

Miah, Md Tota; Aiupova, Nurgul; Erdei-Gally, Szilvia; Fekete-Farkas, Mária

Article

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Digital entrepreneurship ecosystems: Then vs. now-a future perspectives

Md. Tota Miah^{a,b,*}, Nurgul Aiupova^a, Szilvia Erdei-Gally^c, Mária Fekete-Farkas^{a,d}

^a Doctoral School of Economic and Regional Sciences, Hungarian University of Agriculture and Life Sciences (MATE), Páter Károly u. 1, 2100 Gödöllő, Hungary

^b Department of Business Administration, Varendra University, Rajshahi 6204, Bangladesh

^c Institute of Technology, Hungarian University of Agriculture and Life Sciences (MATE), Páter Károly u. 1, 2100 Gödöllő, Hungary

^d Institute of Agriculture and Food Economics, Hungarian University of Agriculture and Life Sciences (MATE), Páter Károly u. 1, 2100 Gödöllő, Hungary

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ABSTRACT

Digital entrepreneurship ecosystem has become a central topic in the digital economy which is characterized by an inclusive and changing framework. This study aims to investigate the key components, trends and latent topics of digital entrepreneurship ecosystem. The data (1234 articles) were obtained from the Web of Science and Scopus database, covering 18 years' data ranging from 2006 to 2023. A hybrid method, integrating topic modeling and bibliometric analysis were adopted. The data were analyzed using R studio software, version (2023.12.0) and the results show notable increase in scientific publications, with a 93 % growth and over 200 articles in the last three years, signifies the growing interest in digital entrepreneurship, particularly in prestigious journals like "Small Business Economics" and "Journal of Technology Transfer." The study highlights the leading contributions of Anglo-Saxon region (US, UK, Australia), and leading European countries like Germany in this area. Six primary topics emerge: 1) digital entrepreneurship in academia, 2) women entrepreneurship and gender role, 3) entrepreneurship ecosystem and innovation, 4) government policy and economic strategy in entrepreneurship, 5) social entrepreneurship and sustainability and, 6) start-up innovation and incubation. Besides, the study proposes a conceptual framework by integrating Quadruple Helix Model for understanding the sustainable digital ecosystem. The findings suggest a comprehensive approach to support policy framework and practices, aiming to foster an inclusive digital entrepreneurship ecosystem in most developing African and Asian countries.

1. Introduction

The rise of digital transformation has recently redefined the nature of entrepreneurial activities (Heshmatisafa & Seppänen, 2023). More specifically, digital technologies such as big data, AI, ICT, and cloud computing have opened up a global digital platform economy, thereby promoting digital transformation, reducing business costs, and minimizing the need for physical facilities (Khalil et al., 2022). During crises, for example, COVID-19, digital technology contributed greatly by lowering barriers for businesses, fostering inclusive socio-economic growth and entrepreneurial resilience (Sharma et al., 2024). Traditionally, entrepreneurship plays a significant role in driving innovation,

economic growth, and creating more job opportunities (Xiong et al., 2024). Such digitization transforms the competitive edge, traditional business models and processes, new startups, and entrepreneurial ecosystems across various economic activities (Font-Cot et al., 2023). This new transition also offers existing businesses a new path to build digital business. As a whole, the development of digital ecosystem needs interactions of various roles and actors including digital platforms, emerging digital technologies, physical infrastructure, human capital, networking, and faster internet access (Ajah, 2025; Dobrovnik et al., 2025). Even so, there are challenges exist in implementing the robust ecosystem which primarily revolve around the need to integrate diverse actors and resources to support startup growth, particularly in regions

Abbreviation: DEE, Digital Entrepreneurship Ecosystem; EE, Entrepreneurial Ecosystem; DEI, Digital Entrepreneurship Index; AI, Artificial Intelligence; ICT, Information and Communication Technology; LDA, Latent Dirichlet allocation; TM, Topic Modeling; QHM, Quadruple Helix Model; LDavis, Latent Dirichlet Allocation Visualization; DTM, Document Term Matrix; SPAR-4-SLR, Scientific Procedures and Rationales for Systematic Literature Reviews; GIDES, Global Index of Digital Entrepreneurship; ADB, Asian Development Bank; SDG, Sustainable Development Goals.

* Corresponding author at: Doctoral School of Economic and Regional Sciences, Hungarian University of Agriculture and Life Sciences (MATE), Páter Károly u. 1, 2100 Gödöllő, Hungary.

E-mail address: miah.md.tota@phd.uni-mate.hu (Md.T. Miah).

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with historically weak entrepreneurial infrastructures. Among them include finance, communications, and business activity promotion, corruption, insufficient startup funds, legal policies, lack of digital skills, and supportive policies (Samara & Terzian, 2021; Zhou & Cen, 2024). For example, countries at the bottom of the DEI are low in poor European and Latin American countries but mostly in developing African and Asian countries compared to developed nations. In consequences of consistent gap in addressing regional, local and global challenges (Bergholz et al., 2024), it is essential to systematically examine the disparities in the existing studies in the digital context. Such as considerable development in digital infrastructure, digital access, digital literacy, and other technological factors (Acs et al., 2020). Despite hurdles, DEE facilitates the development of digital startups and brings together resources and support components beyond the firm level, which is highly relevant to the success of digital entrepreneurship (Zahra et al., 2023). European Commission (2015), defined DEE as the creation of new ventures and the transformation of existing businesses through the development of innovative digital technologies. Elia et al. (2020) characterize collaborative networks with digital actors, activities, motivations, and organization, transforming existing businesses through digital means. Essentially, the digital ecosystem encourages entrepreneurs to create ideas, find and allocate resources, exploit digital market opportunities, gather information, and create innovations (Balli, 2020). In turn, the entrepreneurial activities associated with the creation of innovative ventures, products, and initiatives benefit society and regional economic development (Roundy et al., 2018), which grew keen interest among academics and policymakers as a relatively new research field. While some existing reviews focused on the different themes and trends of DEEs (Paliwal et al., 2023; Robertson et al., 2020), others addressed the digital entrepreneurship platforms (Fernandes et al., 2022a) and dealt with conceptual ambiguity (Bejjani et al., 2023), the roles of digital technology and collaboration in the context of entrepreneurial process, digital innovation and transition (Liu & Pan, 2024), integrating sustainability factors with entrepreneurial ecosystems (Theodoraki et al., 2022). However, few have been conducted by integrating hybrid approaches to a special focus on the regional and socio-economic aspects of DEEs and the inclusive understanding of DEEs framework both in macro and micro level. Considering this gap, this study aims to provide a comprehensive understanding of DEEs in research and practice by clarifying the state of knowledge by exploring key debates and recent advances, regional and global challenges by mapping scientific research, analyzing author metrics, regional research outputs, and socio-economic indicators. Using Quadruple Helix Model, the study also conceptualizes the integration of ecosystem components, presenting structural and thematic analysis for further research. By addressing the following research questions, the current study combines bibliometrics with topic modeling (LDA) in order to explore latent themes and patterns in large databases, intellectual structures, and interdisciplinary links: 1) What is the current state of the knowledge field? 2) What are the latent topics and emerging themes in the DEEs? 3) What are the future research avenues related to the DEEs for scholars? The findings of the study contribute to the holistic understanding of field evolution on a regional basis and provide the challenges and opportunities. The study also offers a conceptual framework using the Quadruple Helix Model, which integrates government, industry, academia, and civil society, to offer a dynamic perspective on DEEs to foster innovation and collaboration. Our study suggests support for policy development that aims to foster inclusive and sustainable digital ecosystems, address gender barriers, and contribute to the achievement of various Sustainable Development Goals. The remainder of this study is organized as follows. Section 2 describes the literature review. Section 3 describes the methodology (bibliometric and topic modeling). Section 4 discusses results and analysis. Section 5 discusses the findings and Section 6 provides the implications, future research directions, and Section 7 concludes with limitations.

2. Literature reviews

2.1. Entrepreneurship ecosystem (EE)

The concept of EE has emerged from diverse origins (Harima et al., 2024) and has been the subject of extensive scholarly exploration over the decades among research, policy, and practitioner fields (O'Connor & Audretsch, 2023). The term “ecosystem” was first used by Bahrami and Evans (1995) in the academic literature on entrepreneurship, specifically in their study of Silicon Valley. However, previous studies argue that the concept of an “entrepreneurship ecosystem” primarily emerged in the 1980s and 1990s (Stam & Van de Ven, 2018; Van De Ven, 1993). This marked a shift in entrepreneurship research from focusing solely on individual entrepreneurs to considering the interconnected network of factors that support new ventures within a region or community. With growing interest in EEs domain, significant definitional ambiguities, gaps, and debatable issues persist within the existing body of literature. Rahatullah Khan (2013) argues that EEs concept remains in its infancy, facing strategic, institutional, and enterprise-level challenges that obstruct its sustainable ecosystem growth. Furthermore, a commonly accepted definition of EEs remains elusive, as it varies across different dimensions, scales, and regional contexts. Many authors have attempted to define EEs in earlier studies. Such as, Malecki (2018) defined EEs as “a complex adaptive system influenced by systemic and contextual factors that collectively create a conducive environment for entrepreneurial growth and innovation.” Similarly, Brush et al. (2019) described the term as “a supportive culture, finance, cultivation and development of human resources, and a variety of institutional and infrastructural support.” According to Brown et al. (2018), “EEs are a diverse and complex phenomenon involving multiple stakeholders who engage in networking, learning, and business-oriented processes.” Stam and van de Ven (2021) further conceptualized the term as “a dynamic concept made up of key entrepreneurs and firms that govern, integrate, and carry out all the necessary functions for entrepreneurship to thrive in a region, contributing directly or indirectly to the economy’s net output, a phenomenon known as productive entrepreneurship.” Regardless of numerous definitions, there remains a lack of theorization and empirical evidence to clearly define the concept. Since earlier definitions, in their formative stages, often raise questions about the balance between local embeddedness and global connectivity, concerns arise regarding external forces such as environmental, regional, and technological disruptions, market changes, and evolving networks. The absence of a universally accepted definition poses significant challenges for policy-makers and researchers in designing and assessing ecosystems, as varying definitions lead to inconsistent frameworks (Fernandes et al., 2022b). Therefore, further research is required to develop a more integrative and adaptive framework that effectively balances structural components with regional, national and global specificities.

However, prior research on EEs can be viewed as the outcome of developments across several related fields, including entrepreneurial success (Suresh & Ramraj, 2012), university entrepreneurship ecosystems (Yusof et al., 2009) and innovation ecosystems (Groth et al., 2015). More recent studies have investigated the challenges faced by startups in accessing financial resources and scaling their ventures (Boutris & Salimi, 2023a), the role of business incubators in fostering innovation (Boutris & Salimi, 2023b), the influence of social entrepreneurship on community development (Warnecke & Balzac-Arroyo, 2023), and the contribution of higher education institutions to entrepreneurial education and research (Wang et al., 2024). Much of these studies focus on developed economies, leaving a significant gap in understanding their impact in developing countries with resource constraints and institutional voids. The adaptation of digital ecosystems to diverse socio-economic contexts is largely underexplored, and there is limited research on how social enterprises navigate institutional challenges in regions like Morocco (Kabbaj et al., 2016). The role of higher education institutions in fostering local entrepreneurship in developing economies

also lacks sufficient attention. Venture capital availability remains regionally concentrated, leading to disparities in entrepreneurial success. While key factors such as social economy organizations, civil society, and public policies are recognized, their interactions and collective influence on ecosystem development require further study. Besides, deeper exploration to the barriers in sustainable entrepreneurship ecosystem in developing economies, such as financial access, market entry, human capital and policy intervention are required for effective policy interventions. Most importantly, there is lack of standardized framework to assess the impact of regulatory, cultural, and institutional factors (Muldoon et al., 2023). Such approach can be integrated with traditional EEs dimensions combining technological and social development actors and factors, such as online platforms, social media, and the sharing economy to dissolve locational barriers and maximizing resource utilization. This transition embarks towards the evolution of digital entrepreneurship ecosystem. Unlike traditional views on ecosystems, which primarily focus on economic growth, DEEs can address a more inclusive approach. Guerrero et al. (2021) signified that a well-configured entrepreneurship ecosystem can contribute to economic development by supporting the creation of innovative and high-growth ventures, which drive employment, innovation, and overall economic dynamism. Moreover, the new phase of ecosystems can balance the economic growth by synergizing the triple bottom-line goals of economic, social, and environmental well-being, referred to as sustainable entrepreneurship ecosystem (Huang et al., 2023).

2.2. Quadruple Helix Model (QHM)

In fostering long-term business survival and sustainable development, study suggest the interactions of various actors, including entrepreneurs, universities, and institutions (Aliabadi et al., 2022). EEs actors, according to Ferreira et al. (2023), originated within the Triple Helix Model (THM), which has subsequently evolved into the Quadruple Helix Model. The QHM framework has been used in recent years for comprehending and understanding EEs (Islam & Wahab, 2023). Earlier studies employed this concept to contextualize social innovation (Galvão et al., 2017a), and the entrepreneurial ecosystem (Cloitre et al., 2023). The QHM model serves as a comprehensive framework through the integration of four significant stakeholders, namely: academia, government, industry, and civil society. They particularly hold an important role to ensure inclusivity, social equity, and promoting innovation within entrepreneurship. For example, academic institutions facilitate the generation of ideas and knowledge through the use of digital technologies and skill development programs for entrepreneurs (Ferreira et al., 2023). Studies also found effective role in increasing regional competitiveness in Greek universities (Ierapetritis, 2019), towards innovation entrepreneurship in European context (Diaconu & Duțu, 2015). Taking into account, the authors emphasized the combined efforts of education, advanced research, networking of knowledge. Universities are considered as knowledge intensive institutions to foster human capital development, innovation and regional entrepreneurship. However, challenges exist in aligning academic research with market needs since universities can play a crucial role in knowledge creation and technology transfer, driving regional economic and social development through research and innovation (Miller et al., 2018). Government entities are crucial in formulating policies, creating legal frameworks, creating funding mechanisms, and developing digital infrastructure. In Finland and Sweden, government support (e.g., policy frameworks, funding, infrastructure) has been the key driver to support the innovation ecosystem and facilitate innovation-driven economy. Such policies have been instrumental in transitioning economies from a factor-driven to an efficiency-driven phase (Galvão et al., 2017b). Compared to developing countries, bureaucratic inefficiencies and policy inconsistencies often hinder the effective implementation of innovation strategies, as seen in countries with lower research and development expenditure, such as Spain and Greece (Medeiros et al.,

2020), and credit, electricity, contract enforcement, and political governance to support entrepreneurship in most African countries (Atiase et al., 2018). With joint collaboration with academic research and government bodies, industry serves as key drivers of economic growth by transforming digital innovations into scalable entrepreneurial ventures. Private sectors can play significant role in collaboration, co-creation and co-specialization within regional and sectoral ecosystems. For instance, MENA regions provide digital transformation, encourage youth empowerment, and support tech start-ups, which drive forward the index of creativity and innovation among entrepreneurs and the general population (Kitsios et al., 2021). However, industry involvement is often driven by profit motives, which may lead to a misalignment of objectives with other stakeholders, particularly civil society. However, the latest inclusion of civil society in the QHM model ensures societal engagement through the advocacy of marginalized groups and understanding the societal needs (Carayannis et al., 2021). As observed in Pakistan the involvement of stakeholders in social entrepreneurial ventures highlights the value of co-creation and supporting ecosystems involving academics, government, profit, and non-profit organizations (Mulyaningsih, 2021). The author contended that the inclusion of civil society consisting of individuals, communities and NGOs is recognized as an essential stakeholder in the innovation process. Overall, through the integration of this framework to this study is an attempt to coordinate among the stakeholders. Most importantly, social inclusion and equity concerns, such as gendered norms, role of NGOs, regulatory compliance by government to promote gender inclusive entrepreneurship and innovation (Lindberg et al., 2014).

2.3. Digital entrepreneurship ecosystem (DEE)

The DEE is an evolving concept that has attracted considerable academic attention in recent years (Roshan et al., 2024). It consists of a fusion of various interconnected terms, deeply rooted in both digital and entrepreneurial studies. According to Van Welsun (2016), the term 'digital' in the context of entrepreneurship means the use of internet-enabled technologies to create new business ventures, products, or services. The concept of 'ecosystem' originally came from biology, which means a community of organisms, their environment, and their interactions. In business, it denotes a network of interconnected entities such as companies, institutions, and individuals that interact and depend on each other (Bula & Schroeder, 2021). According to Ratten (2023), "entrepreneurship is the process of starting, developing, and managing new business ventures, often requiring innovation and risk-taking attitudes". When combined, the entrepreneurship ecosystem' refers to the supportive network of individuals, organizations, and resources that facilitate entrepreneurial activities (Isenberg, 2010). Besides, Digital entrepreneurship has emerged as a key driver of innovation, economic growth, and job creation, leveraging digital platforms within the digital economy. From a theoretical perspective, studies found ambiguity in the conceptualization and integration of DEEs findings into theoretical lenses due to new field. The term digital entrepreneurship has been utilized in previous studies as a subset of entrepreneurship within the digital economy, delineating as digital business models, digital start-ups, digital platforms, and entrepreneurial digital ecosystems (Sahut et al., 2021). Though the existing framework supports in understanding the dynamics of DEEs, such as innovation theory, resource-based views, lean startup methodologies, and institutional perspectives (Pop et al., 2024). Sussan and Acs (2017) outlined a framework consisting of four key components: 1) digital infrastructure governance, 2) digital user citizenship, 3) digital entrepreneurship, and 4) digital marketplace. The author emphasized the significance of digital technologies and users in fostering and maintaining entrepreneurial activities, especially via multisided platforms. Besides, authors reflected entrepreneurial activities in utilizing digital tools, digital platforms (Ince, 2023), offered conducive environment to create new business models (Du et al., 2018). While traditional ecosystem has limitations,

prior study by Li and Yao (2021) highlights the integration of digital technologies in all aspects of entrepreneurship to drive efficiency, scalability, and competitive advantage. In addition, digital ecosystems provide start-ups with significant benefits (e.g., access to established markets, competitive advantage, improved reputation, and enhanced initial public offering opportunities). It also serves as an infrastructure for value creation and attribution for entrepreneurs, assisting new businesses in mitigating market challenges (Nambisan & Baron, 2019). Government policies and strategies also play a critical role in transforming DEEs across different economic contexts. For instance, the Small Business Innovation Research (SBIR) program in the USA (Sipakoly, 2024) and One net in China (Gan et al., 2023), public policies for digital transformation in Barcelona's local startup ecosystem (Font-Cot et al., 2023) have supported digital resources, environments, finance and digital infrastructures by reducing barriers to early-stage financing and risk-seeking behaviors of local government (Mafimisebi & Ogunsade, 2022a, 2022b). Looking into Asian and African contexts, researchers observed persistent challenges such as regulatory frameworks and limited access to digital infrastructure, innovation culture, and capital in India and most African countries (Adel, 2024). These disparities are often exacerbated by bureaucratic policies, innovation culture, fragmented policy implementation and weak institutional support, and poor investment in infrastructure and technology (Igwe et al., 2022). Thus, evidence-based policy and local entrepreneurship needs based policy are sparse in designing policies and programs in scaling digital business. The authors also raise concerns in revealing the critical role of government regulations and non-state actors in making policies based on human and environmental needs (Canestrino et al., 2024). More attention required for a coordinated regulatory mechanism and integrated digital strategies with SDGs to foster sustainable entrepreneurship practices (Herman, 2022). Since, digitization has broadened access to financial services and economic prospects, reducing poverty (Dabbous et al., 2023). Despite its significance, Li et al. (2017) asserts that study on DEEs is limited, and the concept has great development potential in academia, especially in regional and economic context (Ali & Jabeen, 2024). However, reviewing the past literatures from a diverse perspective, we have observed an increasing number of reviews on the entrepreneurship ecosystem, but very few of these have been conducted in a digital context. The summary of previous findings (see Table 1) acknowledges DEEs as an emerging area shaped by diverse methodologies, multifaceted natures, and mostly bibliometric and systematic reviews. Recent reviews have the lack of definitional and conceptual clarity, limited understanding the EEs in digital context (Bejjani et al., 2023a), dynamic research methods to explore the sustainability factors within EEs and a well-recognized theoretical framework (Theodoraki et al., 2022). Therefore, this study strives to overcome these gaps by

addressing the current state of knowledge from diverse viewpoints. For example, exploring the cross-cultural perspectives and impacts in DEEs, challenges faced by women in high-tech environments, collaborations with multiple stakeholders, regional economic impacts in DEEs with a special focus on explaining the regional scientific contribution in relation to the DEEs index and other economic variables and investigating latent themes pertinent to future academic inquiry.

3. Materials and methods

This study employs a hybrid methodology integrating bibliometric analysis with topic modeling (LDA) to systematically explore and identify key components and trends in the digital entrepreneurship ecosystem. We choose this hybrid method because it offers a comprehensive and multi-faceted perspective on the research field (Cobelli & Blasi, 2024). Bibliometric analysis provides a quantitative and historical view of the field's evolution, identifying influential research and key trends across various dimensions. While topic modeling introduces a qualitative dimension, effectively uncovering the underlying thematic structure of the literature (Chen et al., 2021). Together, these methods provide a holistic understanding of the current state of the knowledge and helps in extracting latent topics and research impact. However, we systematically present the methodology section splitting in two distinct parts. The first phase explains the bibliometric approach, together with the data accumulating procedures, analytic tools, and software required and performance analysis, are explained in the first phase. The second phase contains a systematic illustration of the topic modeling stages, which included LDA algorithm, preprocessing, creation of DTM matrix, the number of topics selection, and post-processing (LDavis).

3.1. Bibliometric analysis

Bibliometric analysis is a quantitative method used to explore and analyze large volumes of scientific data. It involves the application of statistical techniques to bibliographic data, such as publications and citations, keywords co-occurrences, to uncover patterns, trends, and the intellectual structure of a specific field (Donthu et al., 2021). This approach differs from traditional literature reviews in several key ways. For example, Bibliometric analysis has become a powerful complement to traditional reviews and relies on quantitative data, such as the number of citations, publications, and keyword occurrences (Aria & Cuccurullo, 2017). It has broad scope and less biases using statistical measurements of scientific activity to provide systematic, transparent and reproducible insights to reviewing scientific literature (Van Eck & Waltman, 2014). In contrast, traditional literature reviews are often qualitative, focus on a narrower scope, high biases in objectivity and

Table 1
Summary of prior reviews on EEs in the digital context.

References	Database/ No. of Paper Reviewed	Time Period	Methodology	Main findings	Research Gaps
(Dana et al., 2023)	Scopus (380)	Until 2022	Bibliometric and content analysis	-Developed four knowledge clusters: 1) Business model transformation through DE, 2) DE as an enabler of innovation, 3) Empowerment (women), 4) Digital platforms	- Cross-cultural approach - Cultural and social challenges (gender role) - Impacts of digital platforms and performance
(Thai et al., 2023)	Scopus, Web of Science, and Google scholar (100)	1993–2021	Systematic literature review	-Three major findings: 1) Emergence of EE research, 2) Common definition of EE through five criteria, 3) Key theories, frameworks, and measurement tools of EE research	- Absence of a universally accepted framework or analytical approach - Lack of depth research in Asia and African nations - Less focus on national and cross-national level
(Bejjani et al., 2023)	Web of science and Scopus (46)	2015–2018	Systematic literature review	-Outlined current state of DEEs and ecosystem attributes, e.g., governance, actors, resources, identification process etc.	- Lack of conceptual gap and framework
(Theodoraki et al., 2022)	Scopus (119)	2006–2021	Bibliometric and systematic review	-Identified three thematic clusters: ecosystem configuration and evolution; the system perspective and sustainability; and the strategic perspective.	- Intersection of the multilevel approach and the integration of regional ecosystems elements

often relying on the subjective interpretation of the literature by the reviewer (Marx & Bornmann, 2016).

3.2. Topic modeling

Topic modeling is a set of algorithms and statistical model used to uncover hidden thematic structures within a large collection of documents (De la Hoz-M et al., 2021). It enables the discovery of abstract topics that occur across the text corpus, facilitating the organization, understanding, and summarizing the data (Blei et al., 2003). In topic modeling, documents are represented as mixtures of topics, and topics are mixtures of words. The fundamental assumption is that there is a set of latent topics that the documents are about, and each document exhibits these topics in different proportions. Among the various topic modeling techniques available (e.g., Latent semantic analysis, probabilistic latent semantic analysis), LDA stands out as the most extensively utilized method in the field of social science research (Mazzei et al., 2021). LDA is a generative probabilistic model that explains each document as a combination of multiple topics, and each topic as a combination of words. Furthermore, LDA, is widely recognized by scholars as a highly valuable tool in the field of bibliometric research which enables researchers to effectively identify and analyze a diverse range of topics and associated terms. Regarding our bibliometric study, it provides a unique approach to a bibliometric mapping and has the potential to make scientific contribution to multiple topics from a large set of data (Duong et al., 2022). The LDA graphical model is typically represented by a plate diagram, as shown in Fig. 1, with each term illustrated. The plate box represents the text. The outer plate represents the document, while the inner plate represents the topic choices and repetitive words in the document. Basically, there are three levels to the LDA representation. The parameters α and β are corpus level parameters, assumed to be sampled once in the process of generating a corpus. The variables θ_d are document-level variables, sampled once per document. Finally, the variables Z_{dn} and W_{dn} are word-level variables and are sampled once for each word in each document.

This process is repeated for every document in the corpus, enabling LDA to determine the topics that most accurately characterize the entire set of documents. The graphical model illustrates how each element of LDA contributes to the topic modeling process and clarifies the structure of probabilistic relationships. The overall probability of the corpus is mathematically expressed as follows:

$$P(D|\alpha, \beta) = \prod_{d=1}^M \int p(\theta_d|\alpha) \left(\prod_{n=1}^{N_d} \sum_{Z_{dn}} p(Z_{dn}|\theta_d) p(W_{dn}|Z_{dn}, \beta) \right) d\theta_d$$

This formula predicts the likelihood of corpus D in the probabilistic

model, using hyper parameters α (controlling topic distribution per document) and β (controlling word distribution per topic). The likelihood is calculated by integrating all topic distributions θ_d and adding all topic assignments Z_{dn} for each word in each document. The observed word W_{dn} is derived from the topic-specific word distribution Z_{dn} , where the topic assignment specifies the word distribution used.

3.3. Data collection and selection protocol

To conduct the study systematically, we take inspiration from the SPAR-4-SLR protocol to develop data collection process developed by Paul et al. (2021). This protocol helps to systematically assembling, arranging and assessing the data sets, thereby provides logical and pragmatic rationale and offers transparency through the reports based on the different stages and sub stages. For this study, we develop a domain-based data collection protocol which is shown in Fig. 2. Such reviews are used in bibliometric analysis to develop the domain in the field of management (Xiao & Watson, 2019). The initial stage (assembling) involves identifying and acquisitions of relevant data. During the identification sub-stage, key elements such as the domain, research questions, source type, and source quality are determined. Research identification was carried out using the Core Collection of Scopus and Web of Science databases. These two world-leading databases, utilized extensively in economics and management field (Pasko et al., 2021), have rigorous content selection and maintenance standards. They use the most extensive publishing information and impact indicators for literature selection, large-scale bibliometric analysis, and research evaluation at all levels, as study argued by Prancutè (2021). The content of the study primarily consists of research publications that have undergone peer review. In the acquisition sub-stage, research articles published between 2006 and 2023 were collected using the search terms (“digita* entrepreneu* ecosystem” OR “entrepreneu* ecosystem” OR “digita* business ecosystem” OR “digita* startup ecosystem”) in the title, abstract, and keywords field. Initially, 4070 data were extracted before the filtering. To ensure that we identified any publication that uses any of the above terms in the field of digital entrepreneurship ecosystem, we considered different spellings and abbreviations. This is indicated by asterisks (*), for example, to the term ‘entrepreneur*’, which thus also covers ‘entrepreneurship’, ‘entrepreneur’, or ‘entrepreneurial’. Inclusion and exclusion criteria were developed and applied to the dataset to define the final selection of studies. For example, books chapters, conference proceedings, conference paper were excluded. The arranging phase of the SPAR-4-SLR process involves purifying the collected material and structuring the literature using organizing codes. We removed 514 duplicate documents from both datasets using r programming after combining them. Microsoft Excel 2019 was used to

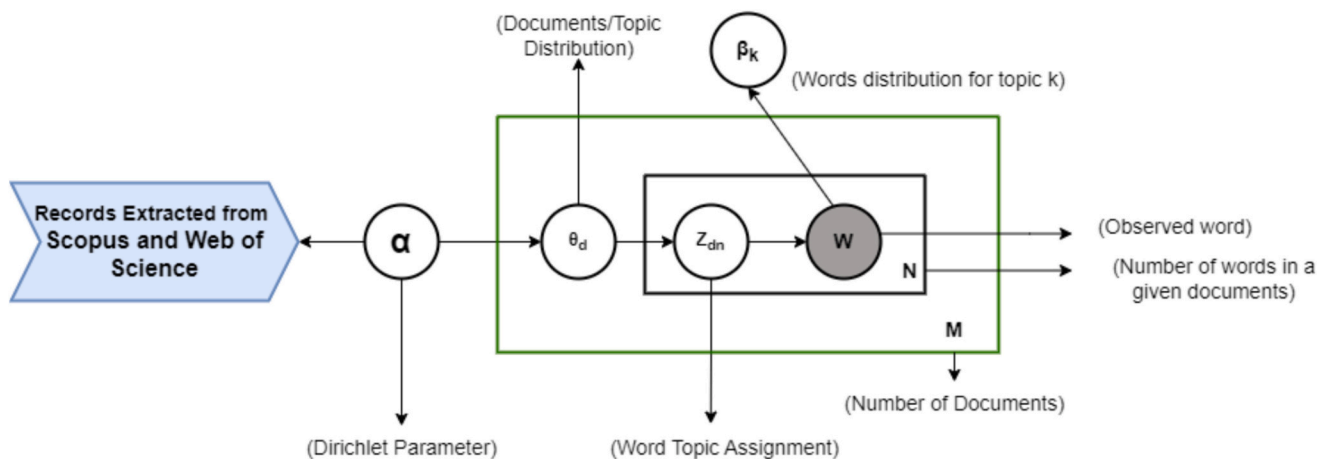


Fig. 1. The graphical model representation of LDA. Regenerated from Blei et al. (2003).

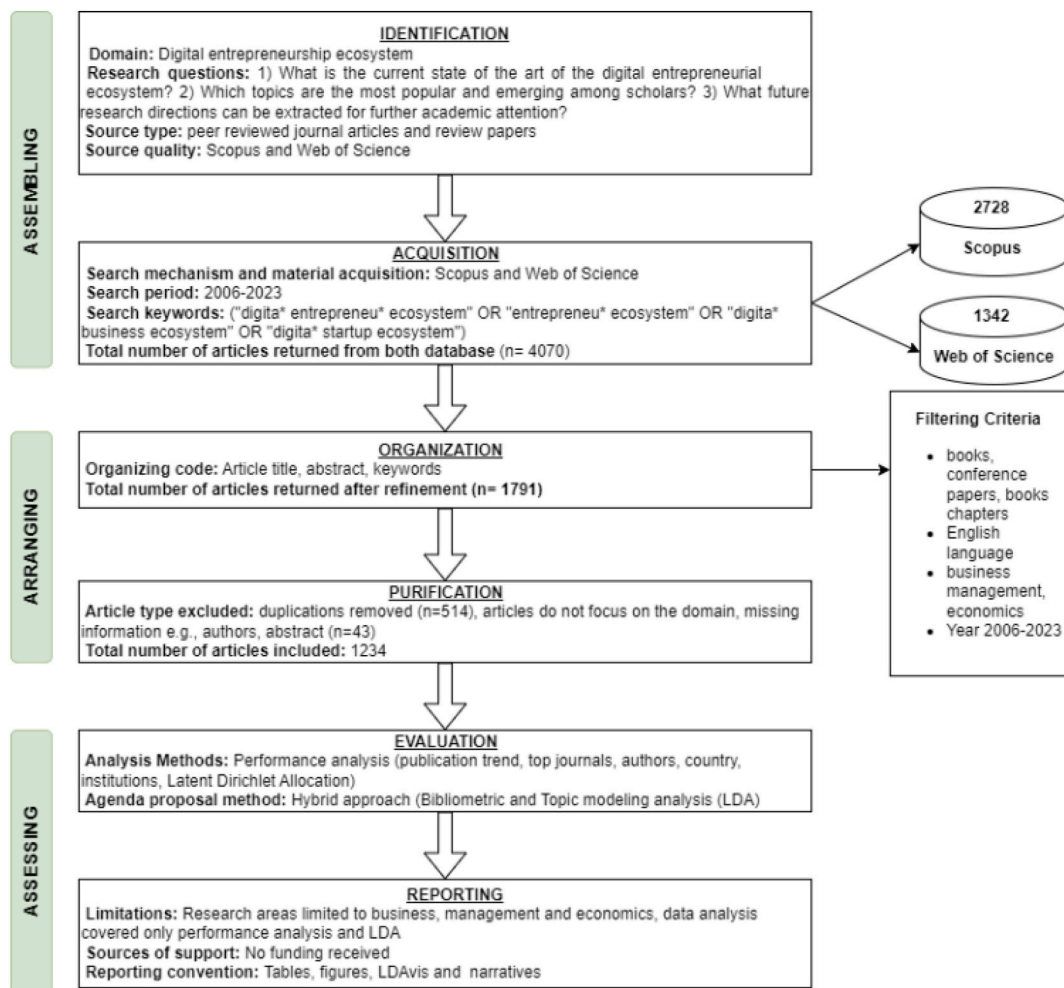


Fig. 2. Bibliometric data collection protocol modified from Paul et al. (2021).

exclude 43 papers with blank abstracts or titles that did not match keywords. The final stage (assessing), focuses on evaluating, reporting and analyzing the final data set of 1234 articles. All the analysis was performed using R studio software since it is a popular integrated development environment for R (Sanga & Aziakpono, 2023). R studio is open-source tool with many packages and they are used for data analysis, visualization, and management used by researchers (Miah et al., 2024).

3.4. Text cleaning and data pre-processing

After the data retrieved from Scopus and Web of Science, we merged the two-database using r programming. The dataset used in this study consists of document abstracts collected in a CSV file. The text data is stored in the 'Abstract' column of the CSV file. The initial stage in topic modeling involves the pre-processing of the corpus of documents. The entire corpus has 245,546 words. In R studio, we utilized the "tm" package to transform the text data into a corpus. We have standardized the text by converting all characters to lowercases. When tokenizing, string objects that are not words, such as special characters, grammatical characters, numeric numbers, and punctuation marks, were eliminated. To improve the accuracy of the keywords, we performed several actions, including removing common stop words (such as 'the' and 'and'), eliminating whitespace in the text, and utilizing a predetermined list from the tm package (Celard et al., 2020). The 'textstem' package is used to stem the remaining words in a document, reducing the unique word count by converting them to their base or root form. To generate

common stem phrases, suffixes are eliminated. For instance, both the terms "entrepreneur" and "entrepreneurs" can be condensed to the common term "entrepreneur". Then, the DTM was created which is a matrix representation of the corpus where rows correspond to documents and columns correspond to terms. The value in each cell represents the frequency of the term in the document. This matrix is crucial for LDA modeling as it quantifies the text data. Finally, output data were structured as a Document Term Matrix. The matrix thus comprised 149,837 words and 4088 (unique) terms. Then, LDavis was applied to demonstrate the topic modeling results and analysis (Kao & Luarn, 2020).

3.5. Optimal number of topics

Selecting the optimal number of topics is an important step in LDA modeling. In our study, we considered a balanced approach that can ensure both the quality of topics, coherence, and interpretability using the 'ldatuning' 'text miner', 'topic modeling' packages in R Studio. The coherence score shown in Fig. 3 is an important quality measure how well a topic is supported by corpus. It measures the semantic consistency of the words within a topic. Röder et al. (2015) stressed that the higher coherence scores indicate that the words grouped together in a topic are more meaningful and interpretable to humans. The graph reveals an upward trend, with coherence improving as the number of topics increases from 2 to around 10, and started gradually decreasing to 12. On the other hand, perplexity is a common statistical method of assessing how well a probabilistic model predicts a sample (Romero et al., 2024).

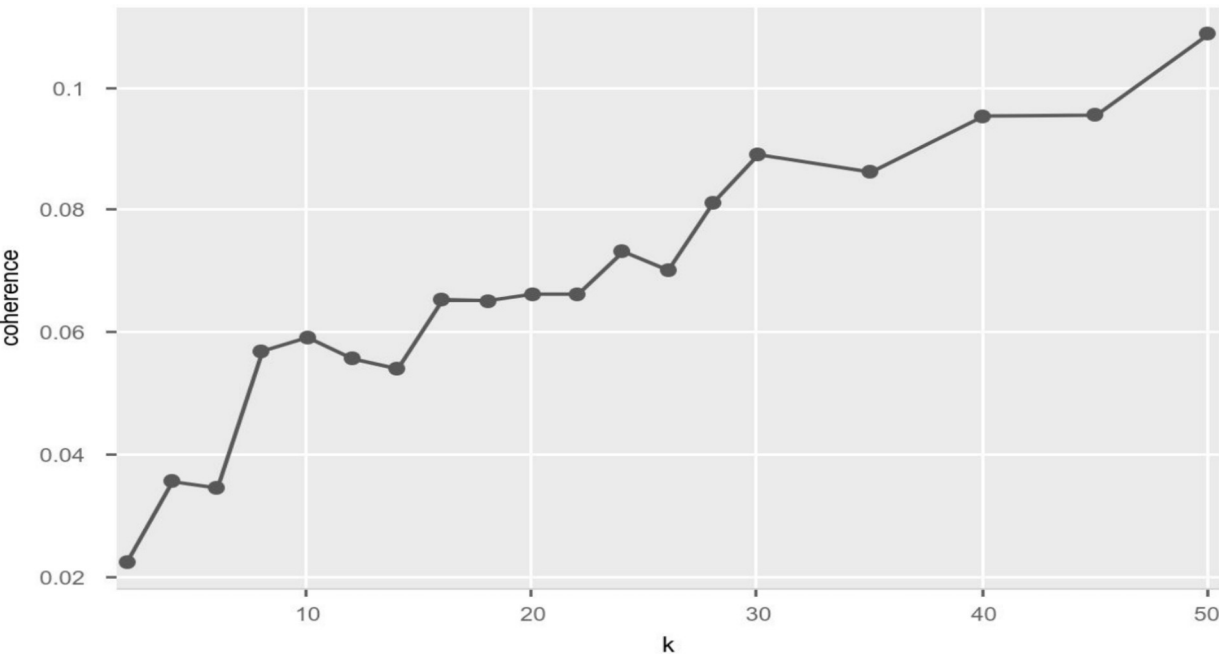


Fig. 3. Coherence score (Source: Authors).

In topic modeling, a lower perplexity indicates a better model fit. As shown in the Fig. 4, the perplexity decreases as the number of topics increases. When the number of topics around 12, the curve started declining afterwards. However, a reduced perplexity score often results in selecting many topics and require human interpretations. The process involved trial and error, we experimented different variations, for example, $k = 15$. The results contain terms with very low similarities, meaning that it contains overlapping topics or irrelevant terms that cannot be used to interpret the current domain (Islam et al., 2024). Consequently, we identified six topics with highly correlated keywords that were consistent across the datasets.

To understand the optimal number of topics, this study also uses four metrics evaluation criteria such as coherence (Deveaud et al., 2014;

Griffiths & Steyvers, 2004), model goodness of fit (Arun et al., 2010), and redundancy reduction (Cao et al., 2009). As shown in the graph (see Fig. 5), the authors adjusted values of K (number of topics) ranging from 2 to 20. The Griffiths2004 metric represented by black circles in the graph, aims to maximize its value. The line indicates a clear upward trend in the metric values, stabilizing around the 10th topic. The Cao-Juan2009 metric aims to minimize its value. The graph shows that the values decrease significantly until around the 5th topic, after which the decrease becomes more gradual. This pattern suggests around 5 optimal topics, as it minimizes the value, indicating a reduction in topic redundancy. The Arun2010 metric, depicted by black squares, also focuses on minimizing its value. It shows a sharp decline in values, reaching a minimum around the 6th topic. Deveaud2014 metric shown

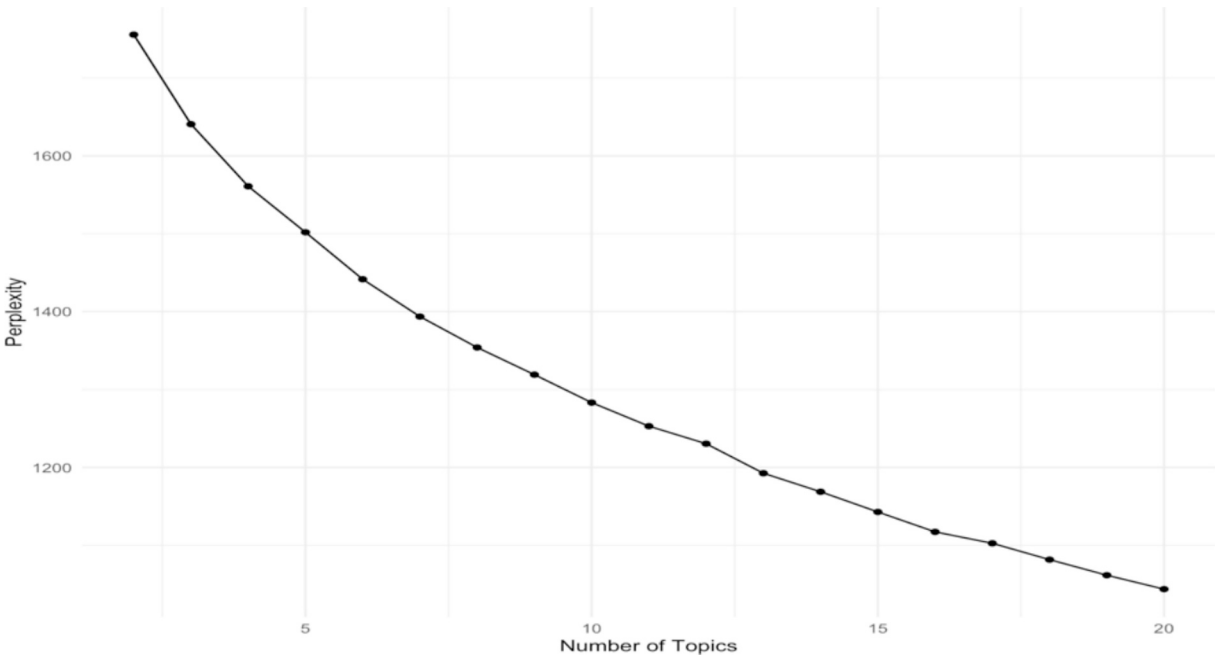


Fig. 4. Perplexity score for model performance (Source: Authors).

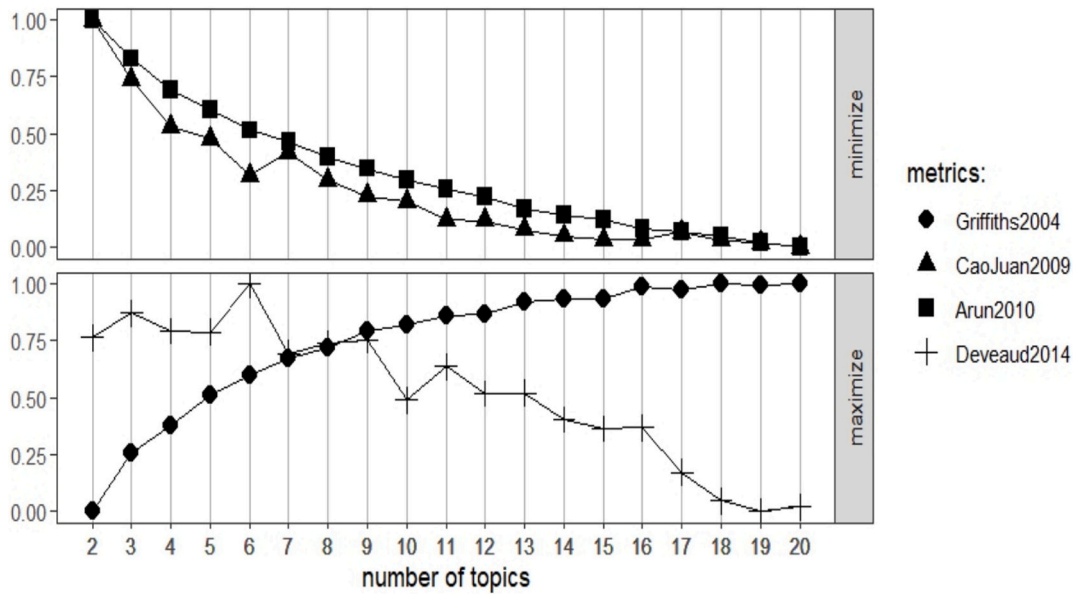


Fig. 5. Selection of optimal number of topics (Source: authors).

by black crosses also maximize its value. The values increase and stabilize around the 8th topic, suggesting that a model with approximately 8 topics would be optimal. Considering the results from all four metrics, coherence and perplexity score, a balanced approach was considered to select the suitable number of topics. So, six topics were determined to be the best fit for our data and make the analysis simple. This range ensures a balance between model complexity, interpretability, and coherence, allowing meaningful topic extraction from the dataset (Mendiratta et al., 2023).

4. Results and analysis

This section presents the findings of the study based on the performance analysis and LDA approach. The aim is to delineate the current state of the digital entrepreneurship ecosystem and to identify emerging

themes. The findings are subjected to performance analysis which includes the evolution of the field, authors, affiliations, and regional contributions and the topic modeling to answer the first two research questions.

4.1. Evolution of scientific publications

Assessing scientific publications is crucial for understanding how a field has developed, which topics are prominent, and how knowledge dissemination is changing. It maps out the field's past and future. In Fig. 6, we categorized the evolution of the domain into three distinct phases. As seen in the graph, the emergence phases (2006–2013) set the stage for the initial interest and foundational studies in DEE, which account for 1.3 % of total publications. The growth phase (2014–2017) shows a sharp rise (93 %) through the expansion phase, reaching over

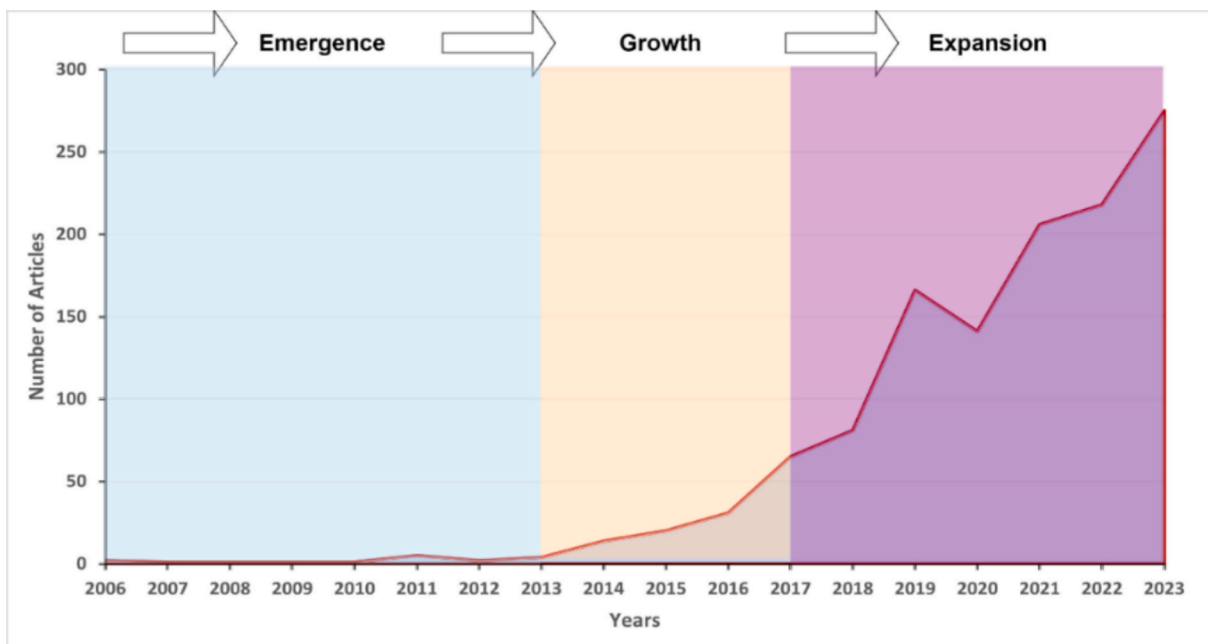


Fig. 6. Evolution of scientific publications (Source: Authors).

200 articles in the last three years. Several factors likely contributed to this surge in research output. For example, research funding, the growing importance of interdisciplinary research, the use of big data analytics, and machine learning have increased researchers' abilities and productivity in data collection, preparation, and analysis (Wurth et al., 2022). During the COVID-19 pandemic, entrepreneurship resilience (Thukral, 2021), digital social entrepreneurship, and the use of digital artifacts and platforms emerged as opportunities for the growth of SMEs, particularly in the technology, healthcare, entertainment, and e-commerce sectors (Modgil et al., 2022). However, the upward trend strongly suggests that the research community has become increasingly active and collaborative, driven by advancements in technology and increased support for research initiatives in this field.

4.2. Regional research collaboration and comparison

The collaboration map shown in Fig. 7 is a powerful tool in bibliometric for visualizing the relationships and synergy between countries. The network shows that the USA leads the top position both in single and multiple country publications, followed by the UK. The USA primarily conducted research studies on key themes, which included establishing frameworks, understanding theoretical foundations, identifying key ecosystem elements for regional entrepreneurial ecosystems, conceptualizing digital entrepreneurial ecosystems, and examining their evolutionary dynamics. The results also identify common research domains among the USA, UK, Italy, and Germany. The favorable digital business environments encompass culture, formal and informal institutions, regulation and taxation, market conditions, physical infrastructure, human capital, knowledge creation and dissemination, finance, and networking support. While most Asian and African countries (e.g., China, India, Bangladesh, Nepal, Kenya, Uganda, Ghana, etc.) highlighted the importance of education in fostering entrepreneurial ecosystems in the digital age.

In Table 2, we also illustrated four key metrics (e.g., GDP per capita, research outputs, DEE index score, and world ranking in DEE) of the top ten countries to compare the relationship in their research productivity. Evidence that developed countries, such as the USA, UK, and Australia, demonstrate a strong correlation between economic performance (GDP) and high DEE scores. Previous results similarly suggest a strong

Table 2

Comparison of top 10 countries in terms of research outputs, GDP per capita, DEEs scores, and global rankings.

Country	Region	GDP (Per capita)	DEE Score	World Rank	Research Outputs
USA	North America	78,675.50	83.8	1	176
UK	Europe	48,866.60	83.5	2	81
Australia	Oceania	64,711.80	79.7	10	55
Germany	Europe	52,745.80	79.1	13	60
Spain	Europe	32,677.00	66.7	22	55
Italy	Europe	38,373.20	61.6	25	74
Portugal	Europe	27,275.10	60.6	30	35
Brazil	South America	10,043.60	40.6	50	34
China	East Asia	12,614.10	37.6	55	47
India	South Asia	2484.80	25.9	83	52

Sources: DEE index 2021 (Szerb, Acs, Song, Komlósi, & Lafuente, 2021); GDP (PPP) data (World Bank, 2023).

correlation between economic resilience and the quality of a country's environment for digital entrepreneurs (Autio et al., 2024). Our results also conclude that leading countries with higher GDP and DEE index scores have high research outputs. As shown in the last column, three of the top 10 countries (USA, UK, and Australia) belong to the Anglo-Saxon region. These countries collectively account for 25 % of the total publications, indicating their prominent position in the research field. In contrast, emerging economies like Brazil (34), China (52), and India (47) show significantly lower GDP per capita and DEE index scores, despite moderate research outputs.

4.3. Leading authors and institutions

In this section, we featured the top 10 prolific authors and organizations in Table 3 to understand the worldwide research collaboration among authors, institutions, and their impact in academia. We based our analysis on the authors' overall scientific production, following a similar analysis by Zhai et al. (2022). Additionally, when extracting the most influential authors based on the overall scientific productions, the results vary due to the different metrics used in the analysis (Muldoon

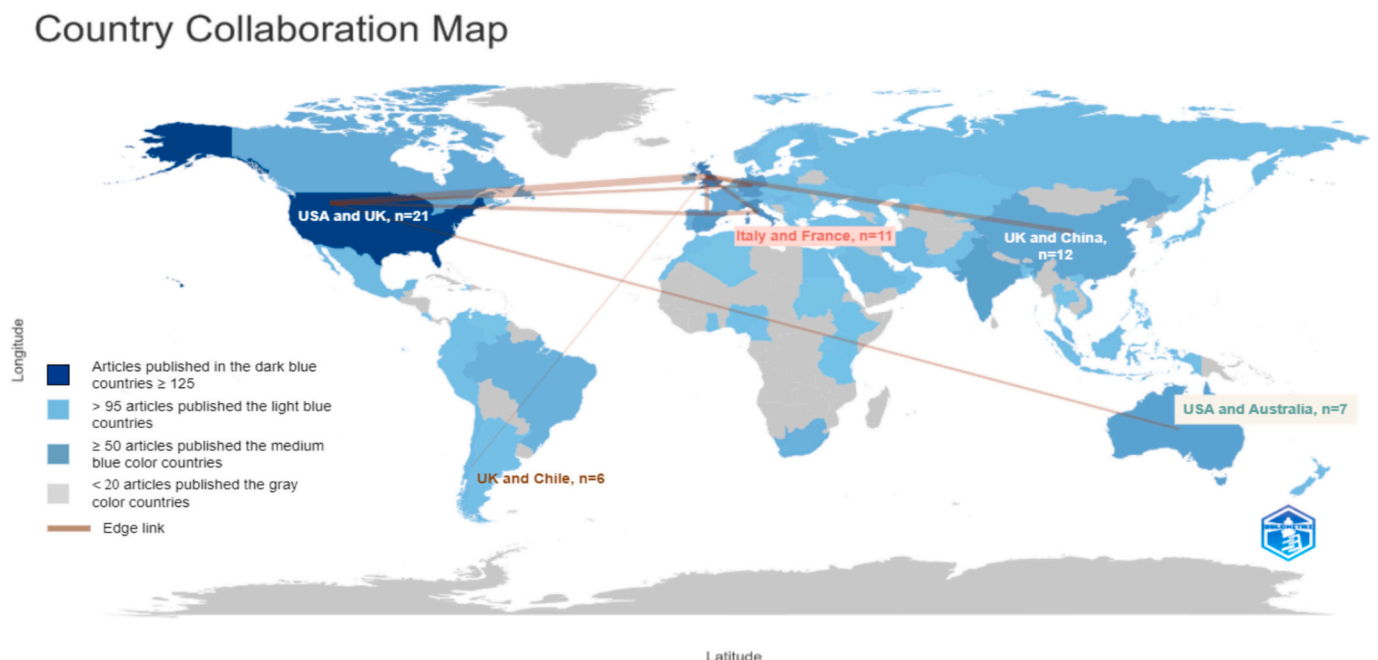


Fig. 7. Collaboration map (source: author).

Table 3

Top authors and institutions in the digital entrepreneurship ecosystem.

Authors	H_index	TC	NP	Institutions	Articles
Roundy Philip T.	14	1121	22	La Trobe University (Australia)	19
Audretsch David	13	1639	20	Indiana University Bloomington (USA)	16
Ratten Vanessa	10	494	13	University Of Campinas (Brazil)	15
Guerrero Maribel	9	485	11	University Of Tennessee at Chattanooga (USA)	14
Cunningham J	8	636	9	Universidad Del Desarrollo (Chile)	14
Fischer Bruno Brandão	8	212	11	University Of Tennessee System (USA)	13
Lehmann Erik E.	7	574	7	University Of Beira Interior (Portugal)	12
Menter Matthias	7	481	8	University Of North Carolina (USA)	11
Acs Zoltan	6	1186	7	George Mason University (USA)	11
Belitski Maksim	6	658	8	University Of Pecs (Hungary)	10

Note: TC = total citations, NP = number of publications.

et al., 2024). The results show that USA is included in 50 % of the top 10 institutions that have made significant contributions. For example, Indiana University Bloomington has extensive collaborations with Universidad del Desarrollo and George Mason University. As shown, Roundy P, affiliated with University of Tennessee at Chattanooga (USA) emerges as the leading author. The authors proposed that we can better understand entrepreneurial ecosystems through the lens of complexity science and conceptualize them as complex adaptive systems. They identified three forces influencing the emergence of entrepreneurial ecosystems: 1) the intentionality of entrepreneurs, 2) the coherence of entrepreneurial activities, and 3) the injections of resources (Roundy & Burke-Smalley, 2022). David B. Audretsch is the second-leading and most influential author. He is affiliated with Indiana University in the USA, and has primarily collaborated with Australia and the UK, a fact that aligns with the findings presented in the collaborative map. His research and co-authors' findings encompass regional entrepreneurial ecosystems, the regional entrepreneurship development index, and the

six domains of the entrepreneurial ecosystem: culture, formal institutions, infrastructure and amenities, information technology, melting pot, and demand (O'Connor & Audretsch, 2023). Interestingly, Acs Zoltan, affiliated with George Mason University (USA), has amassed a substantial 1186 citations, despite relatively low publications (6). This is perhaps due to strong collaboration with other top authors. For example, Eric Stam, Audretsch, and O'Connor. Together, they integrate ideas from the literature on strategy and regional development to examine the entrepreneurial ecosystem approach in a more comprehensive way.

4.4. Top journals and their impact

We used Bradford's Law (see Fig. 8) to identify the top journals in the current field. Bibliometric uses this law as a key principle to identify core journals that significantly contribute to the literature of a specific field. It posits that a small core of journals will account for the majority of relevant articles, followed by a second zone with more journals contributing fewer articles, and finally, a third zone with the most journals contributing the least number of articles. Table 4 lists the top 10 journals and their metrics, such as total citation, impact factor, quartile, and other indexes, based on these principles. Zone 1 publishes the majority of significant articles (410) and comprises a total of 19 prolific articles. This indicates that the top 10 journals belong to the first zone. Small Business Economics and the Journal of Technology Transfer are the most impactful journals in terms of total citations and number of publications. Moreover, the second zone exhibits a rise in the number of journals, albeit with a comparatively lower article count per journal. The red line peaks in Zone 2, indicating the cumulative number of articles reaches its highest in this zone before declining. Zone 3 includes the largest number of journals, yet each contributes fewer articles, consistent with Bradford's distribution model. This distribution emphasizes the concentration of impactful research within a small number of key journals in Zone 1, making them essential resources for researchers in digital entrepreneurship ecosystems. (See Table 5.)

4.5. LDAvis analysis and topic trends over time

Fig. 9 presents the six topics and their top 30-salient terms. The

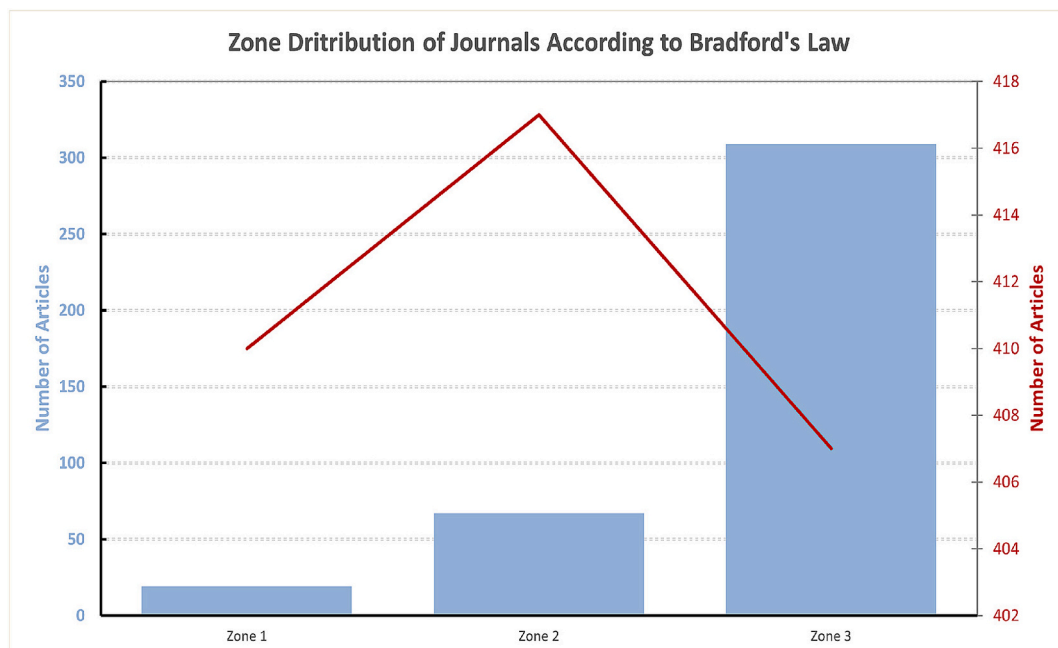
**Fig. 8.** Core sources of journals and articles based on Bradford (1934).

Table 4
Top 10 journals and their metrics.

Journals	H_Index	G_Index	TC	NP	IM	Quartile
Small Business Economics	38	69	5443	69	6.4	Q1/ABS
Journal of Technology Transfer	21	34	1893	34	4.8	Q2/ABS
Entrepreneurship and Regional Development	16	24	768	24	5.6	Q1
Technological Forecasting and Social Change	16	29	1403	29	12	Q1
Research Policy	14	25	1584	25	7.2	Q1
International Entrepreneurship and Management Journal	13	25	670	25	5.6	Q2/ABDC/ABS
Journal of Business Research	13	21	850	21	11.3	Q1
International Journal of Entrepreneurial Behavior & Research	11	17	317	17	5.5	Q2/ABDC (B), ABS-2
Journal of Entrepreneurship in Emerging Economies	11	25	633	29	3.6	N/A/ABS/ABDC (C)
Journal of Enterprising Communities-People and Places in The Global Economy	10	17	291	18	2.4	N/A

Note: TC = total citations, NP = number of publications, IF = impact factor.

Table 5
Label and distribution of salient terms.

S. N.	Topic	Proportion	Top 10 Terms
1	Digital entrepreneurship in academia	17.3	research, entrepreneurship, paper, study, literature, provide, digital, identify, framework, analysis
2	Women entrepreneurship and gender role	16.9	entrepreneurial, study, university, use, factor, finding, result, datum, education, model
3	Entrepreneurial Ecosystems and Innovation	16.7	ecosystem, entrepreneurial, innovation, knowledge, resource, network, role, within, actor, develop
4	Government Policy and Economic strategy	16.6	entrepreneurship, development, policy, economic, country, economy, level, activity, regional, growth
5	Social Entrepreneurship and Sustainability	16.4	entrepreneur, business, social, support, sustainable, market, create, enterprise, challenge, opportunity
6	Startup Ventures and Incubation	16.1	new, venture, startups, firm, technology, capital, startup, incubator, support, accelerator.

authors manually reviewed and labeled each topic (see Table 5:). We used the LDavis package in R Studio to interpret the complex results of topic modeling and provide an interactive visualization. The graph displays the intertopic distance map on the left panel, which we generated through multidimensional scaling. This map visualizes the topics in a two-dimensional space, where the distance between them reflects their similarity. Topics that are more similar to each other are closer together on the plot. Each bubble represents a topic, and the size of the bubble indicates the prevalence of the topic in the corpus. Larger bubbles represent more prevalent topics and subtopics. On the other hand, the right panel lists the top 30 most salient terms in the corpus. Saliency is a measure that combines the term’s frequency and its

distinctiveness for the topic. The bar chart shows the frequency of these terms. The blue bars indicate the overall term frequency in the corpus, while the red bars indicate the estimated term frequency within the selected topic. We used $\lambda = 1$ to rank the terms purely based on their probability within the selected topic. Basically, λ helps explore terms that are either more representative of the topic or more unique to it. Fig. 8 demonstrates the evolution and trend of the topic over time. Fig. 10 presents and analyzes each topic by aggregating the LDA visualization and topic evolution graph.

Topic 1 (Digital Entrepreneurship in Academia): This topic comprises 17.3 % of the tokens in the dataset. In the context of topic modeling, tokens refer to the proportion of words in the dataset that are associated with this topic. The overall global trends (see Fig. 8) in the recent years, especially from 2018 onwards, look stable and get high attention among the researchers and academicians due to their potential to drive economic growth and innovation (Hamburg, 2019). Academic entrepreneurs are giving more importance to enhancing entrepreneurial orientation and capacity for small and medium enterprises. According to Zhai et al. (2022), the emergence of digital technologies, such as big data and artificial intelligence, has further stressed the need for research in this area. However, the field of digital academic entrepreneurship remains under-researched and requires a more comprehensive and holistic approach (Rippa & Secundo, 2019).

Topic 2 (Women Entrepreneurship and Gender Role): Results show a noticeable increase in proportion (16.9 % of tokens) around 2007–2010 maintaining a steady presence afterward (see Fig. 10). The distance map (see Fig. 9) positions this topic further away from other topics, indicating a more distinct thematic area. The most common terms are entrepreneurial, study, university, and education which pointed up the role of women participation in digital economy. This topic signifies digital technologies and entrepreneurial education, enabling them to tackle societal norms and drive economic prosperity with greater flexibility. Prior study explored various form of challenges both in developed and developing nations. For instance, psychological challenges (e.g., work-life balance, persistent gender stereotypes, and online discrimination), organization and financial challenges such as economic conditions, business networks, and access to digital market, demographics and geopolitical factors challenge to foster entrepreneurship behavior among women (Brieger et al., 2024). Moreover, digital literacy and skills, cultural barriers such as male guardianship in Saudi Arabia (Kamberidou, 2020), women under-representation in Europe (McAdam et al., 2020), and gender segregation disproportionately affect women, particularly in developing economies in Bangladesh (Hossain et al., 2024). In South Africa, personal and contextual factors, such as gender, culture, and generational gaps shape women’s entrepreneurial behavior and innovation in digital platforms like social media (Swartz et al., 2022). As demonstrated in the results section, the findings reveal that the strengthening of socio-economic factors, e.g., favorable business environment, human capital, a culture of innovation, and tax policies differentiates the barriers often suffered by countries with poor or weak economies in terms of entrepreneurship education, digital literacy, and gender stereotypes. Overall, it is seen that developed economies offer better access to digital tools and support systems, but gender biases in financing and cultural norms still pose challenges in both economy (Tejeiro et al., 2021). In contrast, women in developing economies face more severe economic, cultural, and technological barriers (Alzamel, 2024), with limited institutional support and timely entrepreneurship education to help them overcome these challenges (Naidu & Chand, 2017).

Topic 3 (Entrepreneurship Ecosystems and Innovation): Topic 3 also has a steady presence over the years, indicating a consistent interest in this area. The results show that the top keywords, such as, ecosystem, entrepreneurial, knowledge, innovation, and resources, suggest subtopics as emerging research areas. For example, the role of innovation, digital knowledge in entrepreneurship and regional development, the impact of digital transformation on startup ecosystems, and the

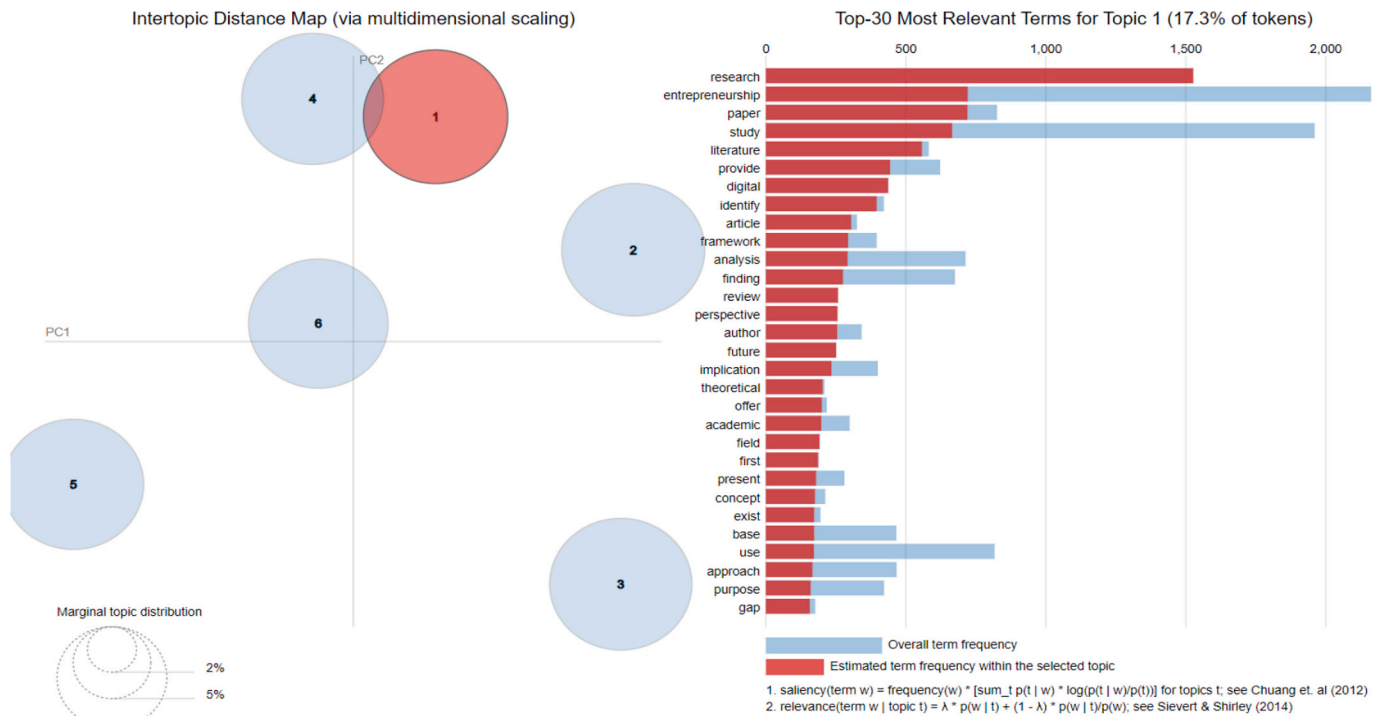


Fig. 9. Topic visualization using LDAviz. (Source: Authors).

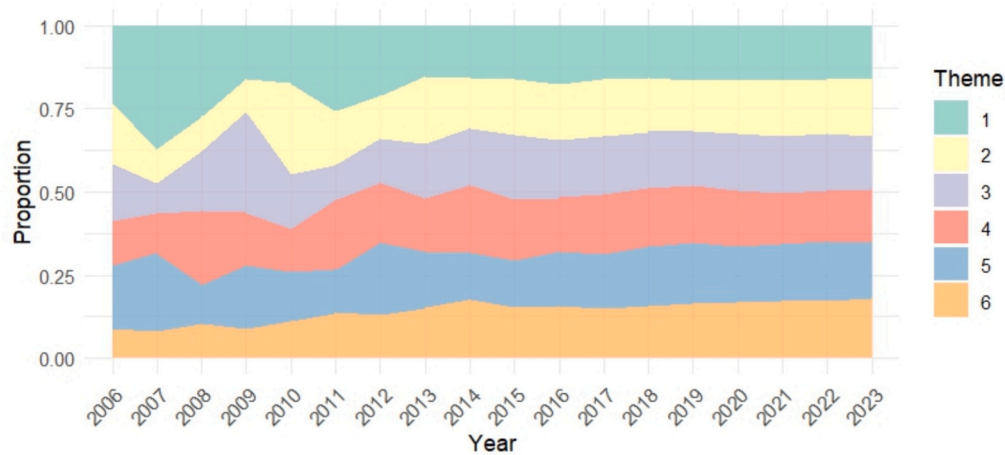


Fig. 10. Topic evolution and trend over time (Source: Authors).

influence of globalization on new business ventures (Wagner et al., 2021). Studies by Ratten (2020) and Lee et al. (2021) acknowledge the necessity of technology innovation and knowledge for entrepreneurship, the role of public administration and policies in supporting entrepreneurial ventures for regional development.

Topic 4 (Government Policy and Economic Strategy): This topic revolves around the role of government policies and economic strategies in fostering digital entrepreneurship. Unlike the theoretical and academic focus of Topic 1, it is more practical and policy-oriented, aiming to provide actionable insights for policymakers and economic strategists. The distance map shows that two circles are close and interlinked. Meaning that both topics share some common areas. Besides, they also share some common terms (e.g., entrepreneurship, base, analysis), which express the common understanding of entrepreneurship in two ways. Topic 1 contributes through theoretical and academic research on digital entrepreneurship, and Topic 2 shares practical application of

policies and economic strategies to foster entrepreneurial growth. For example, Singapore leads the top ranks in the DEEs score index in the world and has demonstrated considerable success in formulating digital transformation policies, e.g., the 'Startup Singapore (SG) program, which bolstered its strong digital infrastructure, financial supports, mentorship, and access to networks, enabling their seamless integration into global entrepreneurship networks and digital innovation (Ajayi-Nifise et al., 2024). Whereas, in Kenya, South Africa, and Ghana, the policy initiatives reveal a mixed narrative. Kenya's Silicon Savannah stands out as a promising case, where government-backed initiatives such as the Youth Enterprise Development Fund and favorable fintech regulations have positioned the country as a leader in Sub-Saharan Africa (Nel-Sanders & Thomas, 2022). Several government policies and strategies have been explored in prior studies which considered potentially successful. For example, digital transformation policies in Spain to thrive startup ecosystem (Font-Cot et al., 2023), digital industrial

policies in Europe to address structural problems (Gruber, 2019), financial and mentoring supports in Bahrain (Mara & Albastaki, 2021). While some countries have implemented policy to support digital entrepreneurship, others success is often hindered by issues related to policy implementation, access to capital in rural areas in India and Indonesia, governance, and infrastructure and lack of shared commitment (Lucky, 2013). Addressing these challenges requires a more systematic and well-coordinated approach. Our findings suggest that both regions must priorities infrastructure development, digital literacy programs, and enhanced stakeholder collaboration to build resilient and inclusive DEEs.

Topic 5 (Social Entrepreneurship and Sustainability): This comprises 16.4 % of the total tokens, making it a unique and well-defined topic. Key terms such as ‘entrepreneur’, ‘business’, ‘social’, ‘support’, ‘sustainable,’ and, ‘market’ define the entrepreneurial initiatives that aim to create sustainable social impact. Besides, ‘stakeholder’, ‘community’, ‘strategy’, and, ‘value’ indicates the collaborative and strategic nature of social ventures. Earlier findings also acknowledge this domain has emerged as a critical area of interest in both academic and practical implementations (Dickel & Eckardt, 2021). As it can be seen in Fig. 8, besides, from 2006 to 2023, social entrepreneurship and sustainability have shown a gradual increase in proportion and high demand for innovative solutions that traditional business models fail to provide (Kamaludin, 2023).

Topic 6 (Startup Ventures and Incubation): Topic 6 accounts for 16.1 % of the tokens and also refers to a distinct theme. The prominence of terms related to new ventures, startups, technology, and support mechanisms (such as incubators and accelerators) suggests that such an area is heavily focused on the startup ecosystems. This includes the processes, challenges, and support systems that new ventures encounter. The results show the frequent mention of incubators, accelerators, and support indicates a significant emphasis on the infrastructure that aids startup development. These terms suggest a focus on how these support mechanisms help new ventures navigate early-stage challenges. Terms like ‘capital’, ‘fund’ highlight the financial considerations critical to startup success. This indicates discussions around funding strategies, investment, and financial management within the startup ecosystem. The emphasis on technology stresses the importance of tech-driven startups and innovation within this topic (Chaudhari & Sinha, 2021). It is evident (see Fig. 8) that Topic 6 shows a steady presence over the years, reflecting the consistent and growing interest in startups and new ventures.

5. Discussion

This study employs a hybrid approach to map the existing knowledge field, extract emerging topics and suggest directions for future study in DEEs. In all metrics, the results revealed that USA, UK, Australia, Germany are in the forefront in scientific contributions to this domain. Our findings coincide with prior studies showing that most developed nations in North America and Europe have excelled in productive entrepreneurship, while developing nations experience stagnation (Chaudhary et al., 2024). Several significant factors contribute to this position, including institutional strengths, socio-economic conditions such as high GDP, a cultural predisposition towards innovation, substantial funding, collaborative networks, and access to critical data resources, as confirmed by previous studies. These factors inherently sparked the interests among scholars and practitioners, facilitating increased productivity in research and global collaboration among the nations (Barham & Yousef Hijazine, 2024). Evident that developing countries specially in Bangladesh, Nepal, South Africa stagnate their performance, as previous study identifies poor physical infrastructure, cultural barriers towards innovation, no recognition of entrepreneur’s contribution (Atiase et al., 2018). For example, in Nepal and South Africa entrepreneurs encounters various challenges, such as limited access to capital, restricted access to markets, skill shortages, digital

infrastructure gap and legislative complexities (Shrestha, 2024). In emerging economy such as Brazil, despite being constrained by limited infrastructure, the ecosystem has gradually expanded due to increased governmental support and a strong emphasis on community and collaboration, which have been crucial for fostering an entrepreneurial culture (Vicentin et al., 2024). Overall, the findings concluded top performing regions have an established frameworks and cross-border collaborations which provide a supportive environment productive research in DEEs, while developing regions are still building foundational aspects to fully support digital entrepreneurship (Dorjnyambu, 2023). Subsequent analysis revealed six significant latent topics identified via LDA. In accordance with previous study, we also acknowledge that there is no one-size-fits-all approach to DEEs. Since, the field is emerging, there is no common understanding of DEEs in the digital context. We explored in our study different perspectives and dynamic of DEEs. For example, Topic 1 heavily addressed the role of ‘academia in digital entrepreneurship’. Study conceded that understanding the digital ecosystem is important due to the transition from traditional to digital-centric business models (Fernandes et al., 2022a), and new skills that traditional education may not cover (Bachmann et al., 2024). As a growing field, academic research can contribute to theory, policy, and evidence-based insights. Our findings appear to be well substantiated by Widjaja et al. (2022) that academic research can further create new pathways for educators and academic entrepreneurs to design curricula to overcome the upcoming challenges and grab opportunities in the digital age. Several institutions have integrated Artificial Intelligence (AI) and digital technologies (e.g., blockchain, big data analytics) into their digital entrepreneurship curricula in various ways. They involve in designing pedagogical approaches in Peru and Ecuador (Solorzano Bajanã, 2024), integrating AI in projects-based learning in MIT, Stanford university in USA (Tula et al., 2024), AI literacy, innovative business models, digital skills, and addressing regulatory, ethical, and institutional challenges in Europe (Santos & Malta, 2023), AI-generated content (AIGC) technology into their innovation and entrepreneurship education in Chinese university (Wang, 2024). While the implementation of these technologies is trending, flexible and accessible education models, creation of innovative technologies, academia, industry collaboration, using cutting edge technology, communication networks are found to be best practices. Regardless of scientific advancements identified in our performance analysis, we suggest several areas need to be addressed in further academic exploration. For example, managing technological transitions in industries, balancing economic and environmental responsibilities, integrating digital tools into existing business models, and addressing ambiguity in sustainable business models (Damasceno et al., 2023). However, careful attention is required regarding cybersecurity risks, the digital divide, the regulatory framework, comprehensive ethical guidelines and robust accountability mechanisms while using this emerging technology. Moreover, practitioners can be benefited from the findings to enhance academic collaboration with industry, to foster strategies, and contribute to the development of innovative educational programs to prepare students for the digital economy. Policy makers can also use these insights to foster Research and development activities, establish ethical guidelines, and increase positive perceptions of AI affordance and its generativity and openness. In Topic 2, we addressed a critical gap in entrepreneurship literature in exploring the role of women in digital business. It is obvious that women can significantly contribute to digital entrepreneurship by leveraging their unique skills and perspectives. Panda (2018) argue that they often excel in areas such as relationship building, empathy, and customer understanding for creating user-centric digital products and services. Additionally, women-led digital ventures are more likely to focus on social impact, thereby addressing both economic and societal goals. Though other study found substantial challenges and biases compounded in the digital business undermine women’s entrepreneurial credibility and confidence (Marlow, 2020). For instances, Women entrepreneurs in Sweden and the UK face hardships like access

to funding, networking opportunities, and societal expectations (Ahl & Marlow, 2021). In China, Wiig et al. (2024) interviewed female entrepreneurs in Beijing and Shanghai and claimed that digital technologies may help women surpass these cultural barriers by allowing them to network, learn, create opportunities, and scale their businesses, empowering them to challenge male dominated structures. However, policymakers and researchers may improve the digital ecosystem for new businesses by tackling these concerns. The topic modeling also places high connection between Entrepreneurial Ecosystems and Innovation (Topic 3). These terms are buzzwords within academic research, reflecting the cultural, economic, social, and political environment supporting productive entrepreneurship. Study posits that the interaction of entrepreneurial actors, institutions, and cultures facilitates new venture development and productive entrepreneurship (Santos, 2024). Besides, digital tools and platforms have dramatically reshaped how businesses operate, pushing the boundaries of traditional models and encouraging new forms of entrepreneurial ventures (Song, 2019). This evolution is driven by a complex interplay of various ecosystem components, including educational institutions, governmental policies, financial resources, and cultural attitudes towards entrepreneurship. Additionally, the role of individual actors within the ecosystem cannot be overlooked. Thus, the importance of academic institutions in bridging the gap between research and practical application is crucial. Besides, strengthening a culture of innovation and allocating required resources, universities and research centers act as pivotal catalysts for entrepreneurial activity. Overall, a supportive culture that celebrates entrepreneurship can enhance the overall effectiveness of the ecosystem. Future research should continue to explore these interactions to provide deeper insights into optimizing ecosystems for innovation and economic development. Thus, requires the support policy and strategy from the government (Topic 4) to promote entrepreneurship and economic outcomes. According to Audretsch and Fiedler (2023), an adaptable policy framework can reduce risks, offer stability, and foster innovation and growth. Through tax incentives, subsidies, and regulatory reforms, government policy can boost entrepreneurship and regional economic development, as our findings suggest. Fkum et al. (2023) studied how government policy, finance, and networks shape Indonesian ecosystems. Thus, funding mechanisms, regulatory frameworks, tax incentives, education programs, and infrastructure development promote startups and enterprises, boosting entrepreneurship in a region or country (Onileowo, 2024). Additionally, Topic 5 emphasizes the importance of 'Social Entrepreneurship and Sustainability' in digital ecosystem creation. Prior study also raises important question about how entrepreneurs use digital technologies to achieve their business and social goals in tandem (Canestrino et al., 2024). Evident that social enterprises can transform systems and improve society by including sustainability into their mission, targeting poverty, education and health (Al-Qudah et al., 2022). Gigaury et al. (2023) opined that social entrepreneurship searches for innovative methods, tools and models to solve pressing social problems. However, the digitalization has induced the digital revolution and paved the way for an innovation-based economy. Digital platforms may help social enterprises track environmental footprints and social impacts, making them more accountable and transparent. Social innovations are essential to tackling major social issues (Dionisio et al., 2024). Audretsch et al. (2022) note that social innovations, often led by social entrepreneurs, can solve complex problems that traditional business models cannot. Digital ecosystems can support experimentation, rapid prototyping, and iterative learning. Overall Digital tools can improve productivity, reduce expenses, and improve social impact monitoring and evaluation. Finally, 'startup innovation and incubation' has emerged significant area for DEEs. Startups' agility and innovation have driven economic growth and technical development. Startups reflect the spirit of creativity and risk-taking that drives new businesses (Kulkarni et al., 2023). These companies rely on adapting swiftly to market changes and using new ideas to disrupt industries. Startups receive support and resources from incubators to turn their ideas into

successful enterprises. Menon and James (2022) emphasize the need for a complete incubation ecosystem with funding, mentorship, and infrastructure. Ecosystems like these lessen startup risks and foster experimentation and iterative development. These findings may improve national policy for startup innovation in underdeveloped nations with poor internet infrastructure. Mafimisebi and Ogunsade (2022a, 2022b) examined how supportive national frameworks affect entrepreneurship. Startup growth and innovation are fostered by policies that ease business, provide tax benefits, and open international markets. Such as, India serves as a notable example of a burgeoning startup hub, ranking third globally in the number of startups (Chaudhari & Sinha, 2021). A strong incubation framework that includes academic institutions, business partnerships, and government initiatives has fueled this rapid growth. These partnerships give startups broad support, helping them develop and scale.

6. Implications and future research directions

Results demonstrated in this study offer valuable contributions, both theoretically and practically. Theoretically, our paper finds a significant gap in academic literature regarding the study of DEEs in developing countries, mostly in Asia and African regions. The findings may serve as a source of inspiration for researchers seeking to make scientific contributions in collaboration with academia and industry. As prior studies also confirm, the entrepreneurship ecosystem has mostly focused on academic entrepreneurship, innovation, regional development, social entrepreneurship, and sustainability (Theodoraki et al., 2022). We propose a conceptual framework which we believe a significant contribution (see Fig. 9) to the holistic understanding of DEEs. The framework integrates the quadruple helix model of innovation which emphasized the multilayered interactions among industry, government, society and academia. The emerging themes derived from topic modeling will influence the existing literature and motivate researchers to delve deeper into the field, encompassing academic institutions, cultural attitudes, public policy, and economic strategies for entrepreneurship. Furthermore, the study's findings hold equal significance for investors, new entrepreneurs, and policymakers, who should closely monitor regional differences in research funds, infrastructures for digital entrepreneurs, economic barriers, ecosystem maturity, and the adoption of digital technology. These findings suggest that tailored policies can bridge these gaps and promote the digital business ecosystem, as evidenced by the success of developed nations' regulatory frameworks across Europe (Autio et al., 2018) and the USA (Ajayi-Nifise et al., 2024), which align well with economic and social structures. Though research has also shown insight that a one-size-fits-all policy approach may not always be effective in culturally and economically diverse regions (Liu & Pan, 2024). Therefore, we recommend incorporating environmental and social factors into the development of digital ecosystems, as they are crucial for comprehending digital transformation in a more sustainable manner. However, policymakers and industry leaders can benefit from this study in formulating strategies, legal and institutional frameworks for startup ventures, and cross-country collaboration. In addition, academics and other practitioners can integrate the findings for their future research. Thus, we suggest the following areas (see Table 6) from the topic modeling, which can provide academic entrepreneurs, researchers, policymakers, and other practitioners something to think about for future research.

7. Conclusion and limitations

The aim of this study is to investigate the key components, identify latent topics, and suggest future research directions for DEEs. We integrate a hybrid approach using topic modeling (LDA) and bibliometric approach. A total of 1234 articles from the Web of Science and Scopus databases was analyzed, spanning the years 2006 to 2023. The findings show that digital transformation plays a significant role in creating and

Table 6

Future research directions and potential research questions.

Emerging Topics	Sub-topics	Potential research questions
Academic research on digital entrepreneurship	Interdisciplinary research in management, business entrepreneurship and development, experiential learning and education	- o How digital artifacts and platforms can be integrated into academic entrepreneurial initiatives? - o What is the relationship between digital transformation and academic entrepreneurship?
Women entrepreneurship and gender role	Digital empowerment, institutional voids, self-perception and digital literacy, family and social expectations, access to resources (financial, network, information)	- o How different cultural and social factors influence the effectiveness of digital technologies in promoting female entrepreneurship in developing countries? - o What is the impact of digital transformation in higher education institutions that can foster academic entrepreneurship among women? - o How digital skills and technologies, financial literacy can be leveraged to close the gender gap in women entrepreneurship?
Entrepreneurial Ecosystems and Innovation	Digital ecosystem, startup ecosystem, innovation, digital user citizenship	- o How do different elements of digital ecosystem support sustainable growth and innovations in developing countries? - o How do cultural, legal, and economic factors influence tech-startups entrepreneurs? - o How the role of human capital, technology availability, labor market and financial market affect in setting government policy and strategy. - o What regional characteristics and cultural support for entrepreneurship can shape entrepreneurial activity and the effectiveness of government policy.
Government Policy and Economic strategy in entrepreneurship	Government policy (cross country comparison), entrepreneurial framework, entrepreneurship education, human capital,	- o How do digital technologies impact business model innovation and the creation of competitive advantage? - o How does the collaboration between academia and industry foster innovation in various sectors? - o What is the impact of different geographical and contextual factors on startup innovation and ecosystem?
Startup Ventures and Incubation	Digital startups, sustainable startup business model and innovation, ecosystem collaboration	

Table 6 (continued)

Emerging Topics	Sub-topics	Potential research questions
Social Entrepreneurship and Sustainability	Sustainable entrepreneurial ecosystem, social capital, social and environmental ecosystem	- o How does university business incubators contribute to the sustainability of entrepreneurial ecosystems? - o How can new business ventures balance social responsibilities and environmental sustainability to create a positive impact on the ecosystem?

operating new businesses. The study underlined the significance of academic research in furnishing evidence-based insights and theoretical foundations for policy and practices. The notable increase in scientific productions (93 % growth) found in the expansion phase (2018–2023) is the evidence of high attention. In addition, most articles are published in high-ranking journals such as “Small Business Economics,” “Journal of Technology Transfer,” and “Entrepreneurship and Regional Development.” We also found the predominant influence of Anglo-Saxon region (US, UK, Australia), and leading European countries like Germany in digital entrepreneurship research due to strong institutions, innovation-driven cultures, collaborative networks, and high GDP. However, poor infrastructure and market access hamper development in Asian and African countries. Findings reveal that targeted support and community participation, foundational development, and cross-border collaboration can close these regional gaps. From the topic of modeling, we extracted six topics: 1) Digital Entrepreneurship in Academia, 2) Women Entrepreneurship and Gender Role, 3) Entrepreneurial Ecosystems and Innovation, 4) Government Policy and Economic Strategy, 5) Social Entrepreneurship and Sustainability, and 6) Startup Ventures and Incubation. We recognize these are the emerging topics and have potential for further academic exploration. Thus, our study offers a conceptual framework of DEEs by integrating the quadruple helix model of innovation, which contains four components (e.g., government, industry, academia, and civil society) within an innovation system (see Fig. 11). The multilayered interactions of different components can be useful to understand digital entrepreneurs from a holistic perspective. The digital ecosystems demand new shapes and industries, and the government must think about the inclusion of sustainable business models along with digital integration. Additionally, the research contributes to the importance of diverse ecosystem components, including academic institutions and cultural attitudes, public policy, and economic strategies for entrepreneurship. Furthermore, the study explains the role that an adaptive policy environment can play to stimulate entrepreneurship and economic growth not only for traditional entrepreneurs but also for social entrepreneurs. The impact of a supportive domestic environment and international dynamics in fostering the growth and innovation of new enterprises is also a major finding of the study. However, the proposed framework can facilitate the integration of digital technologies by bringing together academia, industry, government, and civil society to develop strategies and policies that support a sustainable digital ecosystem for entrepreneurs. The findings of the study and future research directions (see Table 6) can help policymakers and practitioners to develop sustainable regional ecosystems for new entrepreneurs and build a better industrial economy. Our suggestions are also relevant for attaining SDG (8,9) in ensuring decent economic growth and promoting industrial development. Women’s participation in digital business can also help in achieving SDGs (4,5,10) by removing cultural, institutional, and community barriers. Other than that, SDG 13, 17 can be significantly addressed by the implication of the quadruple helix model. The contextual framework might help raise awareness among business ventures and other practitioners by addressing more social and

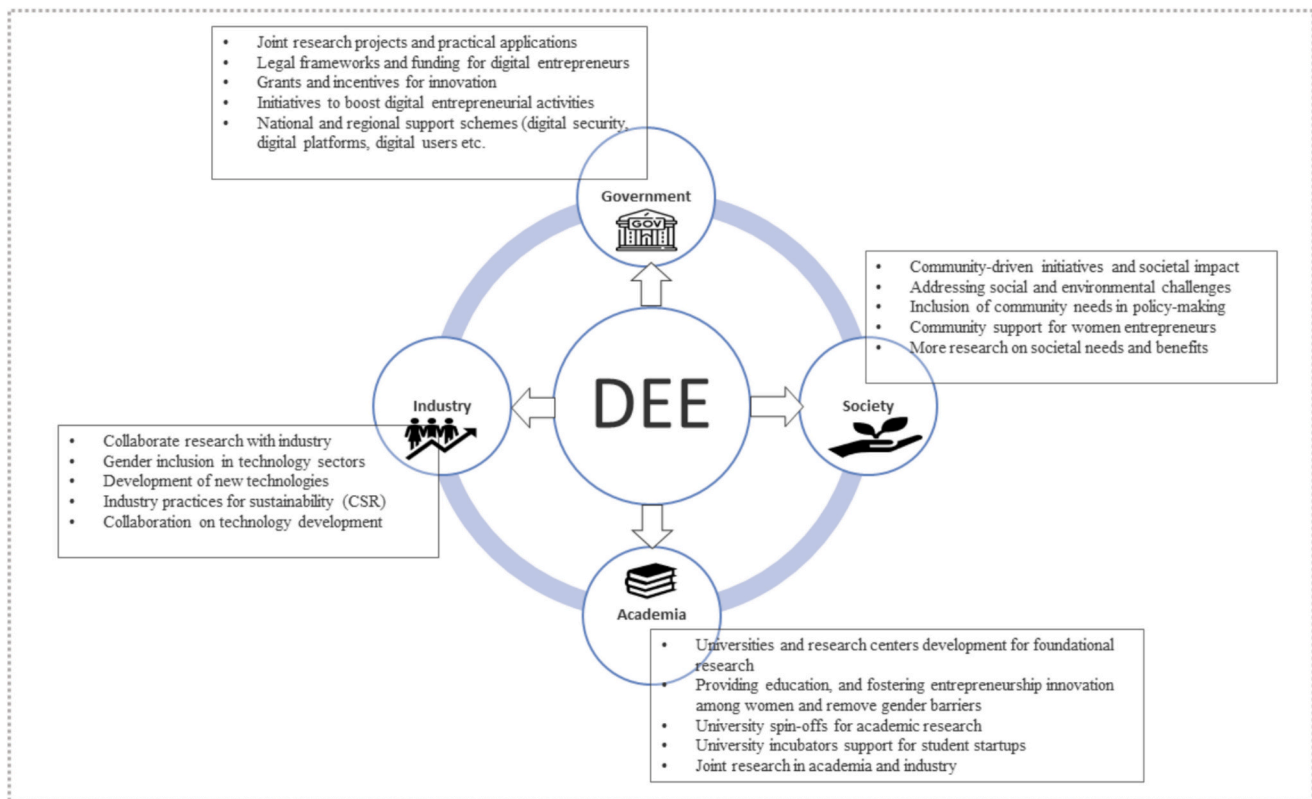


Fig. 11. Integrating the Quadruple Helix Model to the DEE (Source: authors).

environmental issues. Nevertheless, the study has several limitations. One limitation of using LDA in topic modeling is that it can be sensitive to the number of topics chosen, which can affect the interpretability and breadth of the identified topics. For instance, if the number of topics is too high, it may lead to excessive duplication of topics and keywords, reducing their interpretability (Yu & Xiang, 2023). Additionally, LDA assumes that the order of words does not matter, which can be a limitation when dealing with phrases or collocations that carry specific meanings (Gebhardt & Bachmann, 2023). While the LDA algorithm can process thousands of articles, the interpretation of topics heavily depends on human judgement, introducing a degree of subjectivity. Additionally, certain parameters, such as the selection of topics, and its quality require judgement from domain experts to validate topic coherence. Despite LDA providing a robust framework, future studies could incorporate cross-validation with alternative algorithms like harmonic mean score. Other limitations include the sample size and the analytical tools used. For example, data analysis relies on textual analysis and does not consider other influential factors, such as science mapping metrics and latent semantic analysis. Beyond using Scopus and Web of Science, future studies could also expand other popular databases such as Google Scholar, JSTOR, and [Lenses.org](https://lenses.org) to incorporate diverse disciplines. It is also important to consider non-English literature, comprehensive keywords search to analyze regional contexts which is missing in the current study. We also limited our publication coverages up to December 2023 to include the full calendar year, excluding those published in 2024. However, a mixed-methods approach, combining qualitative and quantitative methods, such as interviews or surveys from different stakeholders and compare the results with developing and developing countries could provide more insights into this domain.

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Consent to participate

All authors have equally participated in the article development.

Consent to publish

All authors have agreed on the final draft to submit for publication.

CRediT authorship contribution statement

Md. Tota Miah: Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Conceptualization. **Nurgul Aiupova:** Validation, Investigation, Formal analysis, Data curation, Conceptualization. **Szilvia Erdei-Gally:** Writing – review & editing, Supervision. **Mária Fekete-Farkas:** Writing – review & editing, Supervision.

Declaration of competing interest

The authors declare having no conflict of interest.

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Data availability

Data will be made available on request.

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