The evolving relationship of entrepreneurship, technology, and innovation: A topic modeling perspective

Surabhi Singh
Indian Institute of Technology Delhi, India

Shiwangi Singh (iD)
Indian Institute of Management Ranchi, India

Sanjay Dhir
Indian Institute of Technology Delhi, India

Abstract

Entrepreneurship is considered as a strong pillar for economic growth. In today's competitive era, technology and innovation facilitate firms' competitiveness and long-term survival. Therefore, the research on the interconnection of entrepreneurship, technology, and innovation (ETI) is growing and requires consolidation. This study presents a state-of-the-art review on ETI and presents a research agenda. Based on the topic modeling and semantic network analysis, this study classifies entrepreneurship, technology, and innovation articles into eight different topics and identifies the relationships among them. The study identifies 1407 articles collected through Scopus database. Eight salient research themes emerge: types of innovation (Topic 1), small venture performance (Topic 2), role of gender in digital entrepreneurship (Topic 3), entrepreneurial ecosystem (Topic 4), technological ventures (Topic 5), venture sustainability and growth (Topic 6), technology transfer (Topic 7), and government policies (Topic 8). The theoretical implications highlighting future research avenues are discussed in this study. Additionally, utilizing the semantic network, this study proposes a sequential mediation model. It provides a graphic representation of the interconnectivity between keywords from the identified topics, revealing deeper insights that may not be immediately apparent through traditional review methods. Further, this paper presents a range of insights for researchers and practitioners.

Keywords

entrepreneurship, technology, innovation, topic modeling, Twitter, dimensions

Introduction

Innovation is reshaping business, economy, and society by transforming the relationship between technology and people (Singh, Dhir, et al., 2021). The emergence of technologies such as internet of things (IoT), digital platforms, artificial intelligence, etc. (Akpan et al., 2021; Islam et al., 2020; Singh et al., 2020; Singh, Dhir, et al., 2021; Singh, Paul, et al., 2021; Singh, Sharma, et al., 2021) have enabled various entrepreneurial opportunities (Dana et al., 2021). Entrepreneurs can get advantage from these technologies as reduced cost, more diverse work platforms, accurate decision-making, and opportunities to expand digitally (Akpan et al., 2021; Dewett and Jones, 2001;

Kraus, et al., 2018; Nambisan, 2017). These usages of technology and innovation in entrepreneurial ventures can help to produce superior outcomes. Therefore, it has received substantial research attention, for instance, technology entrepreneurship education (Bolzani et al., 2021; Yami et al., 2021), impact of 3D printing technologies on entrepreneurship (Rayna and Striukova, 2021a), digital entrepreneurship ecosystem (Elia et al., 2020), discussion regarding technology foresight and entrepreneurship (Öner and

Corresponding author:
Shiwangi Singh, Indian Institute of Management Ranchi, Jharkhand, 834008, India.
Emails: profshiwangi@gmail.com; shiwangi.singh@iimranchi.ac.in

Kunday, 2016), and entrepreneurship survival (Ejermo and Xiao, 2014).

A report published by Organization for Economic Cooperation and Development (OECD) titled "Entrepreneurial Ecosystems, and Growth Oriented Entrepreneurship" (Mason and Brown, 2014) highlighted the role of technology and innovation in the entrepreneurial ecosystem. The stronger encouragement to technology and innovation can boost overall entrepreneurial productivity. Further, in a report published by United Nations Conference on Trade and Development (UNCTAD) entitled "Technology and Innovation Report (2021): Catching technological waves Innovation with equity" (UNCTAD, 2021), the role of innovations and technology are emphasized for prospects of generating higher profit, improving the value for consumers and generating avenues for societal developments. The Global Entrepreneurship Monitor (GEM) also captures the essence of technology and innovation through components procedure/technology impact (local/national/global) and digitalization rate.

There are numerous studies on innovation and technology (Burgelman et al., 2008; Dinu, 2022; Khan and La Torre, 2021; van Heerden and Mulumba, 2023), entrepreneurship and technology (Giones and Brem, 2017; Maestracci, 2023; Pretorius et al., 2022), or on innovation and entrepreneurship (Bessant and Tidd, 2007; Kitsios and Kamariotou, 2023; Onetti et al., 2012; Stephan, 2022). Despite of the extensive articles in the area of entrepreneurship, technology, and innovation (ETI), the extant literature lacks a cohesive understanding of the literature published so far. Harb and Shang (2022) discussed the linkage of information technology and entrepreneurship using topic modeling. Further, topic modeling methodology was applied to study the relationship between entrepreneurship and other impacting factors (Joyce et al., 2021, von Briel et al., 2018). However, the study to understand the holistic perspective on the "innovation, technology, and entrepreneurship" is limited. Therefore, this study aims to fill this gap by conducting a comprehensive analysis of the research on ETI. Further, this study synthesizes the findings to develop an in-depth understanding of the relationship between these three areas.

Taken together, the relationship between entrepreneurship, technology, and innovation can impact the economic and social aspects of entrepreneurship. This study accumulates scholarly contributions from different theoretical approaches. This study highlights how technology and innovation are embedded in entrepreneurship. This study contributes to the existing research in three ways. First, an advanced topic modeling algorithm enables a comprehensive, structured, and more objective review than a traditional literature review (Mustak et al., 2021). Second, the research is classified into eight topics based on the frequency of recurring words. Third, the study will provide avenues for future research based on the themes identified and presents a sequential mediation model for future study.

The remainder of this study is organized as follows. Section 2 describes the literature review. Section 3 describes the methodology. Section 4 discusses results. Section 5 provides implications and discusses work to be done in future. Section 6 provides conclusion and limitations.

Literature review

Kent et al. (1982) defined entrepreneurship as the establishment of new business companies by individuals or small groups that are "concerned with the discovery and exploitation of profitable opportunities" (Radziszewska, 2014, p. 35). Therefore, entrepreneurship acts as a process of creating new businesses or bringing new products or services to market. Entrepreneurs are often innovators, as they discover and develop new market opportunities and new products or services to meet those needs. Entrepreneurship showcases innovation by effectively implementing ideas or concepts using available resources (Crumpton, 2012; Karami and Read, 2021; Kim and Kim, 2022). Entrepreneurship serves as a bridge between the subject areas of innovation and technology-based firms (Eesley and Lee, 2021; Mosey, 2016; Shepherd and Majchrzak, 2022).

Ariningrum and Puspita (2022) defined technology as "the convenience obtained from the application of knowledge in running an industry such as creating tools, developing skills, solving problems and others" (p. 3). Technology is a creation of novel devices, pieces of equipment, and methods for carrying out tasks that are founded on current scientific and computational understanding (Patil and Gupta, 2021; Shaikh and Habineza, 2021). Therefore, technology refers to the innovative design, development, and implementation of tools, machinery, and systems that utilize the latest scientific and computational knowledge to accomplish various tasks. Technology facilitates the development of techniques that enhance the effectiveness and efficiency of knowledge information systems (Eliot and Gabrie, 2022). Technology enables communication, efficiency, automation, innovation, connectivity, security, transparency, and trackability (Arrigo et al., 2022; Buntak et al., 2019; Joshi et al., 2022; Mostafa et al., 2019; Panda et al., 2019; Thanaraj et al., 2023; West, 2016).

Innovation is the creativity, invention, and implementation of new ideas (Aytekin et al., 2022; Goswami and Mathew, 2005; Van de Ven, 1986) that creates value (Kalkan et al., 2014; Ortigueira-Sánchez et al., 2022). Lindfors and Hilmola (2016) defined innovation as "a novel, inventive and usable solution, in either material or immaterial space: an end-product, process or method related to people's practical needs and purposes" (p. 373).

Innovation enhances the firm's ability to add advantage, obtain a competitive edge, and develop problem-solving abilities, all of which result in an enhancement in firms performance (Al Jneibi et al., 2023; Harif et al., 2022). Johnson (2001) presented multiple forms of innovation that include change in the product or service spectrum that an organization brings to the market, change in product or service for a purpose that is unrelated to organization's original intent, stealing a competitor's market share, and develop new operational, logistical, and business model innovations. Therefore, innovation can be either technological or non-technological, and it can arise from a variety of sources, such as research and development, customer feedback, and collaboration among firms.

Some studies discussed that innovation is closely linked to entrepreneurship, as entrepreneurs are often innovators who find new market opportunities, ideate new products or services, and develop them to meet those needs (Sahut and Peris-Ortiz, 2014); however, other studies have highlighted technology role for driving innovation, as technological advancements create new opportunities for innovation and enable entrepreneurs to develop new products or services that were previously not possible (Todeschini et al., 2017; Snihur and Zott, 2020). Technological advancements can create new opportunities for innovation and can enable entrepreneurs to develop new products or services that were not previously possible. By using technological innovation entrepreneurs can easily adapt to dynamic market conditions, improve their processes, and operate effectively. Therefore, "entrepreneurship, technology, and innovation" are closely related.

Figure 1 illustrates the keywords that are frequently studied in the context of ETI, as well as their intersections. Entrepreneurship can contribute to sustainable economic growth by leveraging human capital and strategic orientation while fostering education and supporting small ventures (Boone et al., 2019; Browder et al., 2019; Gruber, 2023; Hor, 2023; Terziovski, 2010; Yayavaram and Chen, 2015). The technology research represents that firms must adopt effective strategies for technology transfer, adoption, and planning to enhance performance and remain competitive, while also considering the economic and sustainability implications of their decisions (Fauchart and Gruber, 2011; Fernhaber and Zou, 2022; Li and Atuahene-Gima, 2002; Runge et al., 2022; Vedula et al., 2022; Zahra, 1993). The innovation research represents collaboration and cross-functional integration in driving innovation and enhancing firm performance (Edwards et al., 2023; Hoang and Rothaermel, 2005; Kownatzki et al., 2013; Shepherd and Majchrzak, 2022). The common keywords of ETI research include innovation, performance, public policy, learning, and investment. Therefore, the entrepreneurs can adopt a multidisciplinary approach that incorporates various strategies and expertise to effectively leverage technology and innovation to achieve superior performance.

Entrepreneurs are often the driving force behind new technologies adoption and development of innovative products or services. The use of technology can also enable entrepreneurs to identify and develop new opportunities for creating value. The assessment of innovation, particularly in the domains of technology and entrepreneurship, is a multifaceted concept that has been fragmented into various components, resulting in a lack of consensus among studies (Zhang and Li, 2010). The primary objective of this research paper is to synthesize and integrate divergent perspectives on ETI.

Methodology

Data collection

This study utilizes the published articles indexed in Scopus database. Scopus is considered as a high-quality database (Baas et al., 2020; Dixit et al., 2021; Singh, Sharma, et al., 2021; Singh et al., 2022; Singh and Dhir, 2023) and lists more documents as compared to Web of Science database (Singh and Dhir, 2019; Srivastava et al., 2020). The study aims to cover the articles published with keywords related to ETI. Therefore, for this purpose, a keyword search was performed using search keywords such as technology or technologies, and innovation, and entrepreneurship articles based on the presence of these terms in their "abstracts, titles, or keywords." The search returned 4356 publications. Figure 2 presents a step-wise-article selection procedure followed in this study. Total of 1407 publications were retrieved in the CSV file format with all core attributes information. First article was published in 1975, therefore this study is performed on the publications published from 1975 to 2022. Research on ETI has gained prominence since early 2000s (Figure 3).

Method

A literature review is a critical analysis of the existing literature that helps in understanding the present state of research on a particular topic. A literature review can be carried out in distinct ways such as narrative or integrative reviews, systematic reviews (Singh et al., 2020a; Srivastava et al., 2020), meta-analyses (Singh, Dhir, et al., 2021; Singh, Paul, et al., 2021; Singh, Sharma, et al., 2021), bibliometric analysis (Singh et al., 2020b; Singh and Dhir, 2019; Singh, Dhir, et al., 2021; Singh, Paul, et al., 2021; Singh, Sharma, et al., 2021), and topic modeling (Kraus et al., 2022; Oliveira et al., 2021). Systematic literature reviews (SLR) and topic modeling are two methods that are frequently utilized in research to assess a large volume of textual data (Ignaczak et al., 2021; Sangari and Mashatan, 2022). SLR is a structured approach to discovering, assessing, and synthesizing the current body of research on a given
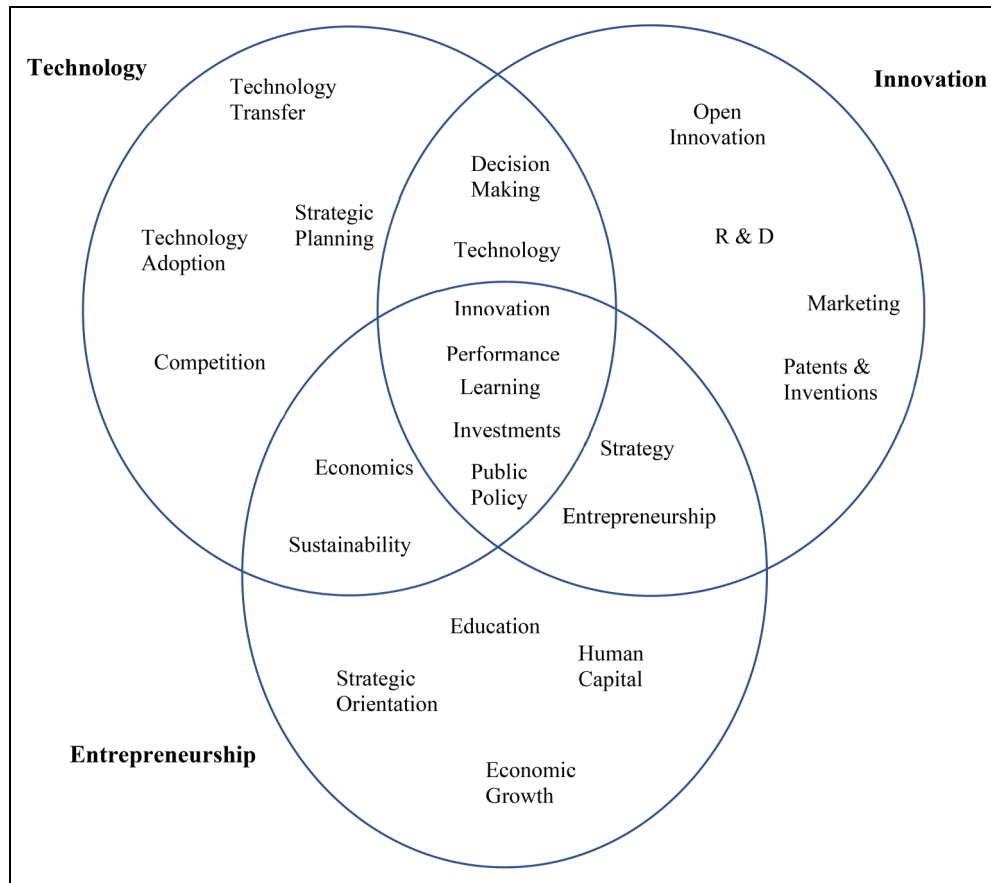
Figure 1. Venn diagram of entrepreneurship, technology, and innovation (source: authors' own elaboration).

topic or research objectives (Bahmani et al., 2023; Okoli and Schabram, 2010) that summarize antecedents, contexts, theoretical perspectives, barriers, facilitators, and outcomes (Ali et al., 2022; Madueke-Laveaux et al., 2021; Singh and Dhir, 2019). While systematic literature review (SLR) is a rigorous method for synthesizing literature, its validity and reliability can be impacted by subjective bias. In contrast, topic modeling is a data-driven approach for objectively analyzing large text datasets, without the influence of subjective biases. Additionally, the selection criteria of study's inclusion and exclusion in a SLR is dependent on the researchers' rationale that can lead to research bias. Whereas topic modeling identifies the underlying topics and themes in the literature by employing unsupervised machine learning techniques. This study utilized latent dirichlet allocation (LDA) to gain a comprehensive understanding of the topic and to identify the main themes and concepts present within a large corpus of text, structural topic modeling (STM) to recognize patterns or topics from the textual data, and to analyze the topic-wise unique words that help in improving the interpretability of topics label, and sematic analysis to visualize the relationships between different topics. These methods are used in this study to get an in-depth analysis of the retrieved data.

Topic modeling. Topic modeling (TM) is a machine-learning (ML) technique that uncovers hidden themes or subjects in a large body of text data (Shahbazi and Byun, 2020). By categorizing related terms into topics and ascribing probabilities of topic inclusion to each document, topic modeling discovers the underlying structure of the data (González Canché, 2023), hidden patterns, trends, and themes in the data without making any assumptions or predictions (Luo et al., 2023; Ozyurt, 2022; Pramanik and Jana, 2022).

Latent Dirichlet Allocation (LDA): LDA is a widely used TM algorithm that models each document as a combination of topics, and each topic as a distribution over words (Anandkumar et al., 2012; Awantina and Wibowo, 2023). LDA allows for the identification of latent themes or topics that may not be immediately apparent through traditional keyword-based searches used in SLR. This is especially useful for identifying emerging or interdisciplinary research areas and for finding reasonably accurate sets of topics from a given document. Therefore, LDA is a combined-membership clustering algorithm (Loureiro et al., 2021) that finds and distributes all hidden topics from a document. In LDA algorithm the sampling of each word from the documents are grouped according to the distributions of the words into the associated topic by
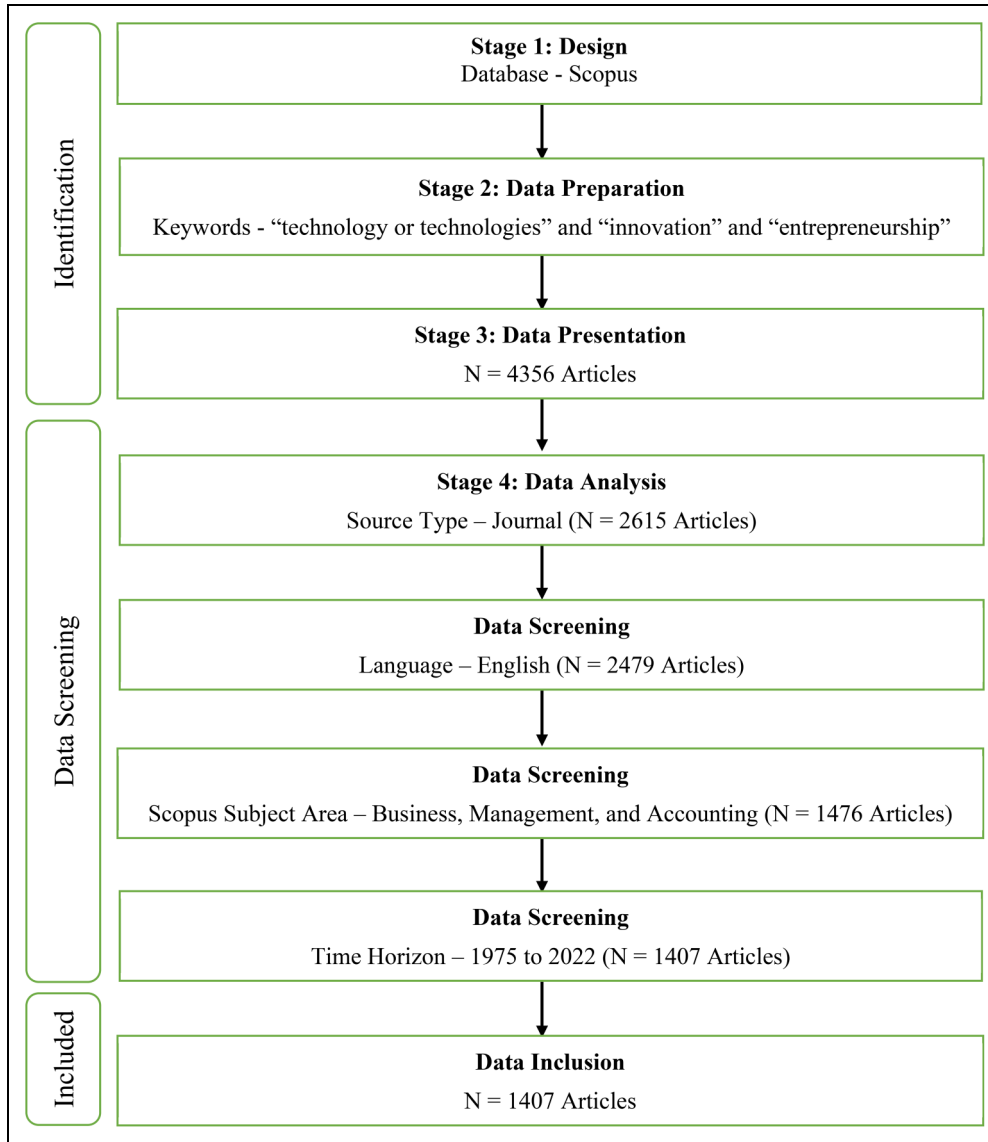
Figure 2. Stages of data search and refinement.

employing Dirichlet distribution (distribution of words in a document or the distribution of topics in a corpus) (Chauhan and Shah, 2021). LDA is the simplest topic model (Blei et al., 2003) that distributes each identifiable word in the document over fixed number of topics. LDA does not take word occurrence and syntactic data into consideration. LDA considers document as word set. In LDA model, a latent topic is chosen from the document-topic distribution, and then the selected cluster is made from multinomial topic-word allocation.

Topic analysis using LDA model includes following steps. First, in LDA model for randomly assigning topics, we assign "K" topics to the entire words from "m" documents. Second, topic count is created that varies with documents. Third, LDA creates assignments of word count that varies directly with topic. It filters count of maximum word

for each topic. Further, it eliminates topic assignments, and it resamples the word. It then calculates the probability of topic (t_k) and likeness by document (d_i):

$$P\frac{t_k}{d_i} = \frac{n_{ik} + \alpha}{n_i - 1 + K\alpha}$$

Where k = Topic indices (Number of considered topics) d_i = Count of expected topics in documen tn_{ik} = Total No. of words in k^{th} topic from i^{th} documentn_k = Number of words in i^{th} documentα = Document-topic density factor (Hyper parameter)LDA algorithm calculates the probability of topic (t_k) and likeness for word (w_j):

$$P\frac{w_j}{t_k} = \frac{m_{j,k} + \beta}{\sum_{j \in V} m_{j,k} + V\beta}$$
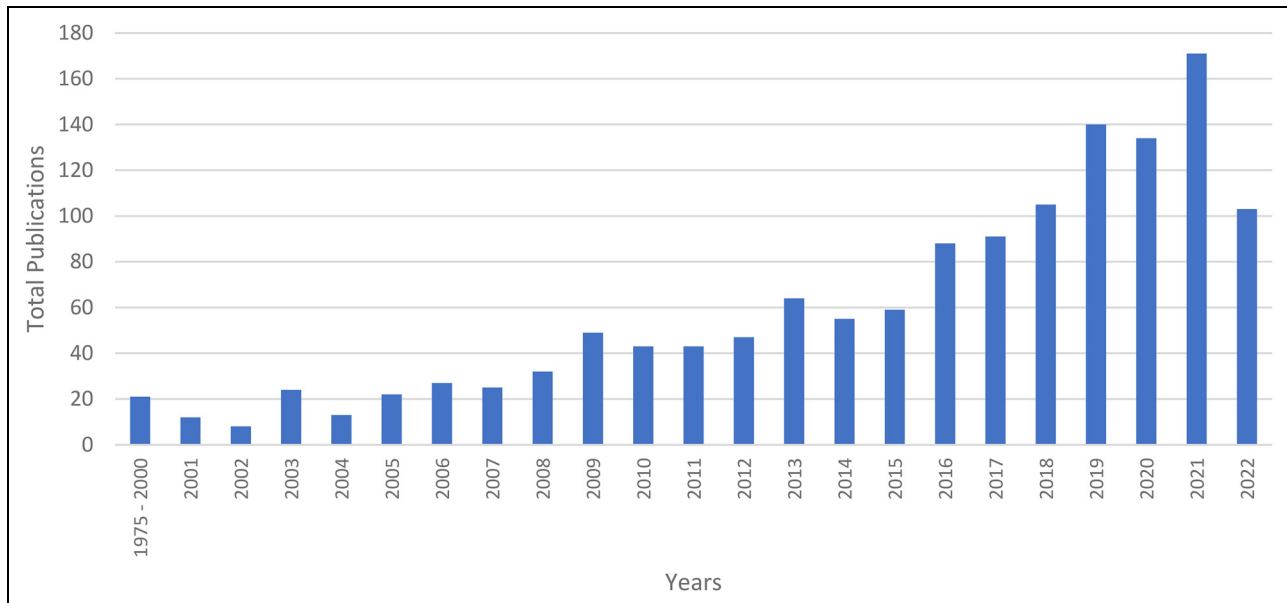
Figure 3. Publication trends.

Where $m_{j,k}$ = Corpus wise assignment of kth topic and w_j word

V = Corpus Vocabulary

β = Topic-word density factor (Hyper parameter)

LDA algorithm then reassigns the corpus of words for discovered latent topic. In the provided document, LDA algorithm finds the topic for which posterior probability value is maximum and resamples the same word to k^{th} topic. At last, a topic coherence score is generated that shows the degree of judgment of topic model. High coherence score indicates that the resultant topic model is better.

Structural Topic Modeling (STM): STM is a statistical framework for analyzing large collections of text data (Wu, 2022) that uses a hybrid approach that uses both text-based and categorical data to recognize a collection of themes that are shared by all the documents in a specific dataset (Rose et al., 2022). STM is an extension of LDA that assumes that each document is a mixture of latent topics (Bai et al., 2021). STM considers the structural information in the text data, such as the metadata associated with each document or the temporal order in which the documents were written. Discovering topics and estimating how they are related to other factors using STM is helpful (Rose et al., 2022). With the R statistical software, the "STM" package is utilized for performing STM analysis. The capability of STM to recognize topic-wise unique keywords is one of its most important characteristics. This functionality allows researchers to identify the most important words associated with each topic, that can provide significant insights into the content and meaning of the text corpus.

Semantic network analysis. Semantic network analysis (SNA) emphasizes the implementation of network analytical tools that focus on paired associations that share common interpretations, rather than on paired associations that are based on behavioral or perceived communication linkages (Doerfel, 1998). Analysis of semantic networks can provide information by learning about the co-occurrence of concepts and how those concepts are semantically associated through the use of automatic coding approaches (Piselli et al., 2022). Therefore, SNA facilitates a comprehensive understanding of textual meaning by detecting and analyzing the co-occurrence of keywords that are adjacent to each other. Specifically, the dataset consists of a matrix with rows representing topics and columns representing keywords. To determine the relationship's strength between words in the data set, the study employed linkage analysis, a well-established method for measuring degree of association between variables in a network (Borgatti and Everett, 1997).

Results

Topic modeling has become valuable due to its capacity of processing an enormous amount of available information, as it goes ahead of human mind managing capabilities (Andrzejewski and Zhu, 2009; Wang and Blei, 2011). Topic model is used to discover the hidden semantic structure and latent topics from the larger dataset. In this study, the article title and keywords are used to analyze the 1407 articles published in the areas of entrepreneurship, innovation, and technology. Figure 4 presents word cloud of the

scientific article. The terms that appear in larger texts are more commonly used in literature. Therefore, a quick look at word cloud presents a quick insight of the published research. In word cloud, the word that appears more in the document appears larger than other words in same topic.

Topic modeling

For determining the optimal number of topics, this study adapts the method proposed by Deveaud et al. (2014), that estimates the appropriate number of topics within the range of four to eight. Further, number of topics are identified using coherence score. Coherence score is highest with eight themes. As a result, the total number of identified topics in this study are eight. Each circle in Figure 5 denotes a topic, and the most salient terms summarize the topic. The topics are: types of innovation (Topic 1), small venture performance (Topic 2), role of gender in digital entrepreneurship (Topic 3), entrepreneurial ecosystem (Topic 4), technological ventures (Topic 5), venture sustainability and growth (Topic 6), technology transfer (Topic 7), and government policies (Topic 8). Table 1 presents the topics, their coherence value, and keywords. High coherence score indicates that the identified keywords in an individual topic are highly associated with each other, whereas a low coherence score indicates that the identified words of that topic are not highly associated with each other. Figure 6 presents the semantic network relationship between the identified topics and keywords. Based on the results the intersection of research on ETI is proposed in Equation 1.

$$
\begin{aligned}
\text{Entrepreneurship} \cap \text{Technology} \cap \text{Innovation} = {} & \beta 0 + \beta 1(\text{Types of Innovation}) + \beta 2(\text{Small Venture Performance}) \\
& + \beta 3(\text{Role of Gender in Digital Entrepreneurship}) + \beta 4(\text{Entrepreneurial Ecosystem}) \\
& + \beta 5(\text{Technological Ventures}) + \beta 6(\text{Venture Sustainability and Growth}) + \beta 7(\text{Technology Transfer}) \\
& + \beta 8(\text{Government Policies})
\end{aligned}
$$

(1)

Equation (1) presents that there is a relation between entrepreneurial technological innovation and identified eight topics. In equation (1) $\beta 0$ is the intercept term, and $\beta 1$, $\beta 2$, ……, and $\beta 8$ are the beta coefficients (standardized slopes) indicating the change in entrepreneurial technological innovation for change in each independent variable.

Topic 1: Types of innovation. This topic aggregates the studies that focus on types of innovation in entrepreneurial firms. Innovation types may provide push boundaries at the industry level, value at the business level, and finally support technological change and sustainable growth (Yang and Chiang, 2022). Technological advantages often enable innovation types to develop new products or services, optimize existing processes, or create entirely new industries. However, entrepreneurial firms are inclined toward technology innovation (process or product) over non-technological innovation (marketing or organizational) (Dunyo and Odei, 2023). The distinctiveness of innovative types can significantly impact firm's strategy, structure, and performance (Damanpour et al., 1989). Adoption of different types of innovations can positively impact organizational performance (Su et al., 2022). Despite the potential benefits of innovation types in various domains, the implementation of new ideas is often hindered by a variety of challenges, including technological complexity, and resource limitations (Coulthart and Riccucci, 2022).

Topic 2: Small venture performance. This topic aggregates the view of small venture performance in context of ETI. Small ventures based on innovation and technological capabilities can exploit the current market opportunities (Beynon et al., 2021; Malerba and McKelvey, 2020). These firms create, diffuse, and use the knowledge to introducing innovative products, services, and technologies, utilizing concepts and resources from their innovative system, and driving change, companies can enhance their competitive advantage (Fischer et al., 2022). Knowledge of the technologies and processes can facilitate the growth of small firms (Paoloni et al., 2020). In small firms, such technical knowledge is often possessed by entrepreneurs. Therefore, entrepreneurs with high technical knowledge have greater chances of attaining better performance. The role of innovation strategies and entrepreneurial orientation can help to attain better performance (Fischer et al., 2022) in small ventures. Further, dynamic capabilities can help to attain better firm performance (Wang et al., 2015). However, extant literature has scantly studied the role of technological dynamic capabilities in small venture performance. Various scholars have argued the unwillingness of small venture entrepreneurs to provide financial data (Haber and Reichel, 2005). In small ventures, measuring performance is challenging due to the evaluation process's complexity in short-term and long-term performance indicators.
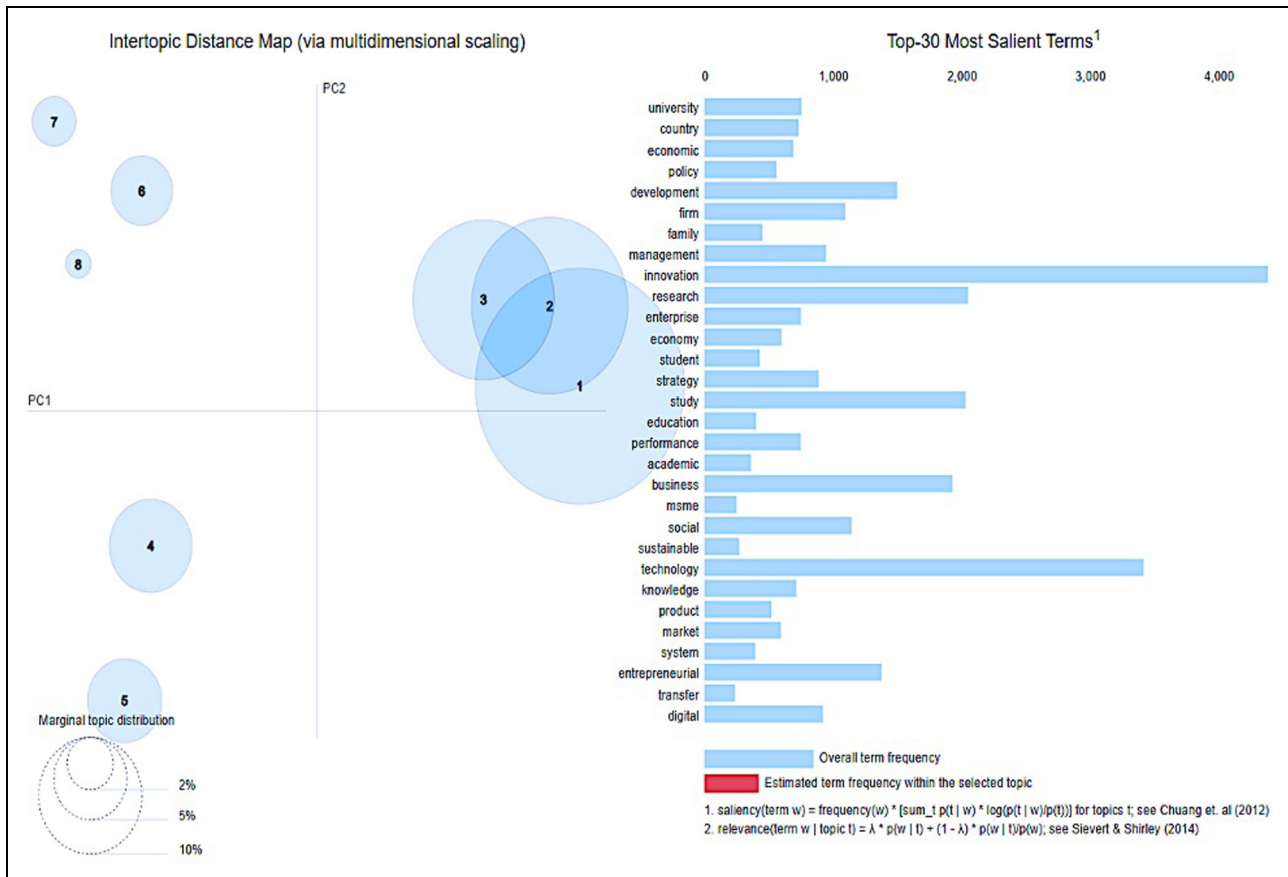
Figure 4. Word cloud of the prominent keywords in entrepreneurship-technology-innovation literature.

Topic 3: Role of gender in digital entrepreneurship. The topic aggregates the view of role of gender in context of digital entrepreneurship (technology and innovation). In high-technology industry, gender stereotypes such as gender-appropriate occupation (Sitaridis and Kitsios, 2019) can hamper the opportunities for female entrepreneurs (Alves et al., 2021). Further, women entrepreneurs have lesser opportunities (Alves et al., 2021). Various studies have highlighted the lack of social support and difficulty in raising capital for female entrepreneurs (Akehurst et al., 2012; Alvarez et al., 2011; Alves et al., 2021) in technology-based firms. Aggressive funding goals are associated with masculine behavior (Brush et al., 2019). Scholars have suggested that the role of female entrepreneurs should be highlighted to challenge gender-based occupational roles (Garcia and Welter, 2013). Additionally, entrepreneurs need to acquire the required skills with the change in environment. For instance, Fernandes et al. (2022) highlighted the need for digital skills for digital entrepreneurship platforms. The skills can provide entrepreneurs the ability to analyze, create, investigate, and share (Rayna and Striukova, 2021b). Technological skills can enhance the likelihood of entrepreneurial firms' creation and success (Shekarian and Parast, 2021).

Topic 4: Entrepreneurial ecosystem. This topic compiles the perspective of entrepreneurial ecosystem. The entrepreneurial ecosystem provides an opportunity to create a high-growth firm in a volatile environment. In the process of creating a high-growth firm in a volatile entrepreneurial ecosystem, entrepreneurs may encounter significant challenges and uncertainties (Ibrahimova and Moog, 2023). It can also influence operational and functional level strategy of the firm. Leendertse et al. (2022) discussed that these strategies may include few elements of entrepreneurial ecosystem, including culture, demand, finance, leadership, talent, and network. Entrepreneurial ecosystem facilitates quicker implementation of strategies to enhance the business performance (Grujić, 2019). By understanding the dynamics and interrelationships of the various elements

Figure 5. Inter-topic distance map of latent modeled topics.

within the entrepreneurial ecosystem, entrepreneurs can identify potential opportunities for innovation and growth, and create strategies that align with their business goals and objectives. Therefore, entrepreneurs can make a decision about the most effective ways to leverage the elements and enhance the capabilities of the entrepreneurial ecosystem. Duan et al. (2021) discussed that an entrepreneurial ecosystem can encourage innovation by implementing effective strategies.

Topic 5: Technological ventures. This topic compiles the perspective of technological development in ventures. In the present competitive scenario, entrepreneurs are focusing on innovative technologies. Many entrepreneurial firms are focusing on digital transformation of their businesses and use digital technologies to conduct day-to-day business activities (Fernandes et al., 2022). Digital platforms such as social media, e-commerce, etc., can help to optimize certain business functions at a lower cost. To create and maintain venture's technical development, manufacturing entrepreneurs experience challenges such as a shortage of resources and uncertain market conditions (Reza-Gharehbagh et al., 2022). They require funds for supporting R&D and production activities. With the emergence of Industry 4.0 technologies, including emerging technologies

(Lee and Lim, 2021) the competitive landscape of technological ventures is changing. These ventures are sourcing AI-driven solutions from external vendors. However, development of these emerging Industry 4.0 technologies still remains a challenge for small technological ventures.

Topic 6: Venture sustainability and growth. This topic compiles the perspective of venture sustainability and growth. The social aspect focus upon community, workers, partners, stakeholders, and customers is given. Environmental aspect focuses upon the protection and care of the environment. At last, economic aspect focuses upon economic performance of the firms. Materiality impact venture social, economic, and economic performance (Coffay et al., 2022), therefore the ability of ventures to achieve credibility and materiality affects ventures sustainability and growth (Gimmon and Spiro, 2013). Scholars have argued that if entrepreneurial firms want to growth in business, they can include sustainability within their business strategy (Terán-Yépez et al., 2020). Due to intense competition and awareness of the consumers and to differentiate themselves from competitors, the firms are focusing on sustainable practices for their long-term survival and growth (Shepherd and Patzelt, 2011). Government policies and regulations can impact sustainability of ventures

Table 1. Topics, coherence value, and keywords.

	Topic	Coherence Value	Keywords
Topic 1	Types of Innovation	0.57	Evolutionary Radical Innovativeness Diffusion Disrupt
Topic 2	Small Venture Performance	0.56	Perform Capability Orientation Strategy Small
Topic 3	Role of Gender in Digital Entrepreneurship	0.52	Digital Social Diversity Platform Gender
Topic 4	Entrepreneurial Ecosystem	0.49	Ecosystem Education Entrepreneurial Knowledge Technological
Topic 5	Technological Ventures	0.35	Venture Startup Capital Finance Equity
Topic 6	Venture Sustainability and Growth	0.59	Business Model Product Sustainability Materiality Market
Topic 7	Technology Transfer	0.20	Transfer Patent Spin-off Spillover Invent
Topic 8	Government Policies	0.47	Policy National Economy Governance Convergence

(Huang et al., 2020). Further, entrepreneurs who wants to attain venture growth can find a balance between environmental, social, and economic aspects of entrepreneurship using sustainable innovative technologies.

Topic 7: Technology transfer. This topic compiles the perspective of technology transfer. Entrepreneurs possess a deep understanding of their industry, customers, and the latest technological advancements. Technology transfer enables entrepreneurs to bring their innovative ideas to the market and create long-term value for their customers. Additionally, it can provide entrepreneurs with new opportunities to solve complex problems and create value

(Battisti, Graziano, et al., 2022; Battisti, Agarwal, et al., 2022). Technology transfer allows entrepreneurs to access new technologies and resources that they can use to create new solutions or improve existing systems (Li-Ying et al., 2022; Singh and Kumar, 2022). National and international entrepreneurs often consider effective technology transfer (Siegel et al., 2023). Technology transfer can help decision-makers and R&D researchers to expand their access to new business opportunities (Cinar et al., 2021). Further, the studies have also suggested that technology transfer is also related to the new technology implementation by entrepreneurs.

Topic 8: Government policies. This topic aggregates the studies that focus upon government policies in relation with technology and innovation in entrepreneurial firms. Government policies can facilitate or constrain entrepreneurial activities (Dai and Si, 2018). It can shape different institutional frameworks such as regulatory quality and rule of law. These institutional frameworks help entrepreneurs in doing business and propose new policies for them (Rubin et al., 2015). Government policies aim to promote technological innovation and help the country to become self-reliant (Taylor et al., 2003). Government can structure the development of emerging innovative technologies into industrial firms while developing new technology-based policies (Hung and Chu, 2006). Government policies should support innovation and technological policies to overcome the challenges of economic advancement (McCarthy, 2011). Entrepreneurs are more inclined to capitalize and invest in opportunities by engaging in entrepreneurial activities if they perceive the usefulness and effectiveness of such policies.

Semantic network analysis

To perform semantic network analysis, the study uses a two-mode network dataset as it is considered the most appropriate representation for capturing interconnections between topics and associated keywords (Alexander, 2005). Figure 6 visualizes the connections between the nodes in the network, the study gained a deeper understanding of the inter-relationships within the data set.

Implication and future research agenda

The topic modeling helps us to present a holistic perspective and discover key topics in the area of ETI. The findings of this study contribute to the existing literature on business and management of entrepreneurship. The study provides a detailed perspective on eight identified themes related to ETI. Further, for each topic, future research agendas are discussed in this section. Table 2 presents a future research agenda for entrepreneurship-technology-innovation literature.

The paper presents a range of insights for entrepreneurs and practitioners. Entrepreneurs can take into consideration technological innovations for their future growth
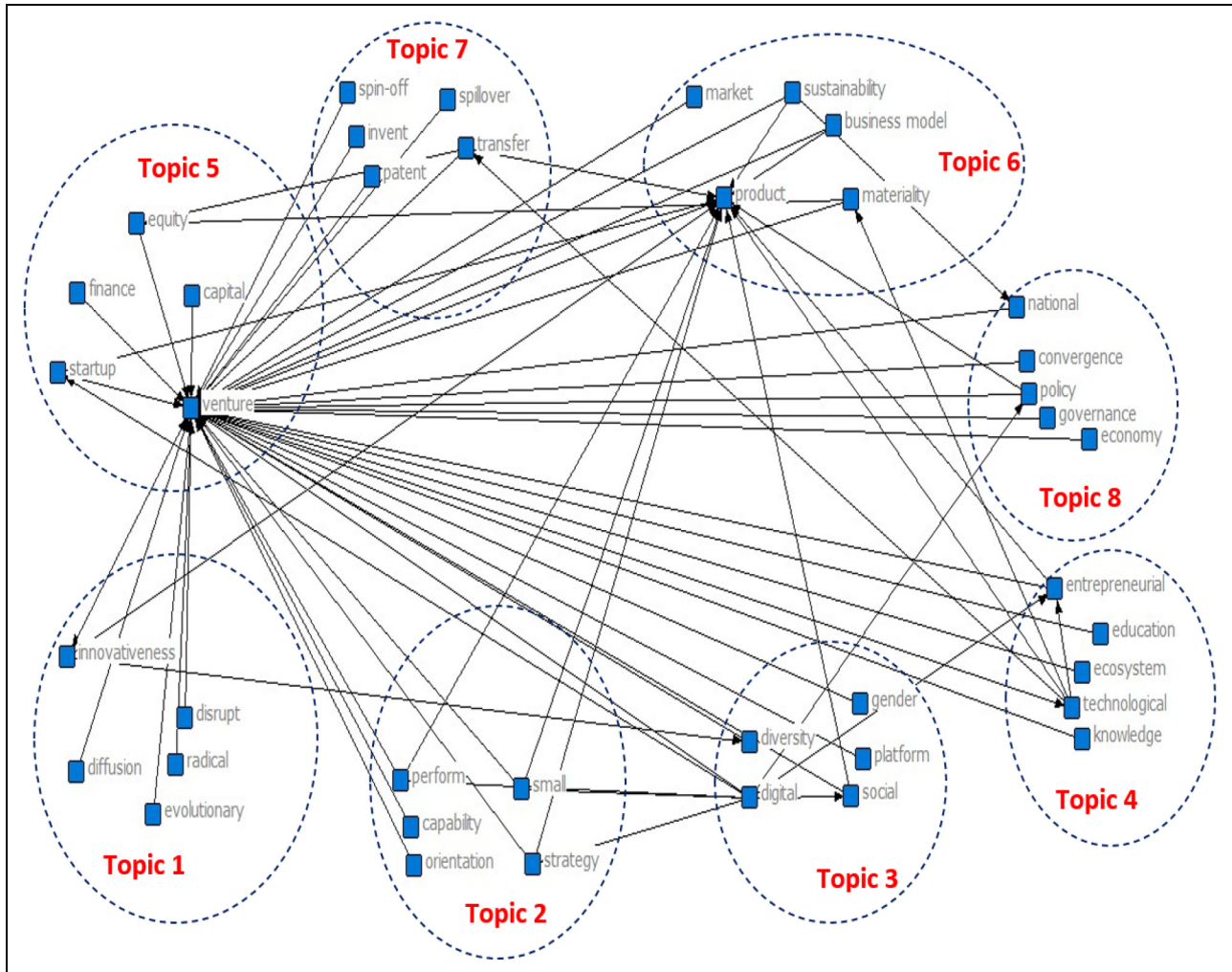
Figure 6. Semantic network.

perspectives. They should additionally consider government policies and ease of doing business in the region. Additionally, they should adopt technological innovations and sustainable practices for their long-term growth and survival. Other key important areas of interest include digital entrepreneurship and key performance indicators for entrepreneurial firms. Government policies should be aligned with boosting entrepreneurship and protecting entrepreneurial interests.

Implication and future research agenda on topic modeling

Types of innovation. Innovation types enable firms to adapt to changing market conditions and consumer preferences, ensuring their long-term viability. Firms can consider how different types of innovation can impact their industry and organizational structures, and how they can leverage innovation to attain competitive advantage. Further, the types of

innovations are significant in the success of entrepreneurship using innovative strategies. Additionally, types of innovation enable firms to adapt to changing market conditions and consumer preferences, ensuring their long-term viability and sustainability. Future research could explore the role of the type of innovation in facilitating firm performance. Furthermore, investigating the relationship between technology and sustainability in the context of types of innovation could provide insights into how firms can achieve long-term sustainability.

Small venture performance. In today's competitive era, better firm performance is one of the significant factors in accessing the growing potential of small ventures (Muhammad Auwal et al., 2020). It is important to understand what are the key technological factors that contribute significantly toward the better small ventures' performance. Moreover, the entrepreneurial technical background can also contribute toward better performance of small

Table 2. Summary of future research question.

Topics	Research questions
1. Types of innovation	How can different types of innovation (e.g., radical, incremental innovation) impact industries and organizational structures differently?
	What are the key barriers and enablers that affect entrepreneurial firms' ability to adopt and implement different types of innovation, and how can these obstacles be overcome?
2. Small venture performance	What are the key technological factors that contribute significantly towards better performance of small ventures?
	What are the required entrepreneurial technical knowledge for better small venture performance?
	How dynamic technological capabilities can influence small venture performance?
	What are the measures of venture performance in short-term and long term?
3. Role of gender in digital entrepreneurship	How gender stereotypes in the technological entrepreneurial process can be reduced?
	What are the key gender roles in digital entrepreneurs to sustain in volatile scenarios? To what extent gender roles can foster technological innovation, reduce time to market, and build a customer base?
	What are the best practices for promoting gender diversity and inclusion in digital entrepreneurship ecosystems?
4. Entrepreneurial ecosystem	How does the structure and composition of an entrepreneurial ecosystem influence the success of firms?
	What factors differentiate entrepreneurs within an entrepreneurial ecosystem, including cultural antecedents, networking forms, entrepreneurial nature, product/service features, and geographical settings?
	What are the key strategies for building and nurturing networks of investors, mentors, and other stakeholders within an entrepreneurial ecosystem?
5. Technological ventures	What are the inhibitors and facilitators of technological development in ventures?
	What is the role of industry-academia and technological venture collaboration in the case of entrepreneurial firms? How the relationship can be leveraged to overcome the effects of inhibitors for technological developments?
	How can technological ventures leverage new technologies, such as artificial intelligence and blockchain, to enhance their performance?
6. Venture sustainability and growth	How can entrepreneurs effectively integrate sustainability into their business strategies to improve the long-term sustainability and growth prospects of their ventures?
	What are the key drivers of sustainability and growth in entrepreneurial ventures, and how do these drivers vary across different industries?
	How do government policy and initiatives impact the sustainability and growth of entrepreneurial ventures?
7. Technology transfer	How can technology transfer initiatives be effectively monitored and evaluated to ensure their success, and what are the most appropriate metrics for measuring their impact on firm performance?
	What are the emerging technologies that can enhance the effectiveness and efficiency of technology transfer in entrepreneurial firms?
	What are the key success factors for technology transfer initiatives in entrepreneurial firms, and how can policies and practices be developed to promote their success?
8. Government policies	What are the challenges faced by entrepreneurial firms? What are the key support and resources required by the entrepreneurial firms from government?
	What are the effects of government policies on the existing entrepreneurial firms?
	How government technological policies and support can foster performance of SMEs?

ventures. Therefore, all technical knowledge can contribute to better firm performance. Based on resource-based view (RVB), strategic resources can be utilized to achieve better performance (Zeb and Ihsan, 2020). Further, dynamic capability theory suggests that in changing scenarios, the resources and compatibilities can be used to attain better performance. However, research is limited in the context of how dynamic capabilities influence SME's performance. In addition, deciding how to measure small venture performance is always a challenge due to complexity in evaluation of short-term and long-term measures. Therefore, further studies can also study different these two measures of financial performance and define ways of measuring them effectively.

Role of gender in digital entrepreneurship. The ETI literature highlight the role of gender stereotypes, lack of social support for women entrepreneurs, and importance of technological and other entrepreneurial skills. The role that gender play in digital entrepreneurship may investigate the nexus of gender, science, entrepreneurship, and technology, with a specific focus on the perspectives of women entrepreneurs. However, future research should explore ways to reduce gender stereotypes in process of entrepreneurship. In addition, technological and other entrepreneurial skills are required to sustain in a volatile and competitive environment. Therefore, the studies should explore the role of an entrepreneur's gender in sustaining volatile environment and how their skills can foster technological innovation. Further, the focus should also be given to understand the ways for imparting their skills to other entrepreneurs.

Entrepreneurial ecosystem. Research on entrepreneurial ecosystem with respect to ETI is limited. Entrepreneurs need proper support from different stakeholders in the process of creating high-growth firms. Various factors, such as technological propensity and availability of funds, can impact the ecosystem. Future researchers can summarize the factors that can influence the sustainability of entrepreneurial ecosystem. The performance of a firm within an entrepreneurial ecosystem can be influenced by its decisions regarding technological innovation, time to market, and customer base. However, adopting an entrepreneurial ecosystem is crucial for fostering productive entrepreneurship that drives economic growth (Opute et al., 2021). Further, there is a need to explore different key strategies for building and nurturing networks of investors, mentors, and other stakeholders within an entrepreneurial ecosystem.

Technological ventures. Entrepreneurs face many challenges in the process of developing technologies, including a lack of funds and skilled manpower. However, the literature has scantly studied the inhibitors and facilitators of technological development in entrepreneurial firms. The role of industry-academia collaboration is appreciated for technological developments. Therefore, the role of start-ups and universities collaboration can be studied to mitigate the effect of inhibitors and promote technological developments. Further, government policies can help entrepreneurial firms to overcome some of the challenges of technological developments through technical support and assistance. Future studies can study the role of government policies in different facets of technology development.

Venture sustainability and growth. Integrating sustainability and business strategy can lead to venture's long-term subsistence and growth. Additionally, sustainability and growth of venture can be achieved by its long-term profitability and capability to accomplish its objectives. Materiality can help entrepreneurs to create new markets for attaining ventures growth. Entrepreneurs can find sustainable opportunities using materiality to enhance their businesses growth by balancing social, economic, and environmental aspects. The extant literature has scantly examined the factors that impact the venture sustainability and growth. Therefore, the studies can focus on providing an in-depth analysis on factors that can help the entrepreneurs to gain sustainability and growth of their ventures. Government policies also influence the sustainability of ventures performance. Therefore, future studies can also focus on various government policies that influence venture sustainability and growth.

Technology transfer. Technology transfer has an impact on innovation potential and technology adoption by entrepreneurs and helps to implement the project effectively. However, entrepreneurs can utilize emerging technologies to enhance the effectiveness and efficiency of technology transfer. Additionally, future studies can explore the key success factors that impact the success of technology transfer initiatives in entrepreneurial firms, including factors related to innovation, collaboration, and knowledge management. Technology transfer can help firms to meet environmental regulations, while simultaneously facilitating the creation of new products and expanding their market opportunities. Future studies can provide insights into implacable policy and practice aimed at promoting successful technology transfer initiatives in entrepreneurial firms for enhancing their firm performance.

Government policies. Government policies aim to support entrepreneurship growth through eliminating the challenges faced by firms and provide critical support required by firms. However, very scant literature has examined the challenges faced by firms and critical support required for entrepreneurial firms' growth. The studies have explored the impact of government policies on start-up rates at national and regional levels (Dai and Si, 2018; Minniti, 2008). However, such policies can also impact the existing entrepreneurial firms. Therefore, future studies can explore the impact of government policies on existing entrepreneurial firms. Further, government policy should encourage ventures' technological outwardness within a firm and improve their information communication technology (ICT) infrastructure to enhance their performance (Chege et al., 2020).

Implication and future research agenda on semantic network analysis

Based on the analysis of semantic network, Figure 7 presents a sequential mediation model. The model highlights the mediating impact of topic on the relationship between other topics. Previous studies have studied topic links such as government policy–gender roles (Ahl, 2006; Bastian et al., 2019), government policies–technological ventures (Fakhimi and Miremadi, 2022; Zarrouk et al.,
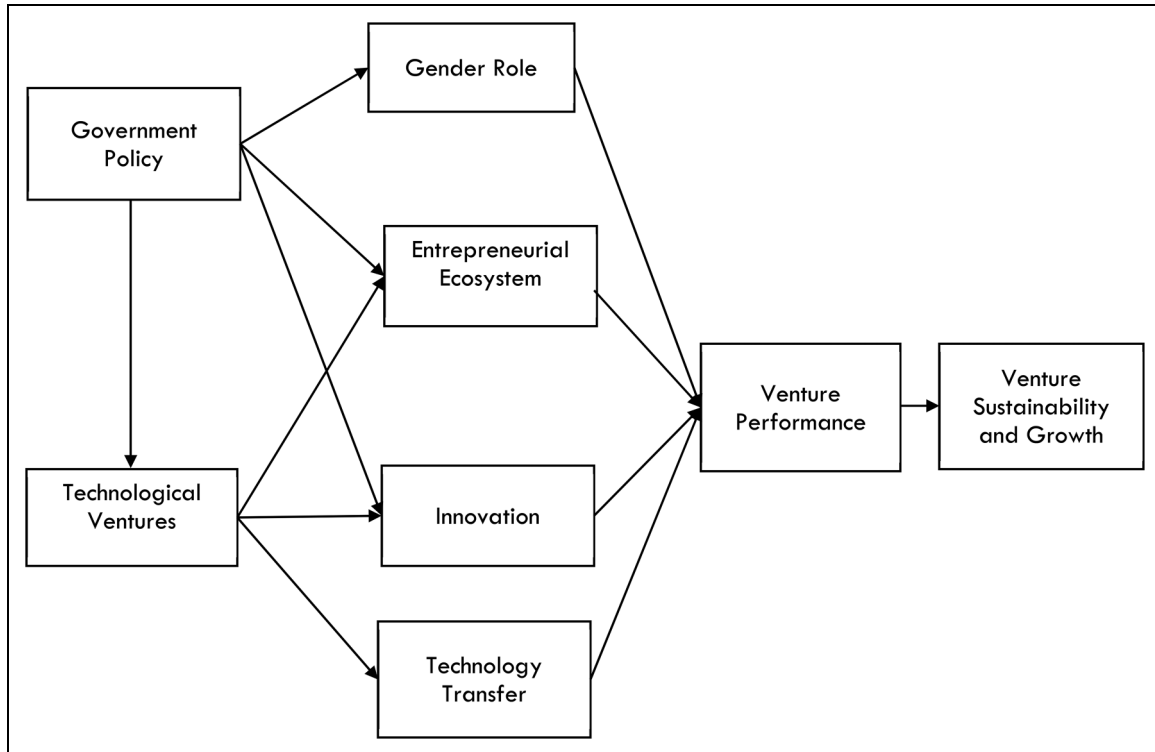
Figure 7. Sequential mediation model.

2021), technological ventures–entrepreneurial ecosystem (Upadhyay et al., 2022), innovation–venture performance (Abidin, 2022; Sudjatmoko et al., 2023), technology transfer–venture performance (Cui et al., 2006; Hafeez et al., 2023), venture performance–venture sustainability and growth (Haque and Ntim, 2022), and few others. However, limited studies have examined a holistic view of the relationship between these disciplines. Therefore, the proposed sequential mediation model represents a significant advancement in the field of semantic network analysis, providing a more comprehensive understanding of the complex interdependencies between topics and presenting a holistic view of their interdependencies. Gender role, entrepreneurial ecosystem, innovation, technology transfer, and venture performance may sequentially mediate the relationship between technological venture, government policy, and venture sustainability and growth of ventures. The identified linkages suggest an intricate interaction between various factors that may impact the venture's venture sustainability and growth. Therefore, future research can build on this study's findings by using the proposed sequential mediation model to analyze the complex relationships between various topics and their potential impact on venture success and venture sustainability and growth. Additionally, by understanding the relationships between these factors, industry experts can develop more effective strategies that promote sustainable growth in the performance of entrepreneurial ventures.

Conclusion

This study uses topic modeling approach to perform a systematic review of "entrepreneurship, technology, and innovation" literature in management research. SLR's reliability can be affected by subjective bias due to researchers' inclusion/exclusion criteria, while topic modeling uses unsupervised machine learning to identify themes objectively in large text datasets. Therefore, this study uses LDA method to identify key topics, and STM to identify the unique keywords, label the identified topics, and their coherence score. The study reviews 1407 articles published from 1975 to 2022. With the help of LDA and STM algorithm, the study identifies eight different clusters of published research, i.e., types of innovation, small venture performance, role of gender in digital entrepreneurship, entrepreneurial ecosystem, technological ventures, venture sustainability and growth, technology transfer, and government policies. Understanding the various types of innovation can help entrepreneurs and organizations to develop and implement effective strategies to stay competitive in the market and drive growth. The performance of a small enterprise is a major factor in determining whether an entrepreneur is successful, and study in this field can provide insights into how to enhance performance. The role of gender in digital entrepreneurship helps to understand the challenges faced by women entrepreneurs and helps to promote gender equality in entrepreneurship. The

entrepreneurial ecosystem encompasses the various factors that impact entrepreneurship, including government policies, access to finance, and cultural norms. Technological ventures focus on the development and commercialization of new technologies. Venture sustainability and growth present how to incorporate sustainability into business operations for achieving growth. Technology transfer involves the transfer of knowledge and technology from universities and research institutions to industry. Finally, government policies support entrepreneurship, innovation, and research, that has an impact on policy decisions that promote economic growth and development. Therefore, topic modeling and semantic analysis uncover the broader topic of published research that cannot be identified at the first glance.

Therefore, this study contributes to the existing research by utilizing a topic modeling approach to review the literature comprehensively and systematically on "entrepreneurship, technology, and innovation" in management research. Through the application of LDA and STM algorithms, this study identifies eight topics, which include types of innovation, small venture performance, entrepreneurial ecosystem, government policies, and their associated keywords. The semantic network analysis provides a visual representation of the interconnectivity between keywords from the identified topics, revealing deeper insights that may not be immediately apparent through traditional review methods.

Limitations

One limitation of this study is LDA does not consider the order of words or the grammatical role, that can result in the neglect of nuanced meanings that are carried by the entire sentence and the connections between its components. In this study, the findings are influenced by articles selected from Scopus database. Although the Scopus data contains 20% more articles, but for future research purposes, WoS database articles can also be used to perform the analysis. Further, the analysis was performed only on published journal articles, as they are considered reliable sources of information. The study does not consider books, unpublished articles, etc. Despite these shortcomings, the study has analyzed 1407 articles that help to identify and analyze the major topics. Although this study has conducted a thorough analysis of the identified topics it is limited in its exploration of these topics within the business, management, and accounting area. Future research can expand to other subject areas to uncover additional insights and advance the understanding of this complex relationship using LDA and STM. This can enable researchers to gain a more comprehensive understanding of the subject. Topic modeling is a popular technique used to identify latent topics present in a corpus of text documents. However, there are limitations to topic modeling that can make it difficult to identify recent emerging concepts. This study helps to identify the key topics of "entrepreneurship, technology, and innovation" and proposes sequential mediation model as a conceptual framework. Thus, it characterizes the area of study and highlights the key research questions that have been scantly researched for future research.

ORCID iD

Shiwangi Singh https://orcid.org/0000-0001-8693-5947.

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