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REVIEW PAPER

Artificial intelligence technologies and entrepreneurship: a hybrid literature review

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Abstract

The disruptive potential of artificial intelligence (AI) technologies involves creating new entrepreneurial opportunities and reshaping the entrepreneurial process. The impact of AI technologies on entrepreneurial activity is also reflected in an explosive level of research interest, leading to the fragmentation of existing studies. This phenomenon makes generating a comprehensive and systematic overview challenging. This paper reviews the existing research on the application of AI-based technologies in entrepreneurial practice. Specifically, it conducts a hybrid literature review, analyzing 345 articles from peer-reviewed journals. It identifies the main contributions to the field; the conceptual, social, and intellectual structures; and the leading themes addressed to date. Despite growing interest in the field, this study concludes that most academic research on the subject has been superficial. This study proposes future lines of research based on the antecedents, decisions, and outcomes (ADO) and the theories, contexts, and methods (TCM) frameworks.

Keywords Artificial intelligence · Entrepreneurship · Hybrid literature review · Research agenda

JEL Classification M130 · M150 · O32 · O330 · Q55

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1 Introduction

According to the well-known U.S. dictionary Harper Collins, the 2023 word of the year was artificial intelligence (AI). AI technologies[1] such as machine learning (ML), the Internet of Things (IoT), automation, and natural language processing have made significant technological advances impacting virtually all industries and society. The emergence of the AI era has created the greatest entrepreneurial opportunity in the history of civilization (Iansiti and Lakhani 2020). Indeed, AI is an example of how radical external changes empower and enable new economic activities (Obschonka and Audretsch 2020a). Moreover, AI has crucial implications for how entrepreneurs develop, design, and scale their businesses during the entrepreneurial process (Chalmers et al. 2021). For example, AI can improve decision-making systems; improve process effectiveness, flexibility, and efficiency; increase productivity; reduce costs; or produce high-quality goods with high levels of customization (Giuggioli and Pellegrini 2023; Kraus et al. 2022a; Roppelt et al. 2023; Szukits and Móricz 2024; Zahlan et al. 2023). Furthermore, AI solutions are now easily accessible to entrepreneurs at a relatively affordable cost. The democratization of artificial intelligence enables entrepreneurs to compete even with large companies, thus levelling the technological playing field (Michael et al. 2023; Truong et al. 2023). This impact of AI on entrepreneurial activity has also attracted considerable interest from researchers in the field. However, existing studies are fragmented, making it challenging to generate a comprehensive and systematic overview. Hence, there is a strong need for a systematic literature review that considers evolution and the need for the establishment of theoretical frameworks to provide guidance and generalizability (when applicable) in research on entrepreneurs' growing interest in adopting AI-based technologies.

The importance of AI and entrepreneurship as a topic is reflected in three recent reviews. Despite these efforts, several gaps remain in the methodological and theoretical perspectives applied to understand entrepreneurs' growing interest in adopting AI-based technologies. Giuggioli and Pellegrini (2023) performed a qualitative analysis of AI's impact on entrepreneurship, presenting a framework that emphasizes AI's role in enhancing decision-making and fostering business opportunities. Li et al. (2022) conducted a bibliometric analysis of AI in entrepreneurial management, identifying key research clusters, but the analysis was limited by its scope and methodology. Blanco-González-Tejero et al. (2023) conducted a descriptive bibliometric study on AI and entrepreneurship, highlighting key topics but lacking in-depth analysis and future research proposals. This study aims to address these gaps by presenting a comprehensive and rigorous review, employing a hybrid systematic review approach that combines quantitative and qualitative methods to provide a holistic understanding of AI's impact on entrepreneurship. Therefore, the study's central objectives are to synthesize existing knowledge, identify structural gaps, and establish theoretical frameworks to guide future research, thus fostering innovative research on AI technologies in entrepreneurial practice.

[1] Artificial intelligence-based technologies are artifacts made with AI methods, AI industry applications (and AI systems and software used to achieve practical goals) (Bahoo et al. 2023).

First, the period under review is expanded to encompass more recent studies, which include, among other challenges, a pandemic, revolutionary technological changes such as ChatGPT, and cultural and generational shifts. Second, the scope of the review is broadened but is still limited. On the one hand, this study uses the framework proposed by Bahoo et al. (2023), which conceptualizes artificial intelligence in a broad way that this study terms artificial intelligence-based technologies (AI-based technologies). Therefore, this review includes the topics of artificial intelligence, automation, big data, chatbots, conversational agents, data mining, deep learning, fuzzy logic, the Internet of Things, machine learning, natural language processing, neural networks, robotics, and text mining. On the other hand, this study manually identifies and excludes studies that use AI-based technologies as a methodology to examine entrepreneurship. Thus, this review focuses on the relationship between AI-based technologies and the practice of entrepreneurship. Third, this review employs the Scientific Procedures and Rationale for Systematic Reviews of the Literature (SPAR-4-SLR) review protocol to provide a transparent and replicable review. Using this protocol, timing, and scope, 345 papers published between 1992 and the end of 2023 were collected from journals indexed in the Scopus database.

This study employs a hybrid systematic review that combines bibliometric analysis, qualitative content analysis and a framework-based systematic literature review (SLR). This review uses the hybrid approach to address the limitations of relying on either qualitative or quantitative methods, ensuring a more nuanced and robust exploration of the topic. Thus, this study explores the dynamism and relevance of AI-based technologies in entrepreneurship, maps the intellectual, social, and conceptual structures that underpin this evolving field, and synthesizes existing knowledge, including research gaps, through a structured framework.

Different theories of knowledge transfer, such as diffusion of innovation (Rogers 2010), knowledge transfer theory (Argote and Ingram 2000) and social network theory (Granovetter 1973), acknowledge the need to reconcile knowledge to understand and identify gaps that facilitate knowledge transfer from research to practice. For this purpose, the organization of up-to-date topics plays a crucial role in advancing the discipline (Kraus et al. 2022b). Therefore, this study conducts a bibliometric performance analysis to identify trends, developments, and the most relevant and high-impact scientific authors, papers, sources, institutions, and countries. In addition, it uses scientific mapping to construct networks to capture conceptual, social, and intellectual patterns. Thus, this study provides insight into the direction and prioritization that academic research has taken through existing relationships revealed by past studies.

This study also presents a content analysis of the literature. It adopts a longitudinal method to analyze the relationships between authors' keywords, mapping them in clusters. On the basis of the conceptual structure, this study identifies the following four clusters: (1) the impact of AI-based technologies on entrepreneurship; (2) AI-based technologies and entrepreneurial business model innovation; (3) AI-based technologies and context; and (4) innovation and disruptive digital technologies.

A key goal of a review article is to identify research gaps by analyzing commonly used constructs, theories, and methods across various contexts and guiding future research with innovative ideas and questions (Kraus et al. 2022b, 2024). To ensure

the depth of the analysis, this study adopts the antecedents, decisions, and outcomes (ADO) and the theories, contexts, and methods (TCM) frameworks (Kraus et al. 2022b) to synthesize existing knowledge in the field, and it highlights key research gaps identified in the reviewed literature and proposed by the authors.

Entrepreneurship is an activity that involves the discovery of new venture ideas, evaluations, and the exploitation of opportunities (Shane and Venkataraman 2000). Entrepreneurial practice is crucial because it drives economic growth, creates employment opportunities, fosters innovation (Obschonka and Audretsch 2020a) and plays a crucial role in the development of society by addressing social issues (Wang et al. 2023c). Given rapid technological advancements and global market shifts, the ability of entrepreneurs to adapt and leverage new technologies has become increasingly vital. This comprehensive review highlights the potential and risks of AI-based technologies to revolutionize how entrepreneurs operate, innovate, and compete. The ability of AI to improve decision-making, reduce costs, and accelerate business model innovation cycles can significantly reduce the barriers to entry for start-ups, making entrepreneurship more accessible and inclusive. However, with a few notable exceptions, most academic research on the subject has been superficial. Several topics, such as the long-term impact on workforce dynamics and creativity, ethical considerations and social impact, innovation ecosystems and collaborative networks, and the impact on each stage of the entrepreneurial process, raise critical questions about the future of human-centered innovation and the role of entrepreneurs in an AI-dominated ecosystem. Further research is crucial for developing strategies that leverage the benefits of AI while preserving the entrepreneurial responsibility that drives innovation and long-term economic growth. Furthermore, this vision invites policymakers, educators, and business leaders to consider how to prepare the next generation of entrepreneurs for a future in which AI tools are integral to entrepreneurial success. In this respect, this review not only highlights the transformative potential of AI in entrepreneurship but also calls for a balanced approach to its adoption.

This study makes significant contributions to the literature on AI and entrepreneurship from both the methodological and theoretical perspectives. Methodologically, it employs a hybrid systematic review approach, combining bibliometric analysis with qualitative content analysis, and applies the SPAR-4-SLR protocol to ensure transparency and reproducibility. This study broadens the coverage of published research by using the Scopus database, expanding the review period, and utilizing modern software tools. Theoretically, the study presents a comprehensive and timely literature review, mapping the existing knowledge and research clusters on AI-based technologies, highlighting theoretical concepts, and revealing connections between them. It identifies the main research streams and emerging elements, such as ethics, natural language processing, and big data. Finally, this study proposes future research directions based on the ADO-TCM framework, emphasizing the importance of AI-based technologies in entrepreneurial practice.

2 Theoretical foundation

2.1 Artificial intelligence-based technologies in entrepreneurship practice

Entrepreneurship is an activity that involves the discovery of new venture ideas, evaluations, and the exploitation of opportunities (Shane and Venkataraman 2000). It involves identifying opportunities, taking risks, and mobilizing resources to bring innovative ideas or products to the market. Entrepreneurial practice is crucial because it drives economic growth, creates employment opportunities, and fosters innovation (Obschonka and Audretsch 2020a). Moreover, entrepreneurial practice plays a crucial role in the development of society by addressing social issues (Wang et al. 2023c). Entrepreneurs must constantly adapt to market conditions, customer preferences and emerging technologies. This adaptability enables them to remain competitive in the face of emerging trends and challenges. The latest of these challenges is artificial intelligence. Entrepreneurs can leverage AI technologies to improve their entrepreneurial operations, automate processes, and collect and analyze data to make better decisions and create innovative solutions (Obschonka and Audretsch 2020a). With the integration of AI, entrepreneurs can develop advanced technologies and solutions with the potential to disrupt industries and create new markets. In addition, AI can enable entrepreneurs to identify trends and opportunities, personalize customer experiences, and optimize supply chains (Giuggioli and Pellegrini 2023).

Scholars in multiple fields have different views on what AI is and how to standardize AI concepts that integrate with technological development (Bahoo et al. 2023). For example, artificial intelligence (AI) has been defined by the Dartmouth Research Project as the problem of "making a machine behave in ways that would be termed intelligent if a human being behaved like this" (McCarthy et al. 1955). Recently, other definitions have stated that AI is "intelligence demonstrated by machines—or, in terms of an academic field (typically seen as a sub-discipline of computer science), the examination of how digital computers and algorithms perform tasks and solve complex problems that would normally require (or exceed) human intelligence, reasoning, and prediction power needed to adapt to changing circumstances" (Obschonka and Audretsch 2020a, p. 540) and "a system's ability to interpret external data, to learn from such data, and to use those learnings to achieve specific goals and tasks through flexible adaptation" (Kaplan and Haenlein 2020, p. 40). On the basis of this conceptual diversity, Bahoo et al. (2023) conceptualized artificial intelligence technologies as artifacts made with AI methods (e.g., machine learning, deep learning, natural language processing), AI industry applications (e.g., Industry 4.0, robotics), and AI systems and software (e.g., automation, Internet of Things) used to achieve practical goals. This study adopts this conceptualization, as it enables a broader scope of discussion and encompasses different related concepts. AI-based technologies are linked to each other; for example, machine learning is frequently categorized as a subset of AI, with deep learning considered a subset of machine learning (Obschonka and Audretsch 2020a).

2.2 Theoretical grounds for the review

The importance of AI and entrepreneurship as a topic is reflected in three recent reviews. First, Giuggioli and Pellegrini (2023) analyze 60 studies up to 2020 to explore AI's impact on entrepreneurship, resulting in the "AI-enabled entrepreneurial process" framework. Their key findings highlight AI's multifaceted benefits. Specifically, AI fosters the creation of new business opportunities, enhances decision-making by improving the quality and efficiency of decisions, boosts firm performance through better operational practices, and supports entrepreneurial education and research. The study provides a structured framework that offers valuable guidance for researchers and entrepreneurs aiming to integrate AI into their ventures, highlighting AI's significant and positive role across various phases of entrepreneurship. The study is entirely qualitative and lacks the quantitative validation found in studies that include bibliometric analysis, which limits the ability to analyze trends or measure the impact of specific publications. Although the framework is well structured, its main objective is to understand existing studies; thus, it does not provide a comprehensive research agenda. Second, Li et al. (2022) present a bibliometric analysis of AI in entrepreneurial management, reviewing 123 WoS papers published up to early 2021. Their findings identify four key research clusters: AI promoting industrial transformation, AI applications in entrepreneurial management, AI algorithms for business management, and the impact of e-commerce on SMEs. The review also maps existing research up to the date of the study. Furthermore, it adopts a philosophical theoretical perspective, emphasizing the need for ontological, epistemological and methodological considerations in future research. Although the study provides valuable insights into the transformative potential of AI in entrepreneurial management, it is limited in scope by its methodology and the database used. Moreover, it lacks the depth and contextual understanding that qualitative or mixed studies provide. Finally, Blanco-González-Tejero et al. (2023) provide bibliometrics on AI and entrepreneurship. Their study maps the evolution and development of key topics within the field, highlighting AI's interdisciplinary nature and transformative potential in entrepreneurial contexts. Advanced bibliometric and semantic analysis techniques provide a solid quantitative basis. However, the study is descriptive and does not present an analysis, conclusions, or proposals for future research.

Therefore, despite these efforts, several gaps remain in the methodological and theoretical perspectives applied to understand the growing interest of entrepreneurs in adopting AI-based technologies. In recent years, AI technologies have become significantly more accessible to entrepreneurs, driven by advances such as generative AI and revolutionary tools such as ChatGPT (Michael et al. 2023). These developments have garnered media attention, highlighting the transformative potential of AI. AI tools are now more affordable and easier to use, enabling smaller businesses and startups to automate tasks, improve decision-making and innovate effectively (Upadhyay et al. 2022). This accessibility has enabled entrepreneurs to scale their operations and develop new products and services (Michael et al. 2023). The recent pandemic, coupled with these technological advances, has accelerated digital transformation across industries. AI has played a key role in helping businesses adapt to changing market conditions and customer behaviors. In addition, cultural and genera-

tional shifts toward digitization have increased the adoption of AI tools in everyday entrepreneurial practices (Truong et al. 2023). The growing interest in AI, fueled by these factors, is also expected to attract increased attention from the scientific community, which will impact both the quantity and quality of research. This development leads to the first research question, which aims to explore the dynamism and relevance of the field.

RQ1. What is the evolutionary trend of publications of AI-based technologies focused on the practice of entrepreneurship?

Different theories of knowledge transfer, such as diffusion of innovation (Rogers 2010), knowledge transfer theory (Argote and Ingram 2000) and social network theory (Granovetter 1973), support the need to reconcile knowledge to understand and identify gaps that facilitate knowledge transfer from research to practice. A rigorous review of past findings using a robust organizational pattern can enable the reconciliation of fragmented bodies of literature. This collation is indispensable for two reasons: (1) it avoids duplication of research efforts, and (2) it significantly advances research in the chosen domain (Öztürk et al. 2024; Sauer and Seuring 2023). On the one hand, journal editors, policymakers and researchers can compare their productivity in the field. In addition, collaborative networks foster knowledge sharing and lead to more innovative research with greater impact. In this way, it is possible to identify structural gaps to foster research on AI technologies in entrepreneurship practice. On the other hand, the organization of up-to-date topics is crucial for advancing the discipline (Kraus et al. 2022b, 2024). These gaps facilitate the connection of dots, revealing existing relationships through past studies and providing insight into the direction and prioritization of academic research. This reasoning leads to the following research questions:

- RQ2. What are the top journals, countries, articles, authors, and institutions in research on AI-based technologies in the practice of entrepreneurship?
- RQ3. What are the knowledge clusters in the intellectual structure of AI-based technologies in the practice of entrepreneurship?

A key goal of a review article is to identify research gaps by analyzing commonly used constructs, theories, and methods across various contexts, guiding future research with innovative ideas and questions (Kraus et al. 2022b, 2024; Snyder 2019). The most popular literature review type is domain based and is classified into framework-based, theme-based, bibliometric, hybrid, and conceptual SLRs. Framework-based SLRs, known for their impact, use structured frameworks to highlight research gaps and integrate diverse literature streams, offering broad coverage and clarity (Lim et al. 2022). This observation leads to the following research question:

RQ4. What opportunities exist for future research on AI-based technologies in the practice of entrepreneurship?

Through these research questions and on the basis of a hybrid literature review, this study explores the dynamism and relevance of AI-based technologies in entrepreneurship; maps the intellectual, social, and conceptual structures that underpin this evolving field; and synthesizes existing knowledge, including research gaps, through a structured framework (ADO-TCM). A hybrid literature review combines

qualitative and quantitative approaches, offering a more comprehensive understanding of the topic. Its key advantage is that it covers a broader range of sources and perspectives by integrating empirical studies with theoretical research. This method enhances the validity of findings through data triangulation, comparing different methodologies and results. It also helps identify emerging patterns and trends while encouraging critical reflection on underlying concepts. Particularly useful in multidisciplinary or evolving fields, a hybrid review balances depth and breadth, providing a more robust and diverse analysis than a single-method approach. Therefore, this study makes significant methodological and theoretical contributions to mapping entrepreneurs' growing interest in adopting AI-based technologies.

3 Methodology

To improve the understanding of a topic and inform future research, review papers identify and critically evaluate fragmented literature, adopting approaches ranging from more qualitative to more quantitative (Pedroletti and Ciabuschi 2023). Therefore, to answer the research questions, this paper adopts two complementary techniques. On the one hand, this study conducts a bibliometric analysis that makes it possible to identify the research trends that influence the academic debate on entrepreneurship and AI-based technologies (AIE). On the other hand, this study adopts the antecedents, decisions, and outcomes (ADO) framework and the theories, contexts, and methods (TCM) framework. Framework-based SLRs synthesize existing knowledge in the field and include key research gaps identified in the systematic literature reviewed and proposed by authors. The present review can be classified as a hybrid systematic literature review that adopts mixed methods (Kraus et al. 2022b). In the academic literature, this approach has been used in many social science areas, such as management, business, and entrepreneurship (e.g., Alshater et al. 2023; Baier-Fuentes et al. 2020; Bhukya and Paul 2023; Osrof et al. 2023; Uriarte et al. 2024; Vishwakarma et al. 2023).

Academic bibliometric analysis is an objective quantitative tool that enables the evaluation of the development of a specific subject through the application of statistical and mathematical methods to many documents recognized and validated by the scientific community (Uriarte et al. 2024). Bibliometric analyses identify developments and trends, as well as the most relevant scientific actors, documents, sources, institutions, and countries with the greatest impact on a specific topic; these analyses are characterized by their accuracy, reliability and verifiability (Alshater et al. 2023). Bibliometric analysis has been used to quantitatively explore knowledge anatomy through two main methods: performance analysis and scientific mapping.

Performance analysis can provide a comprehensive analysis of the performance of units of study, such as papers, authors, countries, journals, and affiliations (Donthu et al. 2021). As in other related research (Baier-Fuentes et al. 2019; Forliano et al. 2021; Gaviria-Marin et al. 2019; Lim et al. 2022; Uriarte et al. 2024), this study applies two performance analysis techniques, namely, productivity analysis and influence analysis. It uses the first to determine the productivity of the units of analysis on the basis of the total number of publications (TPs). This study uses the second to evaluate the

impact and influence of the units of analysis on the basis of the total number of citations (TCs). Additionally, it uses the h-index (H), which is considered a measure of impact in the research community since it measures productivity in terms of the number of publications and citations (Gutiérrez-Salcedo et al. 2017). The analysis also considers indicators such as the average number of citations per paper (ACs), citation thresholds ($\geq 100; \geq 50; \geq 25; \geq 5$), publications in a given period, and the number of papers published in each quartile according to the SCImago Journal & Country Rank (Q1, Q2, Q3, and Q4).

Researchers use scientific mapping to construct networks to capture hidden patterns in a particular field of knowledge's conceptual, social, and intellectual structure (Donthu et al. 2021). While several techniques exist for scientific mapping, the most frequently used methods are co-occurrence analysis and co-citation analysis (Forliano et al. 2021; Lim et al. 2022; Uriarte et al. 2024). This study uses the Louvain clustering algorithm to perform these analyses. This algorithm is a greedy optimization method that identifies communities in large networks by comparing the link density within communities with links between communities (Blondel et al. 2008). To capture the conceptual structures, i.e., the links that can emerge between different concepts or words, this study identifies co-occurrences from the fifty most frequent keywords proposed by authors. This study performs two co-authorship analyses to capture the social structure. The first approach uses authors, whereas the second approach uses countries as the unit of analysis. To examine the intellectual structure, this study uses a co-citation network (Gutiérrez-Salcedo et al. 2017) for the fifty most cited articles in the papers of the field under study.

Moreover, this study presents a content analysis of entrepreneurship and artificial intelligence research. Content analysis is a research method that allows a systematic literature review analysis of collected qualitative data to extract and generalize noteworthy results and findings related to the knowledge structure of a certain field (Alshater et al. 2023; Donthu et al. 2021). This aim is achieved by analyzing the relationships between authors' keywords and displaying them in a co-occurrence analysis map.

Finally, a reliable literature review adopts a consistent and replicable protocol. This study adheres to the Scientific Procedures and Rationale for Systematic Reviews of the Literature (SPAR-4-SLR) guidelines to conduct this review. Unlike other available alternatives, such as the Preferred Reporting Items for Systematic Reviews (PRISMA), this protocol is designed explicitly for the social sciences (Tsiotsou and Boukis 2022), where entrepreneurial research resides. More importantly, adopting a review protocol is the best practice for systematic literature reviews because the protocol promotes transparency and replication of review findings (Lim et al. 2022; Uriarte et al. 2024). The SPAR-4-SLR protocol stipulates that a systematic literature review consists of three stages: *assembling*, *arranging*, and *assessing* scholarly literature (Lim et al. 2022; Uriarte et al. 2024). Figure 1 shows all the definitions of these stages. The following sections explain the main definitions.

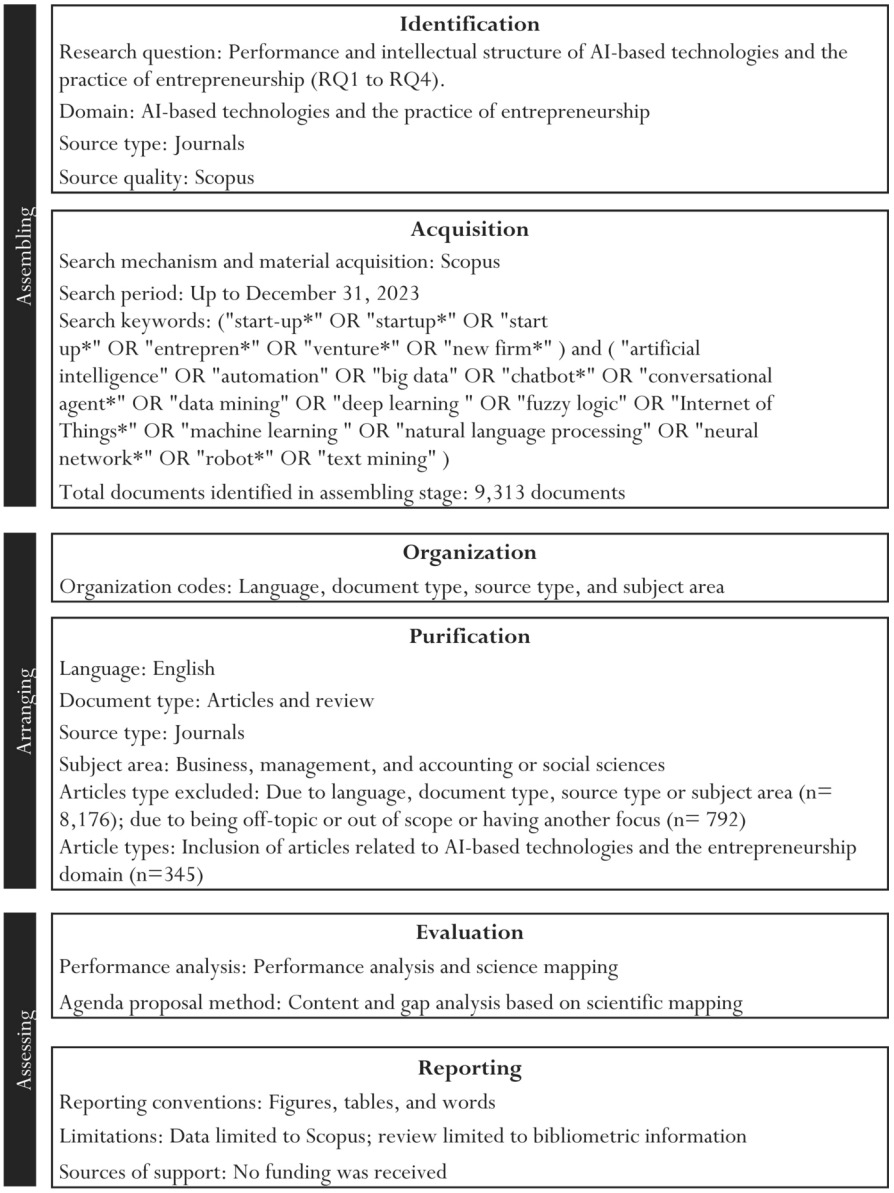

Fig. 1 SPAR-4-SLR protocol

3.1 Assembling

This study focuses on journals because journal publications represent completed research that has undergone rigorous peer review. It does not consider other sources, such as books, conference papers, commentaries, and editorials, as they do not usually receive the same level of scrutiny as conceptual, empirical, and review papers

published in journals do (Baier-Fuentes et al. 2020). This study uses Scopus as the measure of source quality. Scopus is one of the most important databases in the scientific community, offering the same analytical tools as other frequently used databases, such as the Web of Science (WoS) (Baier-Fuentes et al. 2019; Uriarte et al. 2024). In fact, this study cross-referenced all the papers in the WoS and Scopus databases that included the word "entrepreneurship" and found 91% of the WoS papers in Scopus.[2]

The search period is limited to December 31, 2023, the most recent period at the time this paper was prepared. The search keywords related to AI-based technologies and entrepreneurship are accompanied by an asterisk to account for potential variations in these terms, and the search terms are entered in the "title, abstract and keywords" search bar as follows: ("start-up*" OR "startup*" OR "start up*" OR "entrepren*" OR "venture*" OR "new firm*") and "artificial intelligence" OR "automation" OR "big data" OR "chatbot*" OR "conversational agent*" OR "data mining" OR "deep learning " OR "fuzzy logic" OR "Internet of Things*" OR "machine learning " OR "natural language processing" OR "neural network*" OR "robot*" OR "text mining"). The assembling stage yielded 9313 articles.

3.2 Arranging

This study includes only "papers and reviews" written in "English" and published in "journals" in the areas of "business, management and accounting" or "social sciences", which are the umbrella disciplines in Scopus that cover entrepreneurship and business research. This protocol substage resulted in the inclusion of 1137 publications and the exclusion of 8176 publications. The contributions retrieved were then filtered on the basis of three exclusion criteria: (i) no direct relationship with the study topic (i.e., contributions that do not address AI-based technologies or entrepreneurship); (ii) no direct relationship with the scope of this research (i.e., irrelevant reports that do not address AI-based technologies or entrepreneurship); and (iii) no direct relationship with the study focus (i.e., records that do not address the practice of entrepreneurship or AI-based technologies). The authors independently reviewed the titles, abstracts, and keywords of the collected articles and eliminated those that fit into any of the three specified categories. Following this independent filtering process, the authors collectively decided to exclude 792 articles. The final dataset comprises 345 relevant and significant contributions.

3.3 Assessing

This study uses Microsoft Excel and Stata 15 to analyze performance and outline trends in publications, as well as the top journals, articles, authors, countries, and institutions in the field. Additionally, it uses the bibliometrix package for R to help

[2] To conduct this cross-check, this study downloaded, exported, and cleaned all duplicate or incomplete references from all historical data in both the WoS (35,747) and Scopus (53,063) databases that included the word "entrepreneurship" in the abstract, title, or keywords in all areas up to June 2023. This study then cross-referenced the databases using the DOI indicator and the title of the paper (24,447). Subsequently, using the DOI, this study queried the Scopus database for all the papers that were not found in the previous search (8,105). The total number of papers found in both databases was 32,552.

perform science mapping through a collaboration network between authors and countries, keyword co-occurrence analysis, and co-citation analysis.

4 Results of the bibliometric analysis

4.1 Performance of artificial intelligence and entrepreneurship

4.1.1 Publication trends of artificial intelligence and entrepreneurship (RQ1)

Figure 2 presents the trends of total publications (TPs) and total accumulated citations (TCs) on the topic of AI-based technologies and the practice of entrepreneurship (AIE) from 1992 to 2023. The first relevant studies were published in the early 1990s in the journal Small Business Economics. In particular, Segers (1992) studied whether a relationship can be established between strategic technology policy—which is aimed primarily at the diffusion of new technologies—and new technology-based startups in Belgium.

From this starting point until 2018, which this study designates the initial phase, the number of papers increased slowly, relying mainly on case studies (e.g., Kanet et al. 1999) and addressing the field under study through a tangential approach (e.g., Lau et al. 2004; Wang and Swanson 2007). Since 2016, the field has developed progressively, with studies focused on the potential and impact of technologies such as automation (Sorgner 2017), the Internet of Things (e.g., Krotov 2017; Yu et al. 2016), big data (Hartmann et al. 2016), and machine learning (e.g., Shams 2018) for entrepreneurs. In this phase, this study highlights the research of Makridakis (2017), who was the first to call this phenomenon the AI revolution and to compare it to industrial and digital revolutions, addressing the potential changes that could affect life, society and entrepreneurship.

The following years (2019–2021), which this study designates the development phase, launched research on the relationship between artificial intelligence-based technologies and entrepreneurship in different contexts, with an average of 47 papers per year concerning, for example, the financial (e.g., Jakšič and Marinč 2019), health-

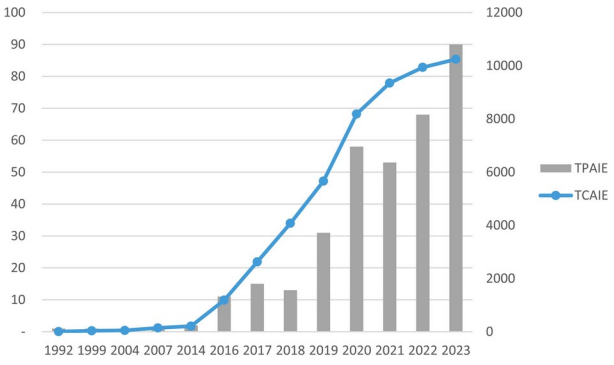

Fig. 2 Evolution of publications and cumulative citations by year

care (e.g., Wang et al. 2021) or tourism (e.g., Mariani 2020) industries; geographic contexts such as China (Liu and Bell 2019), the European Union (e.g., Meys 2020) or the U.S. (e.g., Obschonka et al. 2020b); and pandemic contexts (e.g., Polas and Raju 2021).

The years since 2022, which this study calls the growth phase, account for approximately half of the publications on this topic. In this phase, the discussion has deepened, and other technologies or related topics have become relevant. These topics include ethics (Duke 2022), sustainability (e.g., Govindan 2022; Wang et al. 2023c), blockchain (e.g., Böhmecke-Schwafert and García Moreno 2023) and natural language processing (Dale 2023; Hu et al. 2023; Wang et al. 2023b).

Another way to analyze the literature's growth and influence on this research topic is by considering the general citation structure of the publications, as presented in Table 1. The table orders publications by year, total number of publications, and citations received by the papers published that year. Additionally, the table includes the number of papers published in each quartile according to the SCImago Journal & Country Rank. During the last few years, the average number of publications has more than doubled, but the average number of citations per publication has decreased. However, owing to the categorization by quartiles, this study sees considerable variations and improvements in the quality of research. For example, in the development phase, the average number of publications in first quartile journals (Q1) was 51%, whereas in the growth phase, it was more than 61%.

4.1.2 Top journals for artificial intelligence and entrepreneurship research (RQ2)

As previously mentioned, articles on the intersection of artificial intelligence and entrepreneurship are published in a wide range of journals. Table 2 shows the classification of the 30 most influential and productive journals in the AIE field. Notably, the most prolific journal for entrepreneurship and artificial intelligence research is Technological Forecasting and Social Change, with 19 articles representing 5.5% of the articles published on this topic. Other journals with a prestigious reputation that merit mention due to their history of publishing AIE papers, with over 100 citations, include the International Journal of Production Economics, the Journal of Business Research, Small Business Economics, and the International Journal of Operations and Production Management.

Another important issue indicated in Table 2 is the progress of AIE research in these journals over time. To illustrate this trend, this study groups the papers published in these journals into the three periods defined above (i.e., 1988–2018, 2019–2021, and 2022–2023). Overall, the results confirm that AIE research has recently become a topic of interest. In fact, the last six years have been very productive, and nearly all of the most important journals have published at least one article associated with this field of research.

The results show that only a few journals started their publication in the initial phase (T0). This study highlights Information and Organization and BioSocieties as the pioneer journals in this field. For example, Information and Organization published the article "Launching professional services automation: Institutional entrepreneurship for information technology innovations", which was the first paper to

Table 1 Structure of research topic citations

Year	TPAIE	TCAIE	HAIE	%PAIE	ACP	≥5	≥25	≥50	≥100	Q1	Q2	Q3	Q4
1992	1	6	1	0.3	6	1				1			
1999	1	30	1	0.3	30		1			1			
2004	1	13	1	0.3	13	1				1			
2007	1	95	1	0.3	95			1		1			
2014	2	66	2	0.6	33		2			2			
2016	11	979	10	3.2	89	2	2	3	3	9		1	1
2017	15	1.437	9	4.3	96	4		1	5	11		2	2
2018	13	1.451	10	3.8	112	5	2	2	3	5	4	2	1
2019	31	1.586	18	9.0	51	10	8	6	4	14	7	5	4
2020	58	2.521	25	16.8	43	18	11	6	7	29	13	7	4
2021	53	1.165	35	15.4	22	25	7	3	2	30	15	5	2
2022	68	589	13	19.7	9	23	6	1		41	17	9	1
2023	90	304	11	26.1	3	17				55	23	7	5

Source: Authors' elaboration based on Scopus 2023

TCAIE, TPAIE, and HAIE = total citations, total papers and h-index in the AIE field, respectively; ACP = average citations per paper; %PAIE = percentage of papers compared to the total of papers in the HAIE field; ≥5, ≥25, ≥50, and ≥100 = number of papers with more than 5, 25, 50, and 100 citations, respectively; Q1, Q2, Q3, and Q4 = journal category in the year in which the article was published

study how interested actors termed institutional entrepreneurs develop institutional arrangements to launch an IT innovation for widespread adoption (Wang and Swanson 2007). BioSocieties published "Data for life: Wearable technology and the design of self-care", which explored the vision of technologically assisted self-regulation that drives the design of wearable tracking technology (Schüll 2016).

Regarding the development phase, this study highlights the International Journal of Production Economics, the Journal of Business Research, and Small Business Economics. Relevant publications from these journals are concentrated in this phase. Importantly, this phase started to diversify the research scope and deepen the discussion to include, for example, big data (e.g., Caputo et al. 2020; Obschonka et al. 2020b), the Internet of Things (e.g., Haaker et al. 2021) and automation (e.g., Tortorella et al. 2021).

As noted above, the growth phase is the most productive period in the AIE field. For example, Technological Forecasting and Social Change had the most publications during this period. Among the main topics addressed in this journal are sustainability (e.g., Böhmecke-Schwafert and García Moreno 2023; Gupta et al. 2023) and artificial intelligence-based technologies in the entrepreneurial process (e.g., Jabeur et al. 2022; Wang et al. 2023a).

4.1.3 Top authors in artificial intelligence and entrepreneurship research (RQ2)

A total of 1002 authors have contributed to the development of this research topic. The five authors with the most citations, reflecting the influence of AIE authors, are Makridakis S., Li L., Gatti C., Aquilani B., and Passiante G. However, except for Passiante G., these authors have concentrated on a single research topic and have not contributed to subsequent research. In terms of productivity, the top author is Gupta B., with five publications. Gupta's work on AIE is rooted in artificial intelligence-based technologies for sustainable entrepreneurship. His work is followed by that of Wincent J., Chen Y., Ge B., Lammers T., Panigrahi P., and Gaurav A., who have three publications each. Notably, these authors have a low average number of citations per publication. One reason is that their research has been conducted mainly over the last two years. However, all these authors have published their papers in first-quartile journals, according to the SCImago Journal & Country Rank. Thus, an increase in citations could be expected in the coming years. Finally, authors often collaborate and contribute to other research areas; thus, this study presents these contributions at a general level. The indicators show that several prominent authors have impacted science in general. These include Dwivedi and Yogesh K., with more than 43,000 citations and 604 papers (Table 3).

4.1.4 Top countries for artificial intelligence and entrepreneurship research (RQ2)

Authors from 62 countries are represented in the AIE articles included in the review corpus. Table 4 presents the 20 most prolific countries by total citations. The data clearly show that the U.S. is the leading country in all dimensions. The United States is the most influential and productive country, with 3089 citations and 72 papers, respectively. These results are reasonable considering the size of the country and its

Table 2 Top journals

R	Journal	TCAIE	TPAIE	HAIE	ACP	≥5	≥25	≥50	≥100	T2	T1	T0	SJR	H	TC	TP
1	Technol. Forecast. Soc. Change	1.641	19	12	86	9	3	2	4	9	8	2	2,1	340	224.985	7.309
2	Futures	704	1	1	704				1			1	1,2	105	72.339	4.322
3	J. Bus. Res	606	13	9	47	4	1	4	1	6	7		2,3	260	465.116	9.913
4	Sustainability	531	13	6	41	4	2	1	1	4	7	2	0,6	158	775.923	72.715
5	Small Bus. Econ	404	12	9	34	4	3	2	1	4	7	1	2,1	164	130.490	2.600
6	Int J Prod Econ	399	4	4	100		3		1		3	1	2,0	449	383.142	7.719
7	Int J Prod Res	281	2	2	141			1	1		2		1,9	195	383.452	12.481
8	Int. J. Oper. Prod. Manage	262	1	1	262				1			1	2,3	163	132.563	2.101
9	Rev. Financ. Stud	257	1	1	257				1		1		12,8	234	231.568	2.297
10	BioSocieties	255	1	1	255				1			1	0,8	32	6.268	437
11	Decis Support Syst	229	3	3	76		2		1		2	1	1,6	177	188.583	3.674
12	J. Intellect. Cap	226	1	1	226				1		1		1,3	106	47.951	937
13	Int. J. Logist. Manage	210	1	1	210				1			1	0,9	64	16.246	658
14	Internet Res	205	4	4	51	1		3				4	1,6	109	54.201	1.578
15	J. Prod. Innovation Manage	172	1	1	172				1			1	3,0	167	113.453	1.434
16	Cities	161	1	1	161				1			1	1,1	126	115.378	4.359
17	Sociol. Ruralis	155	1	1	155				1			1	0,7	100	43.033	1.483
18	J. Enterprising Communities	128	2	1	64				1	1	1		0,6	59	4.913	496
19	Bus. Horiz	126	2	2	63	1			1			2	1,2	126	98.409	4.536
20	Calif. Manage. Rev	123	1	1	123				1		1		2,8	1.812	141.038	1.824
21	J. Bus. Ventur. Insights	120	7	5	17	3	2			3	4		1,6	33	5.744	415
22	Risk Manage	111	1	1	111				1		1		0,3	228	1.959	238
23	Entrep. Theory Pract	108	2	2	54				1	1	1		3,8	189	127.194	1.112
24	Int. Entrep. Manage. J	103	7	5	15	4	1			3	2	2	1,3	76	26.439	896
25	Inf. Organ	95	1	1	95			1				1	1,5	70	17.251	347
26	Int. J. Entrep. Behav. Res	91	10	5	9	4	1			10			0,9	135	22.809	957
27	Entrep. Sustain. Issues	89	3	3	30	2		1			3			67	8.657	662
28	Facilities	86	1	1	86			1				1	0,5	55	19.628	2.208

Table 2 (continued)

R	Journal	TCAIE	TPAIE	HAIE	ACP	≥5	≥25	≥50	≥100	T2	T1	T0	SJR	H	TC	TP
29	J. Strat. Manag	85	2	2	43	1		1		1	1		0,6	30	4.819	444
30	Eur. J. Innov. Manage	83	1	1	83			1			1		0,7	156	30.513	1.052

R=Ranking; TCAIE, TPAIE, and HAIE=total citations, total papers and h-index in the AIE field, respectively; ACP=average citations per paper; ≥5, ≥25, ≥50, and ≥100=number of papers with more than 5, 25, 50, and 100 citations, respectively; T2 (2022–2023), T1 (2019–2021), T0 (<=2018)=number of papers in each period; SJR=SCImago Journal rank measures—Scopus 2022; H=h-index of journal; TC and TP=total citations and total papers of the journal, respectively, from SCImago Journal rank

Table 3 Top authors, ordered by the total number of publications

R	Name	TCAIE	TPAIE	HAIE	ACP	T2	T1	T0	TC	TP	H	Q1	Q2	Q3	Q4
1	Gupta, Brij B	38	5	4	8	4	1		21.876	656	77	3	1	1	
2	Wincent, Joakim	173	3	3	58		3		8.284	181	49	3			
3	Lammers, Thorsten	33	3	3	11	1	2		173	23	8	3			
4	Chen, Yong	31	3	3	10	2		1	2.388	81	28	3			
5	Panigrahi, Prabin Kumar	29	3	3	10	3			292	33	7	2		1	
6	Ge, Baoshan	29	3	2	10	2		1	585	17	10	3			
7	Gaurav, Akshat	25	3	2	8	3			311	50	11	2		1	
8	Costa-Climent, Ricardo	2	3	1	1	3			200	12	7	3			
9	Haftor, Darek M	2	3	1	1	3			483	47	10	3			
10	Passiante, Giuseppina	414	2	2	207		2		2.795	82	29	2			
11	Popkova, Elena G	237	2	2	119		2		7.173	371	46	1	1		
12	Sergi, Bruno S	237	2	2	119		2		4.613	243	69	1	1		
13	Obschonka, Martin	160	2	2	80		2		4.950	101	39	2			
14	Parida, Vinit	132	2	2	66		2		12.824	190	59	2			
15	Vrontis, Demetris	130	2	2	65	1	1		9.149	409	46	1	1		
16	Yu, Xiaoyu	126	2	2	63			2	1.603	56	23	2			
17	Nguyen, Bang	126	2	2	63			2	5.631	186	44	2			
18	Mariani, Marcello M	123	2	2	62		2		4.193	109	35	2			
19	Saura, Jose Ramon	111	2	2	56	1	1		3.565	107	35	1	1		
20	Sorgner, Alina	98	2	2	49		1	1	824	34	18	1		1	
21	Momtaz, Paul P	57	2	2	29	1	1		632	27	29	2			
22	Upadhyay, Nitin	46	2	2	23	2			360	35	8	2			
23	Upadhyay, Shalini	46	2	2	23	2			152	27	6	2			
24	Dwivedi, Yogesh K	46	2	2	23	2			43.524	604	109	2			
25	Brem, Alexander	43	2	2	22	1	1		7.430	298	48	2			
26	Battisti, Sandro	43	2	2	22	1	1		168	16	6	2			
27	Wang, Zeyu	24	2	1	12	2			230	35	8	2			
28	Deng, Yue	24	2	1	12	2			38	11	3	2			

Table 3 (continued)

R	Name	TCAIE	TPAIE	HAIE	ACP	T2	T1	T0	TC	TP	H	Q1	Q2	Q3	Q4
29	Cetindamar, Dilek	23	2	2	12		2		680	81	12	2			
30	Kulkov, Ignat	11	2	1	6	2			122	19	5	2			

R = ranking; TCAIE, TPAIE, and HAIE = total citations, total papers and h-index in the AIE field, respectively; ACP = average citations per paper; T2 (2022–2023), T1 (2019–2021), T0 (<= 2018) = number of papers in each period; TC and TP = total citations and total papers received by each author (includes papers in other research fields), respectively; H = h-index of each author (includes publications in other research fields); Q1, Q2, Q3, and Q4 = journal ranking in the year in which the article was published

Table 4 Top countries

R	Country	TCAIE	TPAIE	HAIE	ACP	≥100	≥50	≥25	≥5	T2	T1	T0	Q1	Q2	Q3	Q4
1	United States	3.089	72	24	43	8	4	12	23	31	31	10	54	7	7	3
2	Italy	2.037	36	19	57	5	5	4	13	12	21	3	24	8	4	
3	United Kingdom	1.582	38	19	42	4	4	7	12	19	17	2	30	5	2	
4	Germany	1.016	26	16	39	2	2	8	9	9	13	4	20	3	2	
5	China	958	46	16	21	2	4	3	13	27	11	8	32	10	2	1
6	Australia	900	23	16	39	3	3	5	8	5	15	3	19	3		1
7	Cyprus	841	5	4	168	1	2			3	1	1	3	2		
8	Russia	619	12	9	52	2	1	2	4	4	8		6	3		2
9	France	443	16	7	28	1		2	7	9	5	2	12	4		
10	Netherlands	431	13	10	33		4	2	6	1	8	4	11		1	
11	Spain	360	15	7	24	1	1	1	6	8	5	2	11	1	2	
12	India	337	28	8	12	1	1	1	7	20	7	1	9	11	5	3
13	Georgia	318	6	4	53	1		1	2	2	3	1	5		1	
14	Austria	297	3	3	99	1			2	2	1		3			
15	Finland	252	10	7	25	1		2	4	5	5		9	1		
16	Switzerland	227	6	4	38	1		2	1	2	4		5	1		
17	Sweden	225	11	6	20	1		1	4	5	5	1	10		1	
18	Hong Kong	213	6	4	36	1		1	2	3	1	2	6			
19	Portugal	186	8	5	23		1	3	1	5	2	1	3	2	3	
20	Slovenia	111	1	1	111	1					1				1	

R = ranking; TCAIE, TPAIE, HAIE, and ACAIE = total citations, total papers, h-index and average citations in the AIE field, respectively; ≥100, ≥50, ≥25, and ≥5 = number of papers with more than 100, 50, 25, and 5 citations, respectively; T2 (2022–2023), T1 (2019–2021), T0 (<=2018) = number of papers in each period; Q1, Q2, Q3, and Q4 = journal ranking in the year in which the article was published

high investment in research and development (R&D). The countries that follow the U.S. in terms of influence are Italy, the United Kingdom, China, Germany, and Australia. Europe leads in influence, with 8627 citations, and productivity, with 200 articles. Research on this topic has also been conducted in Asian countries, with China, Russia, Georgia, and Hong Kong among the top 20 countries. However, Asia's average number of citations per publication is much lower than that of other regions. Latin American and African countries do not appear in the rankings.

When the temporal evolution of publications per country is analyzed, the Netherlands and Hong Kong are prominent in the initial phase; Australia and Russia are prominent in the development phase; and China, Cyprus, Spain, India, Austria, and Portugal are prominent in the growth phase. The latter countries have produced more than half of their publications in the last two years.

Another insightful aspect is the productivity of countries in more impactful journals. Notably, Australia, the Netherlands, Georgia, Austria, Finland and Hong Kong published more than 80% of their papers in first-quartile journals, according to the SCImago Journal & Country Rank. In contrast, countries such as Portugal, India and Russia account for less than 50% of the papers published in first-quartile journals.

4.1.5 Top institutions for artificial intelligence and entrepreneurship research (RQ2)

The top institutions for AI-based technologies and entrepreneurship research are presented in Table 5. The table indicates that Jilin University in China has contributed the most papers and is thus highly relevant; moreover, all of these publications are in Q1 journals. Asia University, the Università degli Studi di Torino, the University of St. Gallen, and Symbiosis International (Deemed University) follow Jilin University. Another insight is that several institutions have recently begun publishing articles. Indeed, three institutions—the University of Petroleum and Energy Studies, Lebanese American University, and Uppsala Universitet—have published articles only in the last two years. Another leading institution is the Università del Salento, which accounts for the highest number of citations.

4.1.6 Top articles on artificial intelligence and entrepreneurship research (RQ2)

Another noteworthy aspect is the most influential publications on this research topic, i.e., those that have received the most citations. The number of citations reflects the popularity and influence of each paper in the scientific community (Baier-Fuentes et al. 2019). Table 6 presents the thirty most cited papers on the research topic.

As previously mentioned, Makridakis (2017) is the most cited paper in the field. "The forthcoming artificial intelligence (AI) revolution: Its impact on society and firms" was published in Future and has 704 citations. Notably, among the most cited papers are several conceptual investigations that also examine the potential of AI for entrepreneurship (e.g., Elia et al. 2020; Obschonka and Audretsch 2020a; Rippa and Secundo 2019). Other recurring subjects among the most cited papers are Industry 4.0 (e.g., Hahn 2020; Li 2018) and big data (e.g., Dubey et al. 2020; Hartmann et al. 2016).

Table 5 Top institutions

R	Organization Name	TPAIE	TCAIE	HAIE	Q1	Q2	Q3	Q4	≥5	≥25	≥50	≥100	T2	T1	T0	TP	TC	H
1	Jilin University	7	98	7	7				2		1		5		2	2.451	28.176	271
2	Asia University	5	38	5	3	1	1		3				4	1		1.169	26.565	450
3	Università degli Studi di Torino	5	80	5	3	2			5				1	4		5.215	78.743	824
4	University of St. Gallen	5	225	5	5				1	2		1	1	4		2.854	119.876	5.049
5	Symbiosis International (Deemed University)	5	32	4	3	1	1		2				4	1		1.778	19.171	846
6	University of Petroleum and Energy Studies	5	33	1	3		2		2				5			692	5.682	10
7	University of Technology Sydney	4	33	3	3			1	3				1	3		8.862	133.883	687
8	HSE University	4	254	4	3			1	2	1		1	1	3		5.527	38.563	2.661
9	Lebanese American University	4	30	4	3		1		2				4			1.247	19.464	430
10	University of Cambridge	4	294	3	3		1		2			1	1	2	1	22.694	235.420	1.440
11	Università del Salento	4	608	4	3	1			1		1	2		4		1.452	29.681	1.751
12	Luleå University of Technology	4	197	4	4				2	1		1		3	1	2.361	62.247	1.384
13	Uppsala Universitet	3	2	2	3								3			7.980	116.941	483
14	Vaasan Yliopisto	3	139	3	3				2			1	1	2		1.768	48.832	1.610
15	The Royal Institute of Technology KTH	3	50	3	2		1		3					2	1	4.283	124.863	2.938

R = ranking; TPAIE, TCAIE and HAIE = total papers, total citations and h-index in the AIE field, respectively; ACP = average citations per paper from each university in the AIE field; Q1, Q2, Q3, and Q4 = journal ranking in the year in which the article was published; ≥5, ≥25, ≥50, and ≥100 = number of papers with more than 5, 25, 50, and 100 citations, respectively; T2 (2022–2023), T1 (2019–2021), T0 (<=2018) number of papers in each period; TC, TP and H = total citations, total papers and h-index of the university, respectively

4.2 Science mapping (RQ3)

4.2.1 Intellectual structure

The intellectual structure of an academic field can be revealed through a co-citation network (Gutiérrez-Salcedo et al. 2017). Notably, co-citation analysis is performed not on the papers in the field but on the references cited by them, and the relationship between references is determined by the number of times they are cited together (Contreras Cruz et al. 2022). Here, this study connects the 50 most cited papers through the application of Louvain's clustering algorithm. The results are presented in Fig. 3. According to the figure, four clusters can be distinguished. The blue cluster includes the most prominent and notable authors in entrepreneurial research, such as Barney, Teece, Eisenhardt, Schumpeter and Sarasvathy. The red cluster includes the most influential authors on digital technologies and innovations, principally Von Briel, Nambisan, McMullen and Schwab. The green cluster contains the most influential authors on the relationship between entrepreneurship and AI-based technologies, such as Garbuio, Obschonka and Zhang. Finally, the purple cluster contains the most influential authors on business model research, such as Osterwalder, Teece, Foss and Massa.

4.2.2 Social structure

To illustrate the social structure of an academic field, this study constructs a collaboration network between authors and a country network. Figure 4 shows that there are 12 clusters among the 50 most influential authors, and it presents many authors as isolated nodes. However, these nodes do not mean that these authors do not collaborate. In fact, the average number of authors is 2.9, and only 19% of the publications are by single authors. Furthermore, there is a high level of collaboration among authors from developed economies, such as the United Kingdom, the United States, and European countries. The collaboration rate is represented by more robust lines in Fig. 5, where the darker the country is, the more productive it is. In addition, except for China and India, collaboration among authors from developing countries is scarce.

4.2.3 Conceptual structure

Conceptual structure analysis makes it possible to highlight the connections between the same terms that appear in a specific collection, i.e., co-occurrences. In this study, this study identifies co-occurrences among the keywords proposed by authors. Specifically, it connects the 50 most frequent keywords through the application of the Louvain clustering algorithm (Blondel et al. 2008). The results are presented in Fig. 6. The more co-occurrences there are identified, the closer to the center the words appear in the network map. The more keywords that are used simultaneously by authors, the larger the bubble and the greater their proximity is, resulting in closer and stronger links. The network map shows clusters of different colors (Forliano et

Table 6 Top articles

R	Title	Authors	Year	Journal	TCIAE	C/Y
1	The forthcoming Artificial Intelligence (AI) revolution: Its impact on society and firms	Makridakis S.	2017	Futures	704	117
2	China's manufacturing locus in 2025: With a comparison of "Made-in-China 2025" and "Industry 4.0"	Li L.	2018	Technol. Forecast. Soc. Change	609	122
3	Digital entrepreneurship ecosystem: How digital technologies and collective intelligence are reshaping the entrepreneurial process	Elia G.; Margherita A.; Passiante G.	2020	Technol. Forecast. Soc. Change	360	120
4	Industry 4.0 in management studies: A systematic literature review	Piccarozzi M.; Aquilani B.; Gatti C.	2018	Sustainability	335	67
5	Big data analytics and artificial intelligence pathway to operational performance under the effects of entrepreneurial orientation and environmental dynamism: A study of manufacturing organisations	Dubey R.; Gunasekaran A.; Childe S.J.; Bryde D.J.; Giannakis M.; Foropon C.; Roubaud D.; Hazen B.T.	2020	Int J Prod Econ	284	95
6	Capturing value from big data – a taxonomy of data-driven business models used by start-up firms	Hartmann P.M.; Zaki M.; Feldmann N.; Neely A.	2016	Int. J. Oper. Prod. Manage.	262	37
7	How Valuable Is FinTech Innovation?	Chen M.A.; Wu Q.; Yang B.	2019	Rev. Financ. Stud.	257	64
8	Data for life: Wearable technology and the design of self-care	Schüll N.D.	2016	BioSocieties	255	36
9	Human capital and AI in industry 4.0. Convergence and divergence in social entrepreneurship in Russia	Popkova E.G.; Sergi B.S.	2020	TEC	226	75
10	Understanding the determinants of big data analytics (BDA) adoption in logistics and supply chain management: An empirical investigation	Lai Y.; Sun H.; Ren J.	2018	Int. J. Logist. Manage.	210	42
11	Exploring the impact of big data analytics capabilities on business model innovation: The mediating role of entrepreneurial orientation	Ciampi F.; Demi S.; Magrini A.; Marzi G.; Papa A.	2021	J. Bus. Res.	205	103
12	Industry 4.0: a supply chain innovation perspective	Hahn G.J.	2020	Int J Prod Res	203	68
13	Digital academic entrepreneurship: The potential of digital technologies on academic entrepreneurship	Rippa P.; Secundo G.	2019	Technol. Forecast. Soc. Change	187	47
14	Data-Driven Business Model Innovation	Soresecu A.	2017	J. Prod. Innovation Manage.	172	29
15	A model for the analysis of data-driven innovation and value generation in smart cities' ecosystems	Abella A.; Ortiz-de-Urbina-Criado M.; De-Pablos-Heredero C.	2017	Cities	161	27

R= Ranking; TCIAE = Total citation of article; C/Y = Citations per year indicator.

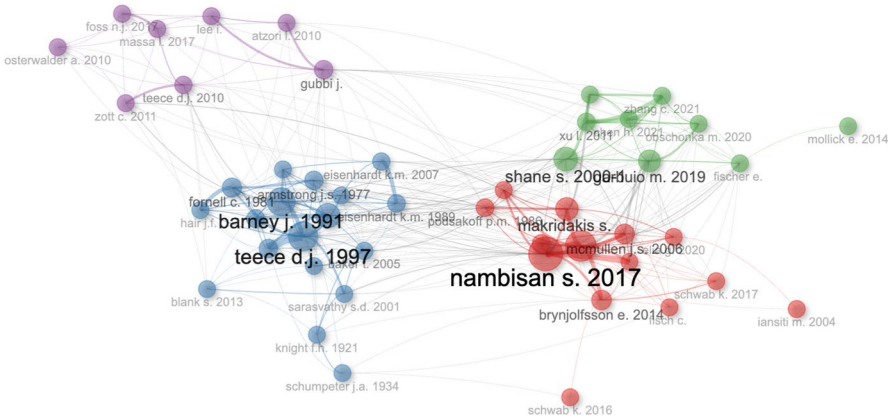

Fig. 3 Co-citation network

al. 2021). According to the figure, four clusters can be distinguished. This study discusses each of these clusters in more detail in the following section.

5 Content analysis

Content analysis extracts concepts into fewer content-related themes to reveal clusters with the same meaning and to obtain a condensed representation of a particular knowledge domain (Alshater et al. 2023). This study identifies clusters via the co-citation analysis performed on the references shown in Fig. 3 and the author keyword co-occurrence analysis map shown in Fig. 6. As a result of this quali-quantitative analysis, four clusters emerge: (1) the impact of AI-based technologies on entrepreneurship; (2) AI-based technologies and entrepreneurial business model innovation;

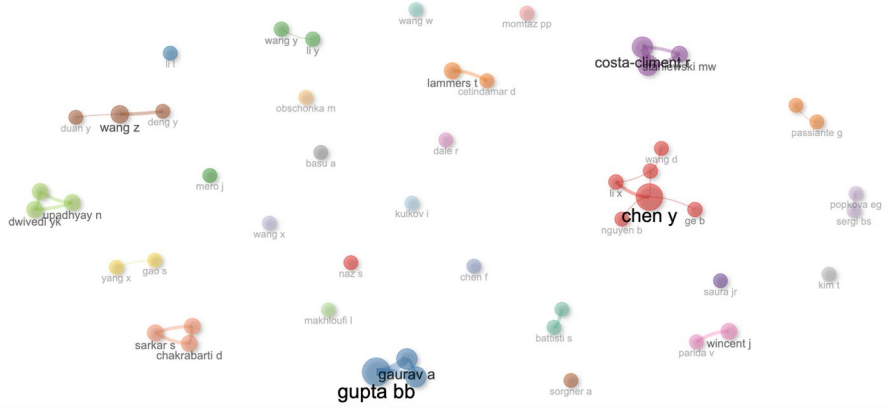

Fig. 4 Author collaboration network

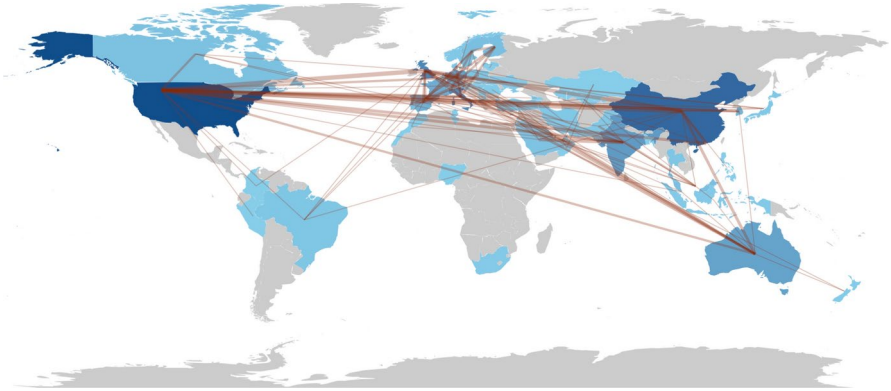

Fig. 5 Collaboration between countries based on author affiliations

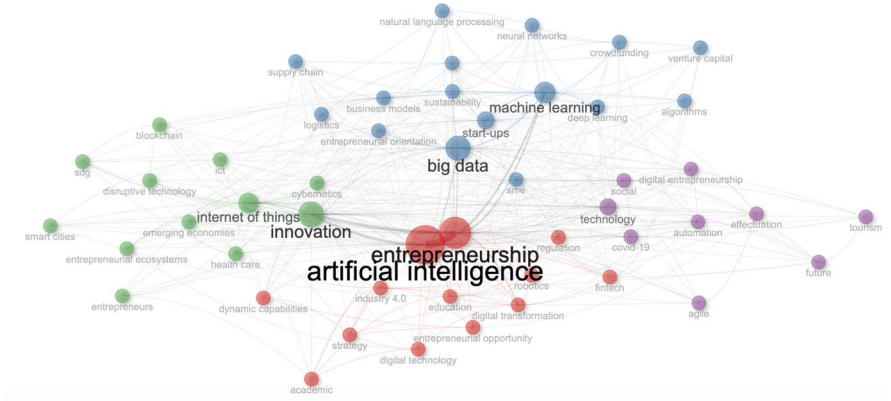

Fig. 6 Author keyword co-occurrence analysis map

(3) AI-based technologies and context; and (4) innovation and disruptive digital technologies.

5.1 Cluster 1: the impact of AI-based technologies on entrepreneurship

Artificial intelligence-based technologies are triggering profound changes in business dynamics in virtually every industry. In the financial industry, robots (and chatbots) are becoming more common, generating significant efficiencies in customer interactions. Similarly, FinTech startups have a profound effect on business models (Jakšič and Marinč 2019; Palmié et al. 2020). However, there are potential risks if the technology is not regulated effectively. In particular, ethical considerations such as discrimination or transparency could affect customer trust (Lui and Lamb 2018). Similarly, in real estate, technologies such as blockchain have pressured the industry to innovate (Veuger 2018).

In addition to promoting the application of artificial intelligence-based technologies, the Industry 4.0 revolution and digital transformation are impacting business and organizational processes. Specifically, they are pushing established businesses to rethink the dynamic and organizational capabilities that support their strategies (Ge and Zhao 2022; Lee et al. 2022). For example, according to Ives et al. (2019), 100% of automated self-service stores opened by Amazon in Seattle, OR, USA, in 2018 boasted disruptive business strategy formats based on digital technology and AI, which can potentially threaten three industries: the convenience store, grocery store, and fast food industries. However, recent evidence shows that adopting AI by businesses and other complementary technologies significantly and positively affects business economic performance (Lee et al. 2022). This evidence suggests the need for new models of strategic entrepreneurial management and dynamic capability development that can foster the survival and development of new enterprises in the context of AI (Ge and Zhao 2022).

In the academic–educational field, training in science, technology, engineering, and mathematics among adolescents and young people has become highly relevant because it may encourage entrepreneurial behaviors. There is preliminary evidence that entrepreneurial training programs that incorporate technologies have a direct positive effect on students' entrepreneurship intentions (Rippa and Secundo 2019; Sedkaoui 2018; Shahin et al. 2021). The importance and urgency of incorporating these new skills and competencies in the academic training of young people are a consequence of the fourth industrial revolution and the digital transformation that all types of companies and organizations—small or large—are undergoing in most countries worldwide (Chatterjee et al. 2022; Fossen and Sorgner 2021).

The impact is also noted in the entrepreneurial process. Recent studies related to the impact of AI on entrepreneurship have proposed that access to and understanding additional new information will impact the detection of opportunities. Existing entrepreneurs could improve, adapt, or create new businesses. Moreover, AI could influence entrepreneurship decisions through the advantages offered by the digital format of entrepreneurship (Elia et al. 2020; Sedkaoui 2018).

5.2 Cluster 2: AI-based technologies and entrepreneurial business model innovation

The emergence of AI-based technologies has created the greatest entrepreneurial opportunity in the history of civilization (Iansiti and Lakhani 2020), enabling radical changes or innovations in business models. Most definitions suggest that a business model articulates how a firm creates value for its customers and how it appropriates this value. Business model innovation is "a change in the value creation, value appropriation, or value delivery function of a firm that results in a significant change to the firm's value proposition" (Sorescu 2017, p. 692). Therefore, several researchers have focused on the application of AI technologies such as the IoT, robotics, automation, and machine learning tools through big data (Iansiti and Lakhani 2020) to leverage internal and external data and innovate products and processes (Sorescu 2017).

Although data-driven entrepreneurship is not a new concept, startups have only recently begun to create new products using data sources such as social networks, smartphones, or sensors (Hartmann et al. 2016). Hartmann et al. (2016) identified six data-driven business models that startups use. These include a free data collector and aggregator, analytics as a service, data generation and analysis, free data knowledge discovery, data aggregation as a service, and multisource data mash-up and analysis.

As noted above, innovation in the entrepreneurial business model does not necessarily refer to product innovation only; it can also be related to process innovation. Among these processes, this study highlights the supply chain—product production and delivery to final consumers—logistics, marketing, and decision-making (Lai et al. 2018). Indeed, Hahn (2020) noted that whereas established companies adopt AI technologies to maintain their business architectures, startups radically change their operating models, relying heavily on data analytics and platform economics. For example, digitalization has disruptively changed food distributor models. E-commerce models and the IoT are essential in helping retailers innovate their business models (Nosratabadi et al. 2020).

AI-based technologies and big data can be sources of competitive advantage and catalysts for successful business models (Sorescu 2017). However, a business model reflects entrepreneurs' hypothesis "about what customers want, how they want it, and how the enterprise can organize to best meet those needs, get paid for doing so, and make a profit" (Teece 2010, p. 172). Therefore, one challenging task for startups is to validate their business model (Dellermann et al. 2019). For example, Wang et al. (2023c) constructed, evaluated and analyzed a recommendation and resource optimization model based on neural network algorithms for entrepreneurial projects. Moreover, Dellermann et al. (2019) proposed design principles for a hybrid intelligence decision support system, i.e., combining the complementary capabilities of human and machine intelligence, for business model validation. Another challenging task is financing the entrepreneurial business model. Here, this study highlights research on the application of machine learning techniques to provide equity investors with new insights into common patterns of successful startups (e.g., Ferrati and Muffatto 2021) or AI approaches to determine success variables and predict the outcomes of a crowdfunding campaign (e.g., Kaminski and Hopp 2020).

5.3 Cluster 3: AI-based technologies and context

The literature, especially recent research, shows that it is impossible to dissociate the emergence of AI-based technologies from diverse social and organizational contexts. For example, the development of technologies has played a fundamental role in improving the capacity to manage epidemic outbreaks in recent decades, when innovation has been vital (Budd et al. 2020). On the one hand, during the COVID-19 pandemic, AI-based technologies played a key role, as they were adapted to help control infection outbreaks or effectively detect possible cases of contagion. For example, Wang et al. (2021) analyzed technological entrepreneurship in developing countries through the use of a robotics-based device that enhanced telemedicine, helped reduce infection rates among medical personnel and improved pandemic management in healthcare facilities. On the other hand, as a result of the COVID-19 pandemic, all levels of education have sought to implement remote teaching through digital technologies, thus advancing digital learning (Guppy et al. 2022), including entrepreneurship education (Ratten 2020). In addition to the impact on how educational services are offered, the education being provided has been affected. For example, Xu et al. (2022) identified new curricula for the tourism and hospitality industry and provided evidence that future professionals should be prepared to use technologies based on AI, virtual reality, or big data, as well as entrepreneurship and innovation.

In an organizational context, adopting artificial intelligence (AI) or the IoT enables companies to efficiently manage and control production processes remotely and synchronously (Le et al. 2019). On the one hand, business agility is critical for adopting emerging advanced technologies and efficiently achieving productivity and performance levels. Sreenivasan et al. (2023) reported that adopting AI or cloud computing drives the operational agility of new firms in increasingly dynamic environments. However, organizational agility from technology adoption is a significant challenge for nondigitally native companies (Grover 2022). On the other hand, automation—a type of corporate entrepreneurship—is seen as distinct from the automation that revolutionized industries in the 1990s. In many cases, current automation is based on the adoption of much more advanced digital technologies, which enable companies to improve the effectiveness and efficiency of their processes (Hiebl and Pielsticker 2023). However, while the digital automation strategy is making companies more competitive, it is causing stress for certain types of employees at risk of losing their jobs (Schulz 2022).

Emerging from the intersection of the social, organizational, and digitalization contexts are concepts related to entrepreneurship, such as digital entrepreneurship and effectuation. Digital entrepreneurship can take forms such as intraentrepreneurship or entirely new entrepreneurial initiatives. In this context, the advent of advanced digital technologies is propelling the creation of new business models and the transformation of traditional models into online business formats, thus digitizing part or all of a company's processes or operations (Upadhyay et al. 2022). As Nambisan et al. (2017) highlight, these technologies promote business processes that are less time bound. In other words, advanced digital technologies facilitate the quicker formation, implementation, modification, or even re-creation of new products or service ideas. Moreover, the opportunities and operational scope that these initiatives can offer

to society or industry are noteworthy (Guo et al. 2016). A clear example is recent health sector innovations, where entrepreneurs have developed new approaches such as teleconsultation, challenging traditional practices in the well-established medical industry. These initiatives can be understood through the framework of effectuation (Sarasvathy 2001), a logic of entrepreneurial decision-making based on the use of available means or resources, such as digital technologies (Guo et al. 2016). Hence, digital entrepreneurs or intrapreneurs employing effectual tactics use digital resources at their disposal, reducing investment costs and tapping into larger markets with lower transaction costs, reflecting the principles of effectuation.

5.4 Cluster 4: Innovation and disruptive digital technologies

This cluster comprises research that emphasizes and connects concepts of innovation and the Internet of Things (IoT) with additional concepts associated with technological fields.

The literature concentrating on more traditional theories of innovation identifies it as a crucial catalyst for countries' economic development (Pessoa 2010). However, these theories have since evolved, with researchers now highlighting that innovation driven by digital technologies has the most significant impact. Indeed, certain researchers contend that traditional innovation theories become obsolete if they fail to incorporate digital technologies (Hinings et al. 2018). The vast array of contemporary technologies, many of which are highly potent, fundamentally alter the operations of numerous industries and institutions. This effect has prompted scholars such as Nambisan et al. (2017) to call upon the scientific community to develop theories on managing innovation that consider the dynamic nature of the modern digital world. Numerous studies have demonstrated that advanced digital technologies foster new forms of innovation, such as digital innovation (Felicetti et al. 2024), leading to enhanced productivity, expanded business activities, and more extensive economic and social benefits (Hahn 2020). One example is the Internet of Things (IoT), which is a disruptive, high-powered technology that operates based on data collected from numerous interconnected devices. This technology is spearheading diverse innovations across various sectors, including manufacturing and even more traditional industries such as healthcare (Krotov 2017). Currently, through the use of smartphones, the IoT, and robotics, citizens can readily access healthcare services (Wang et al. 2021). Other technologies, such as platform technologies, are also facilitating the rise of platform- or app-based entrepreneurs. Such technologies enable new work methods that redefine the boundaries of industries and sectors, exemplified by digital transportation platforms such as Uber (Palmié et al. 2020). The implications of such digital advancements also lead to government regulations and policy modifications that aim to impact and incentivize, for example, access to and usage of digital technologies among various societal actors and to cultivate a digital environment conducive to regional economic development (Nambisan et al. 2019).

In fact, under the smart city paradigm, several governments are advocating for the implementation of new information and communication technologies (ICTs) along with the IoT in urban contexts. This integration can enable the handling of large data volumes for timely decision-making (Yu et al. 2016), thereby enhancing the

utilization of public resources, increasing the quality of government services, and improving the well-being of citizens (Alam and Siddiqui 2023). The most advanced smart cities integrate blockchain technologies, offering transparency and immutability in transaction records (Chen and Pena-Mora 2018). This integration enables the establishment of common platforms that connect with other city services, thereby enhancing societal benefits and fostering a more transparent environment for growth. Smart cities are a prime example of how incorporating and complementing disruptive technologies, such as the IoT and blockchain, can increase efficiency and more effectively address issues stemming from population growth, thus facilitating economic and social development (Kummitha and Crutzen 2019).

6 Research framework and future avenues for AI-based technologies in entrepreneurial practice (RQ4)

This section presents an integrative and extended framework based on the content analysis and bibliometrics above. An organizing framework is necessary to highlight the various contributions of the literature to the theory developed in the area. The framework helps to inform the findings effectively, provides rigor and relevance, and facilitates the impact of the review (Lim et al. 2021). Considering the fragmented literature and the need for discussions on the factors responsible for adopting AI-based technologies in entrepreneurship practice, this study uses the extended framework. Thus, this framework synthesizes existing knowledge in the field and highlights key research gaps identified in the literature reviewed and proposed by authors. This study adopted the ADO-TCM framework, as illustrated in Fig. 7.

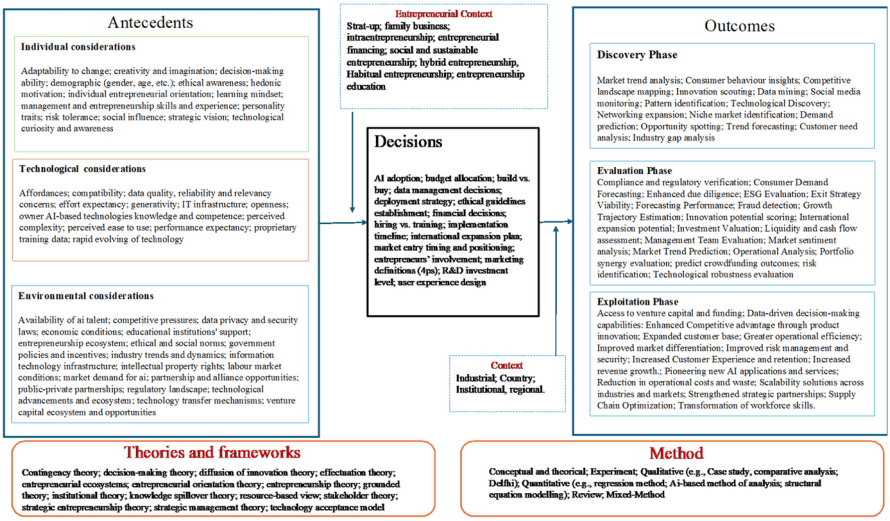

Fig. 7 TCM-ADO framework

6.1 Theories

Theories guide research, providing direction for solving research problems, integrating constructs and variables through propositions, and connecting variables through hypothesis testing. According to this study, only some publications have used sound theoretical foundations or research frameworks, as shown in Table 7. This review revealed 40 theories or frameworks in 107 of the 345 papers analyzed (28%). These results indicate a breadth of theories in the literature but a lack of depth in most research.

The sheer number of theories indicates that an abundance of theories can be considered and applied in future research. Entrepreneurial orientation was the most popular theory. This finding is not surprising, as this theory is one of the most widely used in the entrepreneurship literature. More specifically, research has used this theory mainly to study individual and entrepreneurship antecedents to the adoption of AI-based technologies (e.g., Dubey et al. 2020). It is followed by the business model framework. As noted above, several researchers have focused on the application of AI technologies for BMI (e.g., Liu and Bell 2019; Sorescu 2017). The other three theories used in research are the resource-based view, effectuation theory and diffusion of innovation theory. Fewer than five papers used the remaining theories. This situation highlights opportunities for future research. For example, well-established theories or frameworks such as the dynamic capabilities view, game theory, institutional theory, human capital theory or the technology adoption model are underutilized and may offer valuable insights into "how" and "why" entrepreneurs should use AI-based technologies.

6.2 Context

Context relates to the circumstances of an investigation. As noted above, most studies are from developed countries. This finding raises the following question: What fac-

Table 7 Top theories

Rank	Theory	TP
1	Entrepreneurial orientation theory	11
2	Business model	10
3	Resource-based view	7
4	Effectuation theory	6
5	Diffusion of innovation theory	4
6	Entrepreneurial ecosystems	4
7	Strategic management theory	4
8	Technology acceptance model	4
9	Grounded theory	3
10	Institutional theory	3
11	Knowledge spillover theory	3
12	Contingency theory	2
13	Stakeholder theory	2
14	Strategic entrepreneurship theory	2
	With other theories	25
	Without theory	265

tors hinder the inclusion of AI-based technologies in the practices of entrepreneurs in developing countries? Alternatively, how do entrepreneurial decisions on AI-based technologies differ between developed and developing countries or regions? Future studies can be conducted to understand and compare the cultural, institutional, and sociodemographic characteristics that influence the use of AI-based technologies in entrepreneurship practice.

In addition, the framework presents entrepreneurial contexts that may influence (moderate or mediate) entrepreneurs' decisions. Several researchers have studied the positive and negative impacts of AI-based technologies in the context of sustainable (e.g., Gupta et al. 2023) and social entrepreneurship (e.g., Popkova and Sergi 2020); the benefits and challenges associated with the application of AI-based technologies in entrepreneurship education (e.g., Vecchiarini and Somià 2023); or the role of risk capital in the entrepreneurial financing of ventures based on AI technologies (e..g., Wu et al. 2019). Other entrepreneurship contexts, such as intraentrepreneurship and habitual, hybrid, necessity, or opportunity entrepreneurship, can also create avenues for future research. Thus, some research questions related to the different entrepreneurial contexts could be as follows: How will AI-based technologies change the development of entrepreneurial skills in young people worldwide, both within and outside the STEM field? Considering national, cultural, and institutional differences, how do AI-based technologies influence entrepreneurial business model innovation in terms of both the product and the process? How can AI-based technologies be used to support entrepreneurial finance? What is the relationship between the different types of entrepreneurs (e.g., informal, hybrid, habitual) and AI-based technologies? How does venture capital address ethical issues in entrepreneurship stemming from the use of digital technologies such as artificial intelligence?

6.3 Method

Methodologies include methods and techniques deployed to investigate the research problem. Table 8 provides an overview of the methodologies and analysis methods used in the selected papers explicitly stated in the abstract. Researchers use all significant methodologies, namely, conceptual, qualitative, quantitative, experimental, review, and mixed methodologies. As observed, high participation in conceptual research indicates that the intellectual environment is still defining its fundamental principles and concepts. This research trend suggests that scholars are trying to establish a solid theoretical basis for future empirical research. In addition, many studies are oriented toward presenting the potential of AI-based technologies rather than empirically studying their adoption and implementation.

Moreover, the field shows a beneficial engagement with qualitative and quantitative methods, which is indicative of a multifaceted research approach that values rich, narrative-driven insights as much as the clarity of numerical data. Among qualitative studies, case studies dominate as the primary analysis method (e.g., Wang and Swanson 2007). In quantitative studies, regression analyses such as logistic or linear regressions (e.g., Jabeur et al. 2022), structural equation models (e.g., Chatterjee et al. 2022) and AI-based methods such as neural networks or machine learning algorithms (e.g., Arshi et al. 2022) are employed. This balance suggests recognition within the

Table 8 Top methodologies

Methodology*	TP
Conceptual/theoretical model	77
Conceptual	77
Experiment	22
Experiment	19
Quasi-experiments	1
A/B Testing	1
Mixed method	3
Mixed method	10
Qualitative data analysis	83
Case study	33
Other qualitative data analyses	31
Qualitative comparative analysis	6
Content analysis	5
Thematic analysis	3
Delphi	3
Ethnographic	2
Quantitative data analysis	111
AI-based method of analysis	19
Regression method	15
Structural equation modeling	13
Other quantitative data analyses	47
Random forest	6
Sentiment analysis	5
T test	3
Descriptive analysis	3
Review	17
Literature review	9
Bibliometric	8

*Studies that clearly indicate their methodology in the abstract are included. Quantitative and qualitative studies without detailed data analysis are classified as "other quantitative data analyses" and "other qualitative data analyses", respectively

research community of the complex and layered intersection of AI and entrepreneurship, where qualitative subtleties and quantitative robustness are integral to an overall understanding. The nonsignificant number of related literature reviews (e.g., Gupta et al. 2023) underscores an ongoing effort to aggregate and distill existing knowledge. This work is crucial for identifying gaps in the current literature, connecting disparate studies, and building a foundation for new research.

However, the reduced use of experimental methods raises questions about how current research can test and validate theories in controlled settings. Similarly, the low proportion of mixed methods research offers fertile ground for future studies. Integrating qualitative and quantitative methods in studies could yield more in-depth findings that reflect the complexity of real-world entrepreneurial scenarios involving AI.

6.4 Antecedents

Antecedents are events, conditions, and causes that engage (or disengage) with decision processes and affect outcomes (Lim et al. 2021). In this study, the identified

antecedents can be classified into individual, technological, and environmental considerations, as shown in Fig. 7.

Individual considerations refer to an entrepreneur's personality and background regarding sociodemographics, perception, attitude, behavior, motivation, skills, and capacity (Osrof et al. 2023). The antecedents related to entrepreneurs' sociodemographic characteristics, experience, and education level have been studied as determinants of both decision-making and outcomes (e.g., Kim and You 2020). Other aspects, such as ethical awareness, personality traits, risk tolerance, social influence and hedonic motivations, play crucial roles in understanding the different apprehensions and motivations involved in adopting digital technologies (e.g., Obschonka et al. 2020b). Moreover, the skills required to engage in AI technology-based entrepreneurship, such as creativity and imagination, a learning mindset or a strategic vision, are important mechanisms for mitigating risk factors (e.g., Gofman and Jin 2023).

Technological antecedents are associated with technology in terms of features, functionality, performance, and expected benefits and risks (e.g., Osrof et al. 2023; Upadhyay et al. 2022). Upadhyay et al. (2022) studied different factors influencing the intention to adopt AI technologies for entrepreneurship. These factors include affordances, effort expectancy, generativity, openness, and performance expectancy. Moreover, aspects such as the IT infrastructure, the knowledge and competence of the owners of AI-based technologies, and data considerations are key to successful start-ups and fundraising (e.g., Gofman and Jin 2023).

Several external factors must be considered for entrepreneurs to adopt artificial intelligence (AI) systems. First, a deep understanding of the market demand for AI, the prevailing economic conditions and the competitive landscape is needed, which requires entrepreneurs to align their AI offerings with market needs and trends (e.g., Jabeur et al. 2022). In addition, consideration should be given to educational institutions and the broader entrepreneurial ecosystem to provide the necessary expertise and support for AI innovations (e.g., Vecchiarini and Somià 2023). Second, the regulatory and ethical ecosystem must be considered. Entrepreneurs must navigate the intricacies of data privacy, security laws, and ethical standards and ensure that their AI solutions meet legal requirements while addressing social and ethical concerns (e.g., Ustek-Spilda et al. 2019). Government policies and incentives also play crucial roles in the entrepreneurial process in AI, offering both opportunities and constraints (e.g., Kim and You 2020). Finally, available operational and strategic resources need to be considered. For example, the availability of skilled talent, the capacity of the ecosystem for knowledge transfer or a strong technology infrastructure in the region where the business will be developed is essential for the effective development, implementation and scaling up of AI technologies (e.g., Li 2018).

These antecedents prompt several research questions, such as how does volatility, uncertainty, complexity, and ambiguity affect entrepreneurship decisions in AI-based technologies? How does entrepreneurs' human capital influence decision-making when AI technologies are adopted by start-ups? What ethical considerations do entrepreneurs commonly face when deploying AI technologies, and how do they address them? How critical is the availability of skilled talent and regional capacity for knowledge transfer from AI-based technologies to entrepreneurship practices? Can AI-based technologies replace the creativity and imagination of entrepreneurs?

6.5 Decisions

An entrepreneur's most important decision concerns how to adopt AI-based technologies to facilitate entrepreneurship, whether in discovering, evaluating or exploiting an opportunity (Shane and Venkataraman 2000). Entrepreneurs must navigate a complex matrix of strategic and tactical decisions tied to this decision. Strategically, entrepreneurs must decide on the level of AI integration, the allocation of resources to R&D, and whether to build AI solutions internally or pursue them through partnerships (e.g., Huy et al. 2023). In addition, employers must weigh the advantages of expanding their teams or consulting with AI specialist owners versus educating or upskilling existing staff (e.g., Almansour 2023). Tactically, employers must decide, for example, on the formulation of data management systems, the selection of AI deployment strategies, the establishment of feasible implementation timelines and the design of user experiences that leverage AI strengths.

These considerations raise several research questions, such as the following: Are existing public policies shaping the ethical and responsible adoption of advanced technologies in the entrepreneurial realm, and what are the notable policy gaps that require attention? How do these policies differ in response to varying economic contexts? What budgetary implications and financial models best support AI integration in start-up environments, considering the constraints of limited capital? In what ways do build versus buy decisions impact the agility and innovation capacity of entrepreneurial ventures when implementing AI technologies? How do data management practices affect stakeholders' privacy and security concerns within the entrepreneurial financial ecosystem?

6.6 Outcomes

Artificial intelligence technologies can facilitate transformative outcomes in the entrepreneurial process, i.e., discovering, evaluating, and exploiting opportunities (Shane and Venkataraman 2000). In the discovery phase, entrepreneurs can apply AI-based technologies to obtain valuable insights for their start-up, which may or may not be a technology business. For example, entrepreneurs can analyze market trends and consumer behavior through data mining, extract insights from social media trends, and identify market niches, obtaining a detailed understanding of the demand landscape (e.g., Obschonka et al. 2020b). In addition, it is possible to map competition and identify innovative practices that provide a complete picture of industry dynamics and potential areas of exploitation for their entrepreneurial initiative. It is also possible to forecast demand and trends, which could allow entrepreneurs to anticipate changes in the industry (e.g., Böhmecke-Schwafert and García Moreno 2023; Jabeur et al. 2022). Therefore, in the discovery phase, AI-based technologies can support informed decision-making.

Integrating artificial intelligence (AI) in the evaluation phase can provide various benefits for entrepreneurship. Advanced AI algorithms can facilitate compliance and regulatory checks, enhancing the due diligence process and ensuring that entrepreneurship complies with legal and ethical standards. This application can be extended to ESG assessment, enabling a holistic view of a venture's environmental manage-

ment, social responsibility, and governance quality (e.g., Mansouri and Momtaz 2022). Moreover, AI-based technologies can assist in forecasting consumer demand, predicting market trends, assessing liquidity and cash flow, and detecting financial risks to support robust financial analysis and market viability (e.g., Lin et al. 2020). Similarly, AI-based technologies can help assess a start-up's capacity for innovation and international growth. This capability is critical for evaluating the scalability of entrepreneurship, guiding the formulation of exit strategies, and assessing the robustness of a firm's technology infrastructure (e.g., Ross et al. 2021). In crowdfunding scenarios, AI's predictive capabilities can be used to anticipate campaign outcomes and optimize fundraising strategies.

The use of AI-based technologies can offer entrepreneurs significant benefits in the exploitation phase of their entrepreneurship. Specifically, AI-driven insights can lead to more informed decision-making, increased efficiency and reduced costs (Kulkov et al. 2023). AI-based entrepreneurship innovations can generate a competitive advantage, leading to revenue growth. The potential to improve customer experiences through AI could translate into increased customer loyalty and retention (e.g., Ferràs et al. 2020). Moreover, entrepreneurs could attract more venture capital if they demonstrate that the integration of AI improves profitability and operational efficiency (e.g., Reshetnikova et al. 2019). AI could also cultivate workforce skills, optimize supply chains, and strengthen strategic partnerships, potentially enabling further growth and market expansion (e.g., Dubey et al. 2020).

These potential outcomes inspire several research questions, such as how changing entrepreneurial models based on AI technologies can influence individuals' growth expectations, internationalization, or venture valorization. Which AI-based technologies demonstrate the most effectiveness in improving entrepreneurial processes, and how do they affect entrepreneurial performance? To what extent do AI-driven insights into consumer behavior influence opportunity recognition in nontechnological businesses? How do entrepreneurs measure the outcomes of AI technology implementation in their business practices?

7 Discussion and limitations

7.1 Theoretical propositions

In this study, a hybrid literature review was conducted through a combination of different bibliometric and systematic literature analysis techniques, resulting in a description of the progress of the literature analyzed and the deepening of the field through content analysis and the subsequent proposal of a research framework based on the ADO-TCM framework. These analyses were conducted in response to the fragmentation of the literature and to generate the following theoretical propositions, which should be used to generate a cohesive and structured growth of the literature at the intersection of these fields of study.

Keyword co-occurrence analysis reveals the prominence of terms such as ‘innovation’, ‘internet of things’ and ‘disruptive technology’. These technologies enable companies to analyze data in real time, make decisions based on reliable data, and

automate and optimize processes. This approach increases business competitiveness and contributes to modernizing entrepreneurial ecosystems and promoting more connected and sustainable urban spaces.

Entrepreneurial ecosystems increasingly emphasize the interaction between technological innovations and the business environment. These ecosystems are characterized by collaboration between diverse entities, such as startups, corporations, government institutions and universities, which work in a coordinated manner to foster innovation and entrepreneurship (Baier-Fuentes et al. 2021). In this context, technology incubators and accelerators play a relevant role by facilitating access to advanced technological resources, collaborative networks and specialized knowledge that facilitate the integration of disruptive technologies such as AI. These entities act as catalysts that accelerate the development of innovative solutions and help entrepreneurs overcome initial barriers to implementing these technologies (Li 2018; Vecchiarini and Somià 2023). Therefore, technological factors and the dynamics of these ecosystems influence the adoption of disruptive AI-based technologies (Hartmann et al. 2016; Nosratabadi et al. 2020).

The ADO-TCM analysis reveals that, from the antecedent perspective, technological and environmental considerations significantly impact several entrepreneurial decisions related to implementing AI technologies. These decisions drive the creation of more efficient products and services and facilitate the adoption of more precise entrepreneurial practices aligned with market demands and societal expectations (Kummitha and Crutzen 2019; Le et al. 2019). For example, in healthcare, IoT integration has facilitated the development of telemedicine ecosystems that not only optimize patient care but also improve the efficiency of resource utilization, benefiting all stakeholders, including patients (Krotov 2017; Wang et al. 2021). Based on these arguments, the following proposition for future research is developed:

Proposition 1 *Integrating artificial intelligence technologies fosters innovation by transforming the dynamics of entrepreneurial ecosystems and specific sectors, generating key disruptive technological solutions for competitive business models.*

On the one hand, the co-occurrence analysis of keywords reveals key terms such as ‘big data’, ‘machine learning’, and ‘deep learning’. These technologies excel in implementing innovative processes, optimizing operations and creating added value by offering faster and more efficient solutions (Iansiti and Lakhani 2020). The ability of startups to integrate AI, especially data analytics, allows them to make more informed and agile decisions, which facilitates adjustments to their business models and improves their ability to respond to market demands (Hahn 2020; Mariani 2020).

On the other hand, according to the ADO-TCM analysis, advanced AI technologies directly influence the strategic decisions of startups (Dellermann et al. 2019). AI-related technological skills and knowledge are critical for deploying strategies and optimizing operational efficiency and entrepreneurial performance (Ciampi et al. 2021; Malyy et al. 2021). These capabilities enable entrepreneurship to survive in increasingly competitive and dynamic environments. For example, some startups in the e-commerce sector have implemented machine learning algorithms to optimize their inventories in real time, reduce logistics costs and thus improve their market

performance (Nosratabadi et al. 2020). Another relevant case involves startups that have oriented their operations toward environmental and social sustainability, incorporating advanced data analytics technologies to monitor their carbon footprints and propose innovative strategies to reduce their environmental impact (Govindan 2022).

Finally, the adoption of advanced AI technologies optimizes key logistics and supply chain management processes, generating sustainable competitive advantages. The combination of big data analytics, machine learning, and a profound understanding of market dynamics enables entrepreneurs to adapt and compete in their respective sectors, significantly impacting long-term sustainability and growth (Wang et al. 2023c). These arguments, therefore, underpin the following proposition for future research:

Proposition 2 *Adopting advanced AI technologies enables startups to redesign their business models, optimizing logistics processes and supply chains to generate sustainable competitive advantages.*

The terms revealed in the co-occurrence analysis of keywords such as 'entrepreneurship', 'artificial intelligence', and 'dynamic capabilities' reflect how digitalization and AI provide entrepreneurs with the skills to adapt quickly and to capitalize on opportunities (Brown 2017; Calderon-Monge and Ribeiro-Soriano 2024; Ge et al. 2016). For example, startups implementing AI solutions can analyze large volumes of data in real time. They can identify emerging trends and consumer behaviors that might otherwise go unnoticed. Doing so improves their responsiveness and enables them to anticipate market changes, a key aspect in today's volatile entrepreneurial environment.

As argued in the previous propositions, the ADO-TCM framework underlines the importance of individual and technological capabilities in entrepreneurial decisions. In this context, AI is a tool that reinforces responsiveness in uncertain scenarios (Raneri et al. 2022). For example, a local grocery shop could implement AI-based predictive analytics tools to identify consumption patterns in its community. This implementation would allow the shop to optimize its inventory based on local preferences and diversify its customer base. This approach demonstrates how advanced technologies can have practical applications even in more traditional entrepreneurship, which can establish a solid foundation to innovate and stay competitive in the market (Mero et al. 2020).

In addition, theories such as dynamic capabilities theory explain how entrepreneurs can integrate, build and reconfigure competencies to adapt to environmental opportunities and threats (Ciampi et al. 2021; Dubey et al. 2020). For example, in the education sector, some entrepreneurial educational entities have started to use AI-based technologies to develop personalized learning platforms that optimize resources and offer experiences tailored to the individual needs of students (Ratten and Jones 2021). These tools make it possible to analyze educational data in real time to identify areas for improvement and new business opportunities in a sector that demands constant innovation. The Platzi platforms in Latin America or Coursera in the United States are clear examples. This proactive and adaptive approach is funda-

mental for entrepreneurial success in the AI era. Therefore, the following is proposed for future research based on these arguments.

Proposition 3 *Artificial intelligence technologies enhance the dynamic capabilities of entrepreneurs, facilitating the identification of opportunities in environments characterized by high uncertainty and complexity.*

Digital technologies, such as AI, provide entrepreneurs with the capabilities to develop agile, adaptive initiatives oriented to emerging social needs. In the keyword co-occurrence analysis, the centrality and proximity of the terms 'technology', 'COVID-19', 'social', 'agile' and 'automation', among others, highlight how these technologies are transforming entrepreneurship and driving behaviors that are more flexible, proactive and aligned with the demands of a changing environment (Mero et al. 2022; Upadhyay et al. 2023). For example, during the COVID-19 pandemic, startups quickly adopted digital solutions, such as e-commerce platforms and home delivery services, enabling them to adapt to new market demands and thrive in an uncertain environment.

The ADO-TCM analysis supports this perspective by identifying how AI and digitalization reshape entrepreneurial practices. This analysis suggests that digital technologies enable entrepreneurs to adapt to the changing environment and respond more efficiently to emerging consumer needs (Liu and Bell 2019). From a theoretical perspective, effectuation theory (Sarasvathy 2001) highlights how entrepreneurs use available resources to adapt and create value in complex contexts. Instead of following a rigid plan based on causality, entrepreneurs must be flexible and be willing to pivot their strategies in accordance with emerging circumstances and opportunities (Lupp 2022). An example is implementing data analytics tools that allow entrepreneurs to identify consumer behavior patterns and adjust their offerings in real time. This rapid response capability is critical in an environment where consumer preferences can quickly change. These arguments, therefore, support the following proposition for future research.

Proposition 4 *Artificial intelligence allows entrepreneurs to develop effectual behaviors or initiatives that are agile, adaptive and oriented toward emerging social needs.*

7.2 Contributions

This study makes significant methodological, theoretical and practical contributions to mapping entrepreneurs' growing interest in adopting AI-based technologies.

From a methodological perspective, this study applies a hybrid approach to address the limitations of relying on either qualitative or quantitative methods, thereby ensuring a more nuanced and robust exploration of the topic. On the one hand, this study (i) broadens the coverage of published research by using a larger database, Scopus, rather than other databases such as WoS and expanding the period under review; (ii) applies a protocol that was explicitly designed for the social sciences (SPAR-4-SLR), which promotes the transparency and reproducibility of the review results; (iii) uses modern software such as the bibliometrix package in R, Rayyan and Stata 15; and

(iv) cross-references the data with the SCImago Journal & Country Rank database to determine the number of papers published in each quartile, which is a new measure of the quality of publications in performance analysis. On the other hand, this study responds to the call to increase the quality of review studies in business, management, and social sciences (e.g., Alshater et al. 2023; Donthu et al. 2021; Lim et al. 2022; Robledo et al. 2023; Uriarte et al. 2024).

From an applied theoretical perspective, first, this study presents a rigorous, complete, and opportune literature review of a fragmented research field. A rigorous review of research findings using a robust organizational pattern can help reconcile fragmented bodies of literature. Thus, this study identifies structural gaps to foster research on AI technologies in entrepreneurship practice. The trend analysis revealed significant growth in AI-focused entrepreneurial research, particularly from 2019 onward. This surge can be attributed to advancements in AI technologies and their increased accessibility, enabling entrepreneurs to scale operations and innovate efficiently. The number of publications has more than doubled in recent years, reflecting growing interest in and recognition of the transformative potential of AI in entrepreneurship. This trend highlights the increasing dynamism of the field and suggests a robust trajectory of continued research and development in the coming years.

The bibliometric analysis identified key contributors to the field, including influential journals, authors, institutions, and countries. The United States emerged as the leading country in terms of productivity and influence, with the highest number of publications and citations. Prominent journals such as Technological Forecasting and Social Change, the Journal of Business Research, and Small Business Economics have been pivotal in disseminating research on AI and entrepreneurship. Key authors such as Makridakis, Gupta, and Wincent have made substantial contributions. However, the field has low barriers to entry, few specialized authors, and limited collaboration with authors from developing countries. These results should encourage more scholars to consider contributing to the current debate, especially in collaboration with scholars from developing countries.

Second, this study presents the state of the field, highlights the theoretical concepts used, and reveals the connections between them by constructing a map of the knowledge and research clusters on AI-based technologies. The conceptual analysis identified four primary research clusters: the impact of AI on entrepreneurship, AI-driven business model innovation, the contextual integration of AI technologies, and the intersection of innovation and disruptive digital technologies. Each cluster illustrates a distinct dimension of how AI transforms entrepreneurial practices. For instance, AI's impact on entrepreneurship encompasses various industries and highlights both opportunities and challenges, such as ethical considerations and regulatory issues. The AI-driven business model innovation cluster emphasizes the potential for AI to radically alter value creation and delivery processes, enabling startups to leverage data-driven insights for competitive advantage. The contextual integration cluster highlights how AI adapts to different social and organizational settings, influencing digital entrepreneurship and effectuation. Finally, the innovation cluster connects AI with broader technological trends such as the Internet of Things (IoT) and blockchain, showcasing their combined potential to drive economic and social development.

The study also underscores the diversity of theoretical frameworks applied in the field, ranging from entrepreneurial orientation to business model innovation. However, there is a need for deeper theoretical grounding and more empirical research to validate and expand existing frameworks. The analysis revealed that while many studies have proposed conceptual frameworks, few studies have rigorously tested these theories in empirical settings. This gap presents an opportunity for future research to strengthen the theoretical foundations of AI in entrepreneurship, ensuring that robust academic insights inform practical applications.

Finally, this study proposes an applied theoretical framework for future research. The ADO-TCM framework provides a comprehensive lens through which to understand the impact of AI on entrepreneurship and to address the identified gaps. Antecedents refer to individual, technological, and environmental factors influencing entrepreneurial decision-making, such as personality traits, AI functionality, and market demand. Decisions encompass strategic and tactical choices regarding AI integration, including resource allocation and deployment strategies. Outcomes capture the transformative impact of AI on entrepreneurial processes, from identifying opportunities to enhancing decision-making and efficiency. By incorporating diverse theories, contexts, and methodologies, this framework encourages a deeper exploration of AI in various entrepreneurial settings, addressing existing research gaps and fostering a deeper understanding of AI's role in entrepreneurship.

The integration of AI technologies into entrepreneurship has practical implications for innovation, business operations, and accessibility. AI tools empower entrepreneurs to enhance decision-making, automate processes, and redesign business models, driving competitive advantages. These technologies optimize supply chains, improve operational efficiency, and reduce costs, enabling startups to scale rapidly and compete with larger firms. The democratization of AI has lowered the barriers to entry, making advanced tools accessible to small and medium-sized enterprises, fostering inclusivity, and levelling the playing field in competitive markets.

Entrepreneurial ecosystems, involving collaboration among startups, corporations, universities, and government entities, are critical for facilitating the diffusion and adoption of disruptive AI technologies. These ecosystems provide access to resources, networks, and expertise that accelerate the integration of AI into business practices. In the educational realm, integrating AI into entrepreneurship training equips the next generation of entrepreneurs with critical skills to thrive in a digital economy, fostering innovation and preparing these young entrepreneurs for an AI-driven future.

AI’s ability to analyze data, forecast trends, and identify consumer behaviors enhances entrepreneurs' capacity to recognize opportunities and adapt to volatile market conditions. This fosters resilience and agility, enabling businesses to anticipate changes and respond effectively to uncertainty. Furthermore, the application of AI-driven insights can personalize customer experiences, improve loyalty, and boost revenue growth.

However, the adoption of AI in entrepreneurship also raises critical ethical and regulatory considerations. To build trust and ensure responsible implementation, entrepreneurs must address challenges such as data privacy, security, and potential

biases in AI systems. Policymakers and business leaders must work together to establish frameworks that promote ethical AI usage while encouraging innovation.

7.3 Limitations

This study has several limitations that should be acknowledged. First, the rapid growth in the field means that some of this study's bibliometric performance analysis results will change over time. However, this study provides a comprehensive overview of the field through bibliometric performance. It goes further by undertaking a more exhaustive review through novel methodologies, such as the ADO-TCM framework, from which different propositions are made for future research. Second, in this performance analysis, this study includes indicators such as the h-index that do not benefit the visualization of highly cited but moderately productive researchers; therefore, readers should be careful when interpreting the data, and they should assess the results comprehensively. Third, the inclusion and exclusion criteria applied to the references mean that the analysis and conclusions of the study are limited to only those articles that met the established criteria, and some references may have been omitted from this analysis. However, although the exclusion or loss of references is often a problem in this type of study (Jacsó 2008), to the best of the authors' knowledge, this review understands that by using the Scopus database, it is covering a broad reference base that is also recognized as comprehensive for social sciences (Mongeon and Paul-Hus 2016). Fourth, although this study attempts to minimize the disadvantages of quantitative and qualitative research designs by combining them, qualitative analysis is particularly subject to possible researcher bias. Finally, this study examines only articles written in English in business, management, accounting or social sciences. Therefore, this analysis does not include research conducted in other languages and domains. While these issues represent limitations of the current study, this study moves toward a better organization and understanding of the field and offers avenues for future research.

8 Conclusion

AI-based technologies hold significant potential for revolutionizing entrepreneurial practices. By automating processes, enhancing decision-making, and fostering innovation, AI enables entrepreneurs to navigate complex market dynamics and capitalize on new opportunities. However, to fully realize these benefits, further research is necessary to address existing gaps and develop robust theoretical and methodological frameworks that can guide the effective integration of AI in entrepreneurship. This study provides a foundation for future research, highlighting critical areas where additional insights are needed to harness the transformative power of AI in entrepreneurial contexts.

Declarations

Consent for publication Declaration of generative AI and AI-assisted technologies in the writing process during the preparation of this work, the author(s) used ChatGPT and Grammarly to improve language and readability. After using these tools, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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