feature*, *algorithm*, *data*, *internet*, *game*, *feature*, *development*, *manufacture*, and *technology*), and papers that are mainly dealing with topics related to business, management, and commercialization of the final products (e.g., *product*, *business*, *firm*, *customer*, *market*, *organization*). The vertical axis was more challenging to interpret. Still, the presence of the most significantly contributing keyword (*market*) in the northmost part of the graph suggests that the vertical axis captures the conceptual distinction between papers emphasizing the role of institutional macro and meso-level elements in the northern quadrants (e.g., *market*, *university*, *environment*, *industry*, *economy*, and *government*) and aspects related most abstract analyses of strategical importance (e.g., *knowledge*, *platform*, *co-creation*) in southern quadrants of the plane. The latter clearly indicates

that the papers in this part of the graph are more centered on what we call meta-level analysis, treating themes and topics common to micro, meso, and macro levels of analyses. Moreover, when it comes to the DIE framework (Figure 5), the keywords denoting all of its elements are present in the PCA results. While the embedded institutional environment is clearly captured by the vertical axis and technology is captured by the horizontal axis, keywords denoting both physical and social environments are distributed more or less evenly on the plane (e.g., *customer*, *actor*, *ecosystem*, *organization*, and *firm*).

A valid follow-up to a visual exploration of PCA results is typically given by an agglomerative hierarchical clustering. The method follows a “bottom-up” approach, starting with single observations being considered as clusters on their own, and then proceeding through the aggregation of clusters until within-class variance is minimized and between-class variance is maximized. In the context of this work, the clustering was performed to further validate the interpretation of the PCA factorial plane (and, hence, the underlying semantic space it represents).

To perform the clustering, the Euclidean distance was chosen to measure the similarity between individual observations (papers), and Ward's linkage method was

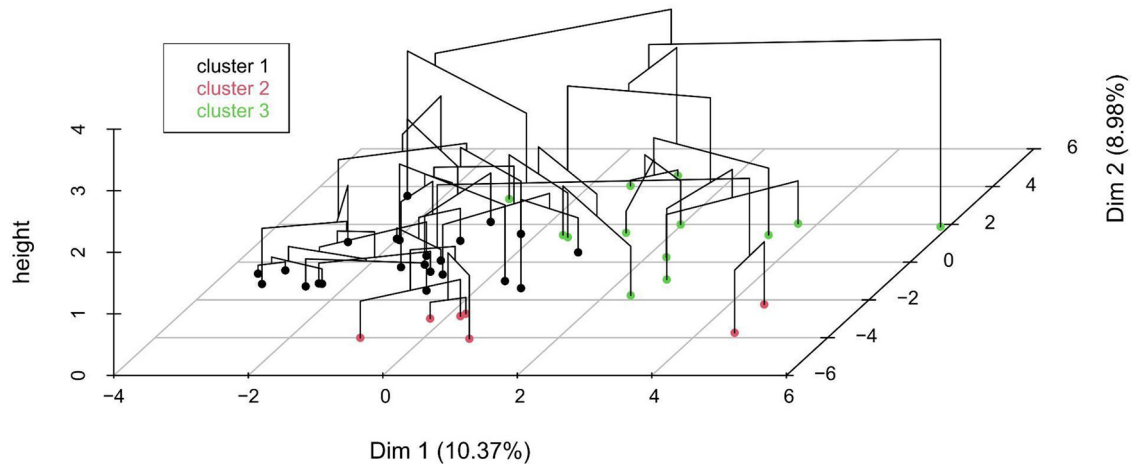


Figure 8. Cluster dendrogram projected on the first two PCA dimensions.

Source: Authors' contribution.

used to ensure partitioning with small within-class variability and high between-class variability. Figure 8 shows the resulting cluster dendrogram projected onto the first two PCA dimensions (with dots denoting individual papers). The partitioning of papers into three macro-thematic clusters was deemed optimal by the R package used for the analyses (*Factoshiny*). Indeed, additional variability gains from considering the fourth cluster and onward were not substantial.

Table 5 shows the importance of individual keywords (and, hence, the related themes and topics) in the three clusters. Some keywords, such as “digital,” “system,” “network,” and others, present in the semantic space, are completely missing within the clusters' definitions as they were not significantly contributing to clusters' definitions. In essence, those were equally present not only within

clusters, but also between them, and the related differences were not statistically significant. In this regard, Table 5 reports the ten most contributing keywords to the definition of each cluster (with p -value < 0.05).

Cluster 1 is the most numerous and is defined mainly in terms of keywords related to different organizational and business factors of micro and meso levels of analysis while also emphasizing physical and social environment components of the DIE framework (e.g., *actor*, *business*, *organization*). Cluster 2 is the most balanced, albeit least numerous. Indeed, the related papers mainly seem to belong to the meta-level of analysis, showcasing topics of more transversal relevance (e.g., *co-creation*, *strategy*, *knowledge*, and *improve*). The emphasis, however, is slightly in favor of managerial and organizational topics rather than blockchain technology itself (e.g., *contract*, *distributor*,

Cluster 1 – keywords	Cluster 1 – contributions	Cluster 2 – keywords	Cluster 2 – contributions	Cluster 3 – keywords	Cluster 3 – contributions
Organization	3.14	Game	4.45	Development	4.77
Business	3.11	Co-creation	3.65	Industry	3.84
Product	3.07	Enterprise	3.25	Environment	3.13
Firm	2.7	Strategy	2.79	Financial	2.94
Service	2.7	Platform	2.77	Smart	2.8
Design	2.66	Knowledge	2.37	Technology	2.61
Actor	2.65	Transformation	2.01	Manufacture	2.5
Information	2.52	Improve	1.47	Economic	2.45
Ecosystem	2.02			Technological	2.32
Market	1.2			Company	2.24

Table 5. Ten most contributing keywords (t -scores) within the clusters ($p < 0.05$).

Source: Authors' contribution.

retailer trade). Finally, the third cluster is focused on the macro level of analysis, emphasizing both institutional (e.g., industry, financial, and environment) and technology (e.g., *smart*, *technology*, and *manufacture*) factors.

In conclusion, clustering analysis mirrors the opposition and integration of micro-macro dynamics in the definition of DIE, as resulting from qualitative analysis and depicted in Figure 4. The opposition is captured mainly by the most contributing variables (highest *t*-scores in Table 5), which are more organization-centric in the first cluster, and more context-centric in the third, with the second cluster being more balanced. The integration dynamics are also present as certain synonyms have contributed to the creation of distinct clusters – i.e., firm, business, enterprise, and company. Hence, the identified categories and different levels of analysis of the conceptual framework in Figure 4 are all distinctly represented within the analyzed semantic structure of the analyzed textual corpus.

4. Conclusion

This research examined the phenomenon of DIEs as it is presented in the scientific discourse nowadays. The SRL approach sheds light on the state of academic discourse on the topic and gives insights into the nature of the DIE and contributes to the formulation of the comprehensive definition of the DIE, identification of its components, and elaboration of the conceptual framework that illustrates the interconnections inside the DIE. The DIE conceptual framework was further statistically validated by the LSA. Four system levels of the DIE operation were also distinguished and discussed.

The authors see the main limitation of the study in a limited literature sample; however, the literature studied represents a significant contribution to the rising scientific discourse on the topic. The authors intentionally focused their literature review solely on discussions related to DIEs, excluding other ecosystems' types with similar characteristics; this approach aimed to study the specific attributes of DIEs as they are understood and implemented by scholars. Future research could help overcome the above-mentioned limitations. Future studies could focus on comparing different types of ecosystems, which would reveal their differences and complementarities. This approach could provide evidence of how these ecosystems can cooperate, what their key dimensions are, and the role of stakeholders within them. Another promising research avenue is shifting from theoretical discussion to practical application. To achieve this, the DIE concept could be implemented in a real-life environment to assess its viability.

Despite the fact that the DIE discourse is at an early stage of its development, the present study may provide some interesting scientific contributions and managerial implications. The theoretical contribution of this research lies in the conceptualization of common elements of DIEs within scientific discourse, filling a previously overlooked gap in the literature. A shared understanding of DIEs' definitions and conceptual framework can stimulate future academic research and discourse. The research provides several managerial and institutional implications. DIEs can become a meeting point for businesses, local administrations, and skilled human capital. Development and conscious participation in DIEs will allow businesses to create and share knowledge and value, produce innovations, create collaborations, and attract creative human capital; at the same time, IT businesses can become suppliers of digital technologies for the DIE development. Local and country administrations must take care of the creation of favorable institutional context in terms of laws, regulations, and policies that will guide cooperation between DIE stakeholders.

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Author contributions

Irina Gorelova: concept, data acquisition, analysis and interpretation, writing, critical revision; Ihor Rudko: concept, data acquisition, analysis and interpretation, writing, critical revision; Fabrizio D'Ascenzo: concept, analysis and interpretation, guidance, critical revision; Francesco Bellini: concept, analysis and interpretation, guidance, critical revision.

Conflict of interest statement

Authors state no conflict of interest.

Data availability statement

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

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