Article

JIM
ISSN: 2183-0606
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Vol. 12, 1 (2024)
p. 109-138
AM: Apr/2024
SM: Sep/2023

Exploring Innovation Capabilities in Organizations through a Scientometric Approach in the Context of Manufacturing Industry

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Abstract

Over the last four decades, innovation capability has been studied to examine the innovation phenomenon based on the specific characteristics of organizations and systems under the theory of resources and capabilities. However, "capability" has diverse applications, and its correlation with innovation remains unclear. This study aims to clarify the definition of "innovation capability" in the context of the manufacturing industry and to comprehend how researchers presently investigate this concept. In order to meet this, an exhaustive search was conducted in the Scopus and Web of Science (WoS) databases, covering the period from 2018 to 2023. The selection of documents for analysis was determined by applying the scientometric method. The authors of this research identified 462 documents, and the bibliometric analysis, conducted using VOS viewer and Bibliometrix tools, revealed four main thematic areas within the research domain: sustainability, business performance, technology transfer, and knowledge management. As a result, this study identified the seminal authors of the concept. It provided a precise definition of "innovation capability", highlighting the significant interest that this research topic arouses in current academic literature.

Keywords: Technological Innovation Capabilities; Innovation Capability; Manufacturing; Scientometrics; Bibliometrics.

Cite paper as: Paipa, E.G., Escalante, F.S., Coronado, J. R., Adarme, W., (2024). Exploring Innovation Capabilities in Organizations through a Scientometric Approach in the Context of Manufacturing Industry, *Journal of Innovation Management*, 12(1), 109-138.; DOI: https://doi.org/10.24840/2183-0606_012.001_0006

1 Introduction

Innovation stands out as an essential capability in the pursuit of organizational competitiveness. It empowers the creation of transformative changes in economies and societies that can be differentiating or paradigm-shifting (Montoya Suárez, 2004; Olaya Dávila, 2008). Innovation is a systemic, social, economic, cumulative, and temporal phenomenon involving multiple actors' participation, generating uncertainty about environmental changes (Parayil, 1991).

Innovation is a component in manufacturing companies that improves production efficiency, reduces costs, and develops new products, among other benefits. Because of this, companies must identify threats and opportunities, address weaknesses, and leverage strengths in the constant pursuit of creating new and improved artifacts that seek competitive differentiation (Teece,

2007). Manufacturing companies can strategically direct their efforts towards areas of opportunity by understanding and comprehending market trends, changing consumer demands, emerging technological innovations, and the organization's innovation capabilities.

There are various approaches to analyzing the development of innovations. Some of them consider the interaction of actors, as suggested by the helix models (Carayannis & Campbell, 2010; Etzkowitz & Laydesdorff, 1997); another approach focuses on market needs, using the concepts of technological pull and push. Additionally, an approach focuses on identifying intermediaries in managing, transferring, and developing knowledge and artifacts (Ruiz Castañeda, 2016). However, one of the most relevant perspectives is the Resource-Based View (RBV), which focuses on the organization and its needs, conceiving the concept of innovation capability (Barney, 1991).

Due to the breadth of this concept, the application and measuring instruments of capacity vary considerably, and this diversity depends on the field of study. *Capability* refers to the combination of skills, knowledge, and experiences required to perform tasks and use resources (Castellanos Domínguez et al., 2011; Zapata Rotundo, 2020). Measuring technological and innovative capabilities will enable the company to make decisions and identify which areas of improvement are priorities. This is important because developing these abilities can help a company adapt to the constantly evolving business environment and gain a competitive edge through efficient and strategic resource management.

Nowadays, innovation capability analysis is conducted through dynamic frameworks that categorize organizations' capabilities and artifacts into two main components: ordinary and dynamic (Waleczek et al., 2019). Ordinary capabilities, as highlighted by (Teece, 2014), are assessable with physical and/or economic indicators, facilitating the evaluation of an activity's performance conducted by an artifact or system.

On the other hand, dynamic capabilities (DC) are evident in decision-making and internal relationships within organizations, resulting in superior performance that consolidates competitiveness through effective knowledge management, which is essential for creating and configuring artifacts (Teece, 2014). Accordingly, measuring the dynamic component of innovation capabilities is of great interest to the literature, as it is expressed as tacit knowledge due to the human component in decision-making that creates a superior performance that is challenging to replicate (Ali et al., 2012).

Considering the above, innovation capability is the capacity to manage both dynamic and ordinary capabilities (Vu, 2020). Developing these capabilities can enhance growth and adaptability, fostering the company's evolution.

In the manufacturing context, organizations continuously measure and size their capabilities due to the need to achieve efficiency, effectiveness, and productivity (Mičieta et al., 2021). Changes in the environment where manufacturing companies operate, such as digital technologies and sustainability (Beske, 2012; Zhang & Hartley, 2018), also influence the study of decisional and operational capabilities (Sansone et al., 2017). As a result, the observation approach to innovation capabilities shifts according to the analytical interest found within companies, environments, specific operations, or artifact studies.

Providing a precise and comprehensive definition of innovation capability proves challenging due to its broad application and academic evolution within dynamic frameworks. This has led to the analysis of the concept from specific perspectives, prompting literature reviews to focus on studying and understanding the innovation process and innovative capability of companies within specific thematic areas, such as firm size (Saunila, 2020), the relationship with ecology (Salim et al., 2019), or geographic factors (Bittencourt et al., 2019). This underscores the need to expand research on innovation capabilities from a more general perspective, particularly in the

manufacturing sector, aiming to gain a clear understanding of existing innovation capabilities approaches.

In this context, the present study seeks to address these gaps and offer a comprehensive view of innovation capabilities in the manufacturing industry. The authors of this research utilized a scientometric methodology to conduct the review, examining databases such as Scopus and Web of Science (WoS) to trace the evolution of the concept and identify prevailing study trends.

To ensure the successful accomplishment of the study's objective, the authors have addressed the following research questions (RQ)

> Q1: What is innovation capability for the manufacturing industry and what is its importance?
>
> Q2: What is the origin of the concept?
>
> Q3: Which study approaches does the current academic literature consider for innovation capability?

This study offers a valuable contribution to business management by clarifying and delineating the concept of innovation capabilities, particularly in the context of the manufacturing industry. By clearly defining these capabilities, the study enriches the academic domain. In the manufacturing industry, innovation capabilities go beyond merely generating new ideas or improving existing products, encompassing the ability to effectively implement these innovations in production processes, among other capacities. A comprehensive understanding of this concept is essential for companies to adapt and compete in an increasingly dynamic and changing environment.

Furthermore, by mapping existing knowledge on innovation capabilities, the study provides a solid foundation for academic professionals to delve deeper into the subject and develop new research. Although the results may be of greater relevance to academics, managers of manufacturing organizations can also significantly benefit from this knowledge by understanding and enhancing innovation capabilities within their own companies. Ultimately, this can substantially improve competitiveness and business success.

The rest of the article is organized as follows: Section 2 presents the methodology used during the study and the inclusion and exclusion criteria of the review. Section 3 is dedicated to presenting the results. Section 4 provides a detailed analysis of the results. Section 5 addresses the study's limitations and proposes directions for future research. Finally, Section 6 presents the main conclusions.

2 Methodology

This article adopts a methodology based on scientometric methods, which relies on bibliometric analysis (Amézquita López et al., 2011). The latter was used to conduct quantitative analysis and establish a framework for the state of the art in the field of study to clarify the current landscape. This methodology is justified by the wide range of statistical tools that bibliometric analysis offers to examine scientific production and understand the dynamics and impact of research in the relevant field of knowledge (Donthu et al., 2021). Bibliometric analyses enable the application of various data analysis techniques, such as citation analysis, co-citation analysis, keyword analysis, co-authorship analysis, and network analysis, which are important in this research (Donthu et al., 2021).

Following, the employed methodology is presented, which is grounded in the work of Kitchenham et al. (2010):

2.1 Inclusion and Exclusion Criteria

To ensure the relevance, timeliness, and ease of access to information, the authors of this research established the following selection criteria to determine the study sample:

(1) The inclusion criteria encompassed studies published within the five years, ranging from 2018 to 2023.
(2) The academic nature of the documents was a requisite for inclusion.
(3) The study excluded duplicate documents.

Because of the scientometric nature of the research, the authors did not comprehensively read all documents in the various repositories. Instead, they performed a superficial review of the entire sample, as the use of diverse academic databases required the elimination of duplicated documents.

2.2 Sources of Information

During the database selection process, the authors of this research considered the leading international search engines specialized in academic publications, namely WoS and Scopus. These engines enable the formulation of a preliminary search equation that can be refined by applying filters. Furthermore, they allow for the extraction, measurement, and clear identification of metadata within various records, facilitating scientometric analysis.

Table 1. Search engines

Databases	URL
Scopus	www.scopus.com (Accessed in December 2023)
Web of Science	access.clarivate.com (Accessed in December 2023)

2.3 Search strategy

Following the research objective, three keywords were considered, constituting the search equations applied to the selected search engines. The keywords in the first group pertain to the central research topic, capabilities; the second group comprises the specific object of study, companies; and the third group encompasses the specific study sector, manufacturing. Table 2 presents the terms utilized.

Table 2. Keywords and preliminary search equations used in the study

Group	Keywords	Search equation	
1	"Innovation capabilities" "Technological capabilities" "Technological innovation capabilities"	Eq. 1	"Innovation capabilities" OR "Technological capabilities" OR "Technological innovation capabilities"
2	“Companies” “Firm” “Corporation” "Enterprise" "Business"	Eq. 2	("Innovation capabilities" OR "Technological capabilities" OR "Technological innovation capabilities") AND ("Companies" OR Firm OR Corporation OR "Enterprise" or "Business")
3	“Product Performance” “Manufacturing”	Eq. 3	("Innovation capabilities" OR "Technological capabilities" OR "Technological innovation capabilities") AND ("Companies" OR Firm OR Corporation OR "Enterprise" or "Business") AND (“Product Performance” OR Manufacturing)

When developing the measurement of the document repository composed of search equation number 3 (Eq. 3), four thematic lines pertinent to the study of capabilities in the current context are delineated. Given the research objective, the scientometric analysis of the identified lines is integral to the study's goals. Consequently, four search equations were formulated using keywords discerned through analytical tools. Table 3 showcases the keywords alongside their corresponding search equation employed for extracting the record repository of the thematic lines.

Table 3. Keywords and search equations in the identified fields of study

Group	Keywords	Search equation	
3.1	Sustainability "Sustainable Development" "Green Innovation" "Economic Development" "Firm Size"	Eq. 3.1	("Innovation capabilities" OR "Technological capabilities" OR "Technological innovation capabilities") AND ("Companies" OR Firm OR Corporation OR "Enterprise" or "Business") AND (“Product Performance” OR Manufacturing) AND (Sustainability OR "Sustainable Development" OR "Green Innovation" OR "Economic Development" OR "Firm Size")
3.2	“Dynamic Capabilities" Collaboration "Firm Performance" "Market Orientation" "Competitive Advantage" "Research and Development"	Eq. 3.2	("Innovation capabilities" OR "Technological capabilities" OR "Technological innovation capabilities") AND ("Companies" OR Firm OR Corporation OR "Enterprise" or "Business") AND (“Product Performance” OR Manufacturing) AND (“Dynamic Capabilities" OR Collaboration OR "Firm Performance" OR "Market Orientation" OR "Competitive Advantage" OR "Research and Development")
3.3	"Developing Countries" "Industrial research" "Industry 4.0" "Investment" "Technology Transfer" "Innovation Performance"	Eq. 3.3	("Innovation capabilities" OR "Technological capabilities" OR "Technological innovation capabilities") AND ("Companies" OR Firm OR Corporation OR "Enterprise" or "Business") AND (“Product Performance” OR Manufacturing) AND ("Developing Countries" OR "Industrial research" OR "Industry 4.0" OR "Investment" OR "Technology Transfer" OR "Innovation Performance")
3.4	"Human Capital" "Knowledge Management" "Knowledge Sharing" Networks "Process Innovation"	Eq. 3.4	("Innovation capabilities" OR "Technological capabilities" OR "Technological innovation capabilities") AND ("Companies" OR Firm OR Corporation OR "Enterprise" or "Business") AND (“Product Performance” OR Manufacturing) AND ("Human Capital" OR "Knowledge Management" OR "Knowledge Sharing" OR Networks OR "Process Innovation")

2.4 Analytical tools

To eliminate duplicate documents and standardize the information extracted from search engines, the authors of this research utilized the bibliographic manager Mendeley and the Bibliometrix tool, executed in R-Studio version 4.3.0, complemented by Microsoft Excel. Subsequently, the authors measured consolidated datasets using VOSviewer version 1.6.19 and Bibliometrix software. The information consulted includes publication years, countries, institutions, journals, authors, areas of knowledge, document types, collaboration networks between countries, co-citation networks, co-occurrence networks, and co-authorship networks. Science mapping trees, keyword clouds, and the most cited references and documents were also analyzed. A significant portion of this data underwent processing in Microsoft Excel to enhance the quality of the figures that present the study's most critical results.

3 Results

In Figure 1, the sizes of the different document repositories to be studied in the research are presented:

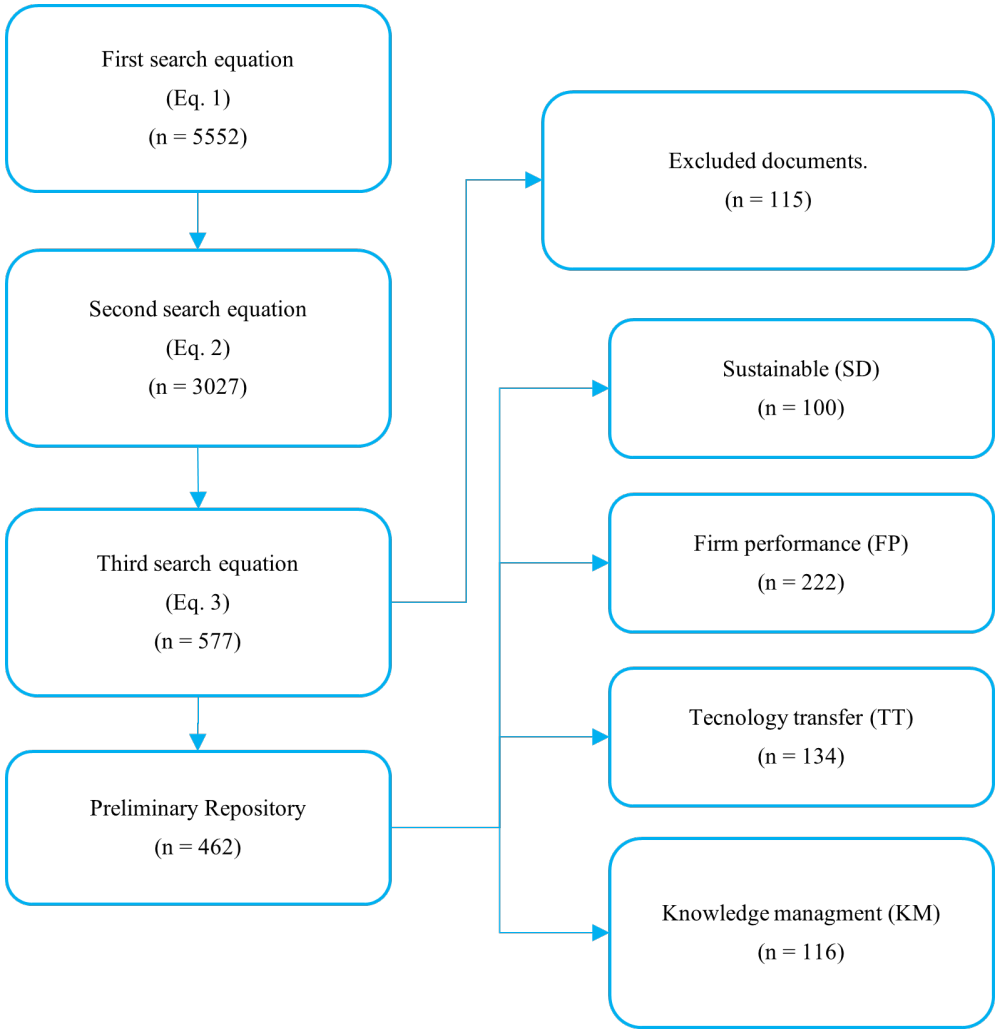

Figure 1. Sample Selection Process

3.1 Scientometric Analysis of the Preliminary Repository (Eq. 3)

Through methodological tracking, it was confirmed that the records obtained via search equation 1 (Eq. 1) span from 1969, totaling over 9,000 publications. Figure 1 highlights the significance of the research topic in academic literature, and by applying Equation 3, the number of found records is reduced to 979.

The investigated thematic areas revealed a high relevance for management (30%), followed by engineering (14.8%), computer science (14.5%), social sciences (12%), economics (10%), and decision sciences (7%). The distribution across these areas remains consistent in the three search equations to select the target document repository. Additionally, multidisciplinary studies have been identified, establishing connections between innovation capabilities in various industries. This has led to the expansion of thematic areas into fields such as medicine, agriculture, materials science, arts, and others, emerging as additional focal points in the study of innovation capabilities. In Figure 2, the distribution of located documents is depicted based on different areas.

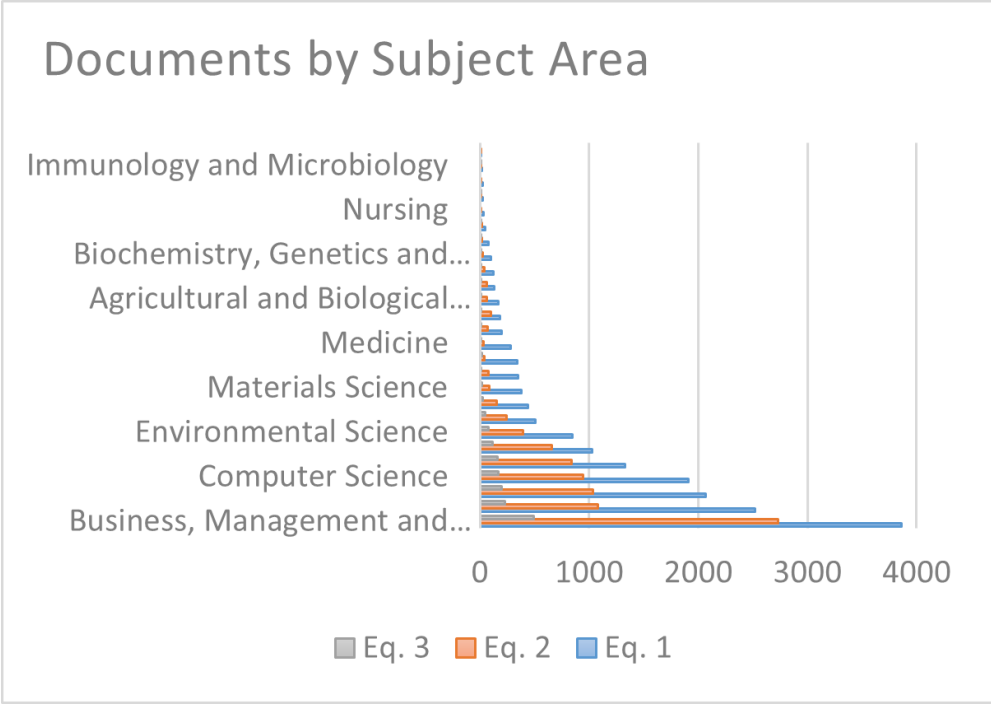

Figure 2. Documents by subject area

Focusing on the key document repository defined in Equation 3, it is evident that most documents identified through this equation are scientific articles. These articles primarily center on the empirical exploration of capabilities or theoretical development. Additionally, this repository contains documents corresponding to conferences, book chapters, and literature reviews. Figure 3 illustrates the number of publications by document type for each database.

China leads global research with 259 publications (35.2%) among countries with the highest scientific production. Following closely are Malaysia with 54 publications (7.3%), the United States with 46 publications (6.3%), South Korea with 39 publications (5.2%), the United Kingdom with 39 publications (5.2%), and Spain with 34 publications (5.2%). Colombia takes the lead in scientific production on a Latin American scale, contributing 18 publications (2.4% of global production).

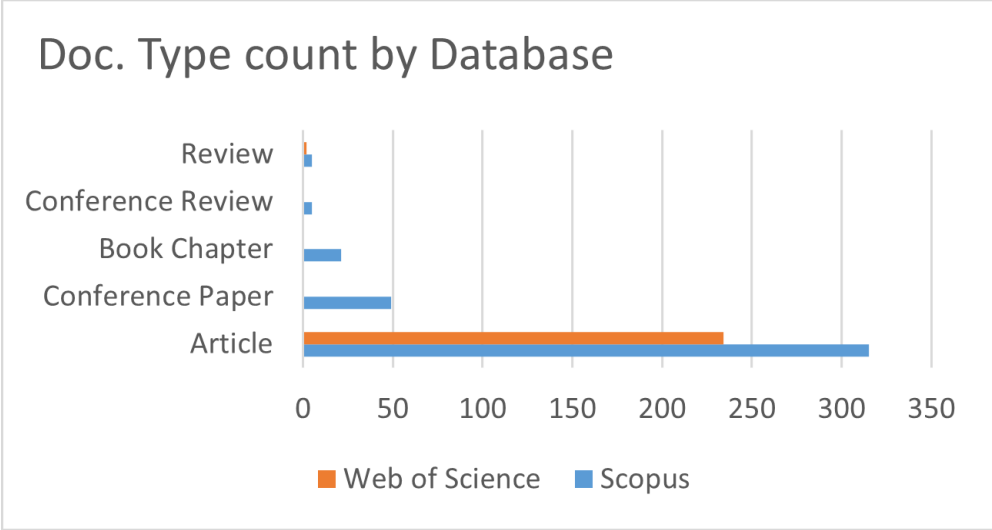

Figure 3. Number of publications by document type

Figure 4 reveals collaboration networks among various countries, indicating a multicultural interest in the study topic. This phenomenon underscores an active dialogue among diverse perspectives and a continuous exchange of knowledge on a global level, applied in different contexts in pursuit of technological development in global societies.

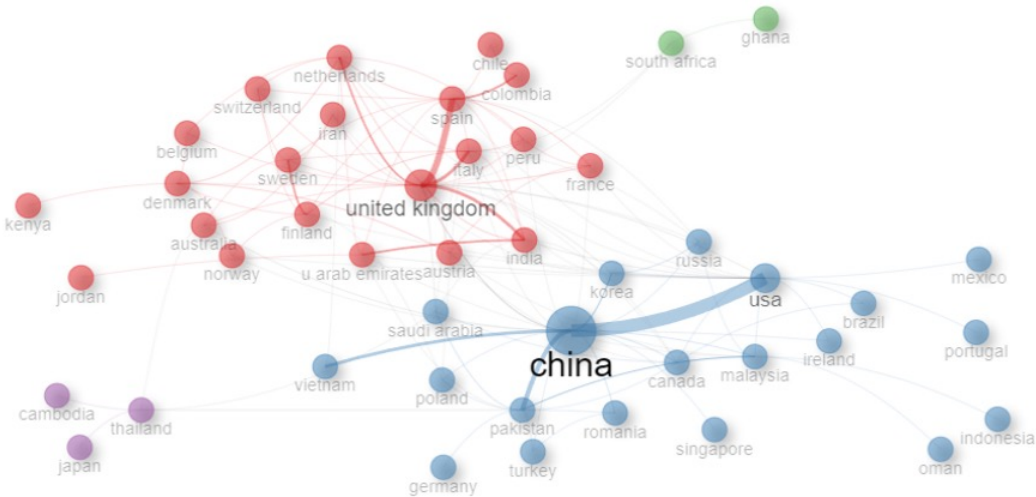

Figure 4. Map of correlations between countries

The co-authorship networks illustrated in Figure 5 show dispersion across multiple clusters of authors. This suggests that numerous studies encompass a specific thematic area or focus on a particular country's industry. Considering the topic's global relevance, various authors contribute diverse and enriching insights to the literature.

Figure 6 illustrates a knowledge tree that connects current publications, theoretical references, and relevant authors. On the right panel, keywords associated with the articles in the study repository are displayed. Among these keywords, terms such as "performance," "management," "R&D," "dynamic capabilities," "strategy," "industry," "enterprise," "knowledge," and "product" stand out.

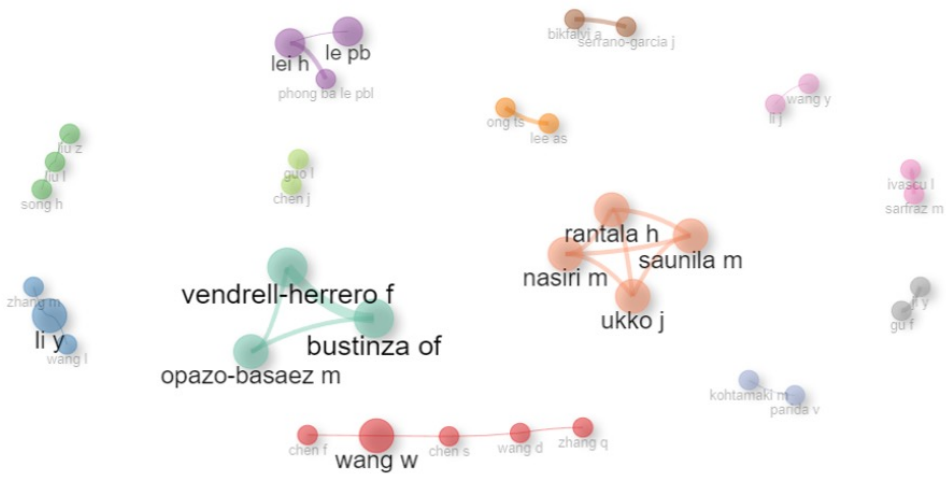

Figure 5. Co-authorship networks identified in the preliminary document repository.

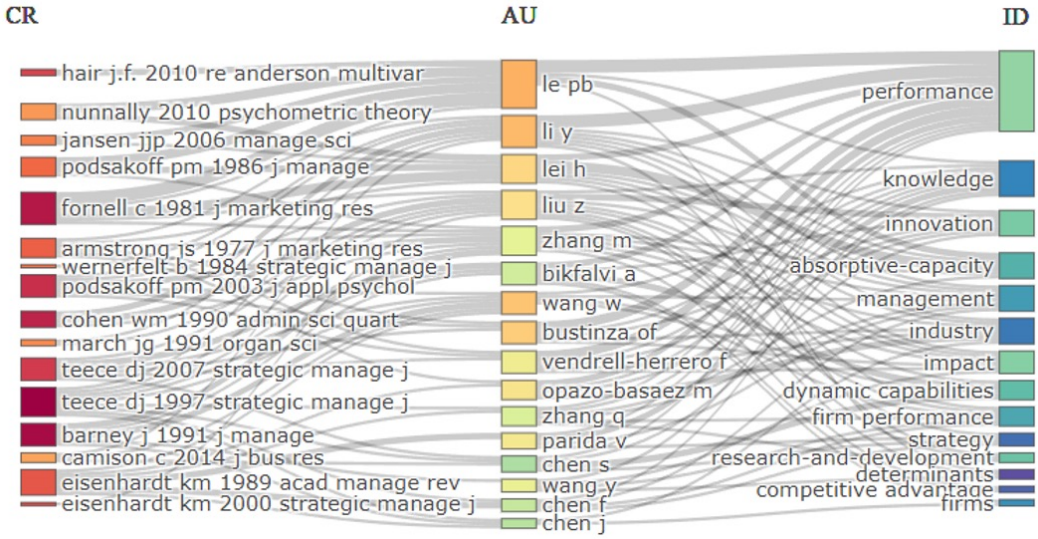

Figure 6. Science Tree from the preliminary repository.

In Figure 7, the co-citation network is presented, facilitating the identification of affinities among the sample documents. In this representation, groups with similar patterns are distinguished by different colors. These groups form through the interconnection of citations they share, enabling a clearer understanding of the relationships between documents, meaningful connections based on co-citation, and the influence of authors in the network. Among the most influential authors are Teece, D.J.; Barney, J.; Fornell, C.; and Podsakoff, P.M.

The records under study encompass a broad spectrum of topics related to innovation capabilities within organizations, contrasting with the current context and critical business areas subject to continuous improvement. The relevant areas of interest in studying innovation capabilities in the manufacturing industry include the following keywords: Manufacturing, innovation capability, manufacture, innovation, industrial research, sustainable development, and technological capability.

Figure 8 presents co-occurrence networks among the keywords authors utilize in academic literature within the selected document database. Five clusters of documents addressing different topics related to innovation capabilities can be identified, each represented by different colors.

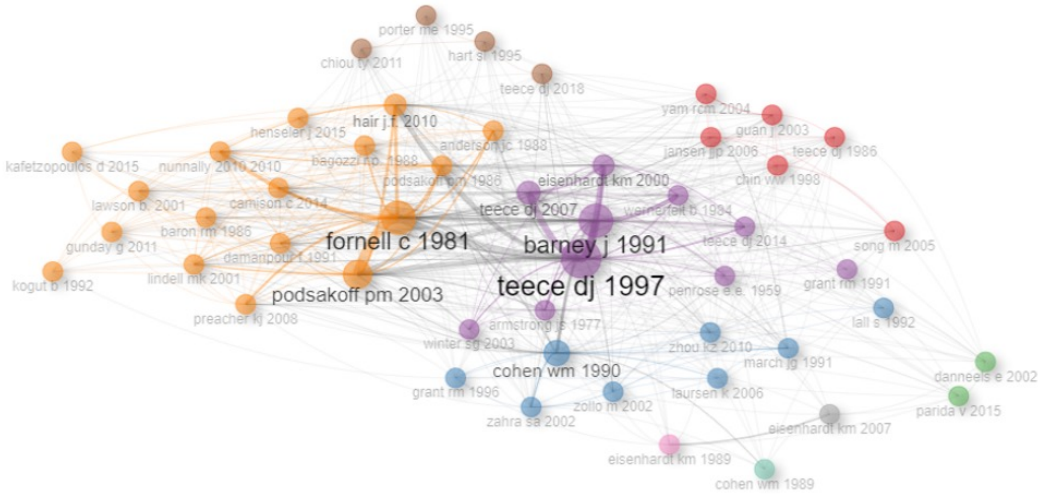

Figure 7. Identified Co-citation Networks.

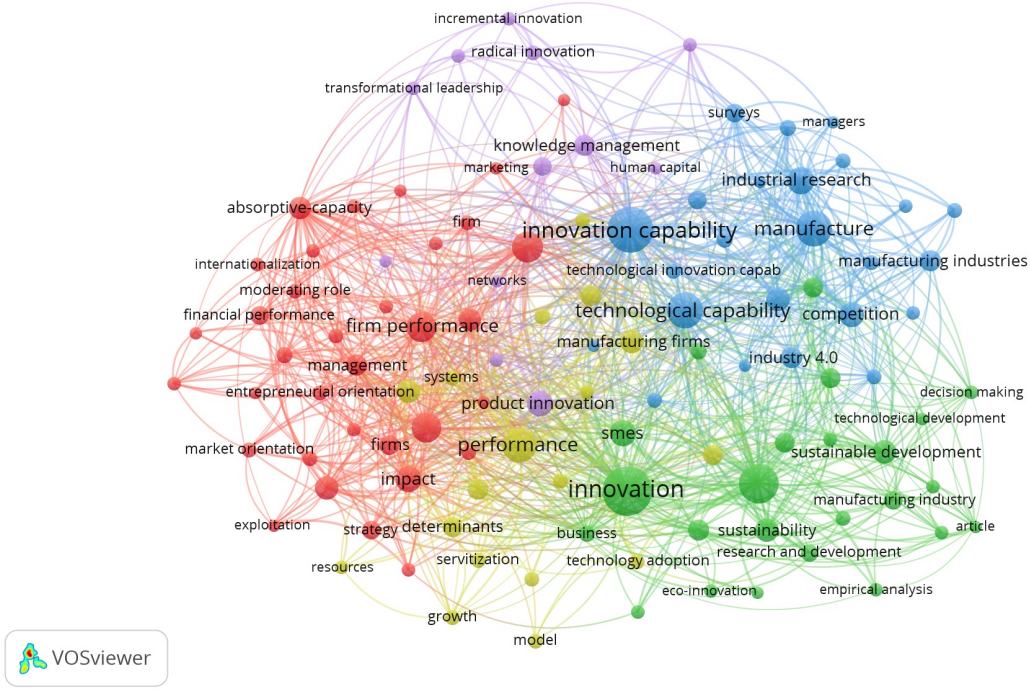

Figure 8. Co-occurrence Map.

3.2 Scientometric Analysis of the thematic lines identified in the study

The scientometric Analysis of thematic lines in this study suggests a division into four general approaches in the examination of innovation capabilities identified through the co-occurrence network. The scientometric investigation of these approaches constitutes a pivotal research objective. The software-identified results about keywords across different approaches have created four new document repositories through modifications to the search strategy. The specific details of these findings will be presented later. The following are the four approaches:

A. Innovation capabilities in manufacturing activities with a sustainability focus (SD) (Eq. 3.1).
B. Innovation capabilities in manufacturing activities focusing on firm performance (FP) (Eq. 3.2).
C. Innovation capabilities in manufacturing activities focusing on technology transfer (TT) (Eq. 3.3).
D. Innovation capabilities in manufacturing activities focusing on knowledge management (KM) (Eq. 3.4).

Upon examining scientific production by countries and journals, as illustrated in Table 4 and Table 5, it is evident that, on a global scale, the journal Sustainability and the country of China spearhead the leading contributors to publications. However, it is essential to note that the nations identified initially in the production phase continue contributing significantly across various thematic lines. Scientific production is distributed among countries in Asia, Europe, and America.

Regarding journals, a predominant focus on management themes is highlighted. Nevertheless, it is important to point out that the journal's breadth encompasses thematic areas that extend beyond, including environmental sustainability, economics, technological and innovative management, and knowledge management.

Table 4. Scientific Production by Countries

Sustainable Development (SD)		Firm Performance (FP)		Technology Transfer (TT)		Knowledge Management (KM)	
China	73	China	140	China	96	China	51
India	20	USA	40	South Korea	17	India	11
Malaysia	16	UK	37	UK	15	Malaysia	10
Spain	12	Malaysia	34	USA	15	Pakistan	10
Pakistan	11	Spain	31	Malaysia	14	Thailand	10
Romania	6	Italy	23	India	12	Spain	9

Table 5. Scientific Production by Journal

Sustainable Development (SD)		Firm Performance (FP)		Technology Transfer (TT)		Knowledge Management (KM)	
Sustainability (switzerland)	19	Sustainability (switzerland)	10	Sustainability (switzerland)	7	Sustainability (switzerland)	9
Business strategy and the environment	4	IEEE transactions on engineering management	5	Journal of industrial engineering and engineering management	4	Journal of business research	4
Environmental science and pollution research	3	Journal of business research	5	Journal of manufacturing technology management	4	Journal of manufacturing technology management	4

Sustainable Development (SD)		Firm Performance (FP)		Technology Transfer (TT)		Knowledge Management (KM)	
Journal of cleaner production	3	Environmental science and pollution research	3	Journal of cleaner production	3	Journal of knowledge management	3
International journal of environmental research and public health	2	European journal of innovation management	3	Kybernetes	3	European journal of innovation management	2
Administrative sciences	1	International journal of production economics	3	European journal of innovation management	2	Journal of business and industrial marketing	2

Figure 9 depicts keyword clouds for the four identified thematic lines.

Within these keyword clouds, terms such as manufacturing, industrial research, innovation capability, innovation, management, and research and development can be observed. This indicates that the research domain centers around management and innovation-driven activities, contrasting with the recurring keywords in the preliminary repository. It delineates the overarching scope of investigations regarding innovation capabilities within manufacturing enterprises.

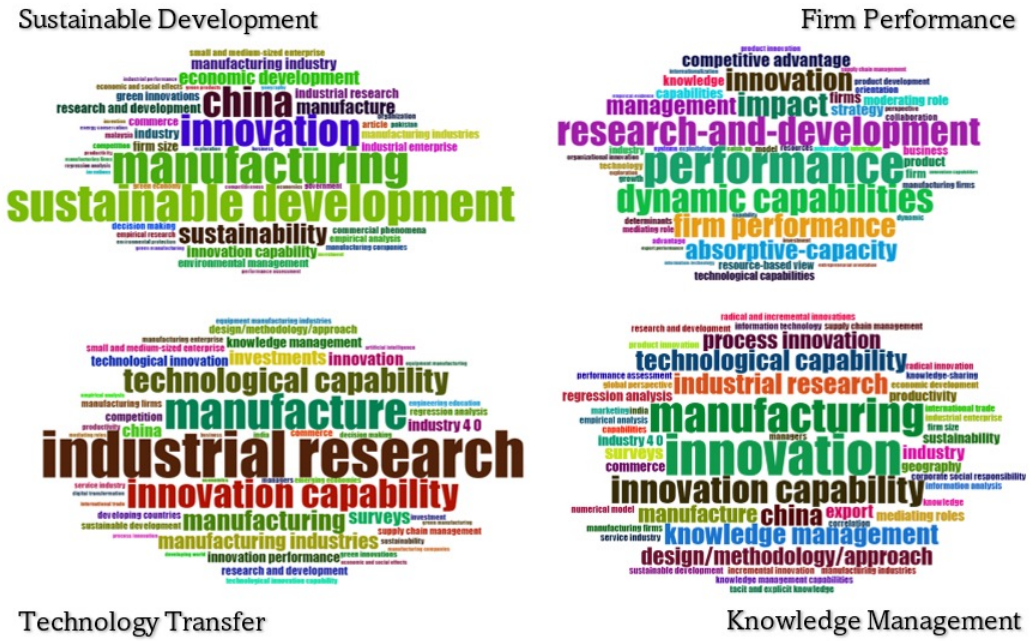

Figure 9. Word Clouds in the different identified thematic lines.

In keyword clouds, terms such as sustainability, performance, technological capability, innovation process, and knowledge management also stand out. These terms outline the study's focus on document repositories, addressing the capacity for innovation from the perspective of promoting cleaner and socially responsible technologies; innovation capabilities as a cornerstone of

organizational competitive advantage; innovation capabilities for technological development and process improvement; and innovation capabilities derived from knowledge and talent management.

Figures 10, 11, 12, and 13 illustrate co-occurrence networks of keywords, providing a richer analysis of the topics within each thematic line. Within the sustainability thematic line, the significance of exploring economic development, the impact of innovation, and the assessment methods for organizational competitiveness in clean technology and social responsibility become evident.

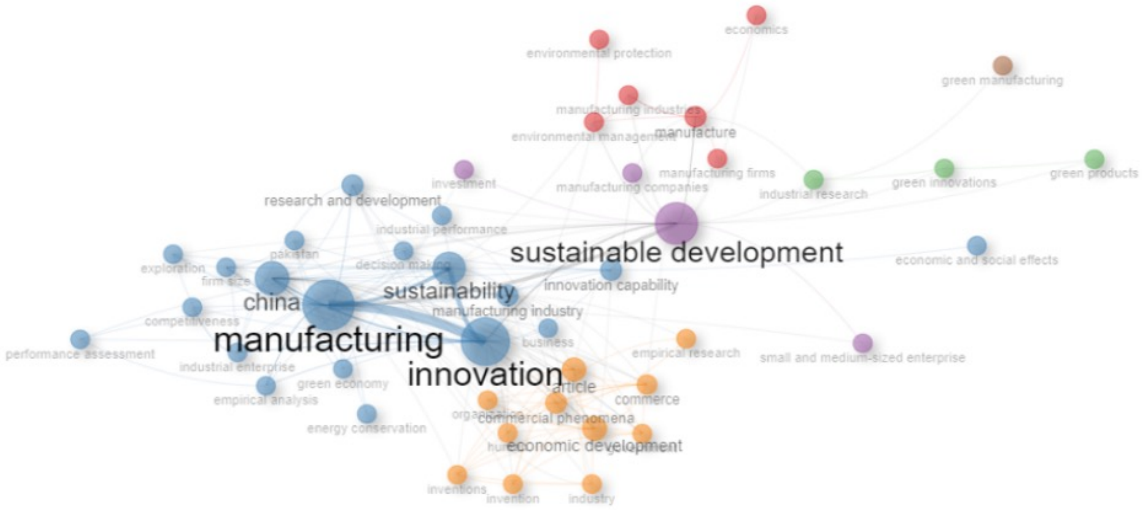

Figure 10. Co-occurrence Graph under SD Approach.

The network shown in Figure 11 represents the assessment of firm performance. Keywords like dynamic capabilities, performance, impact, absorptive capacity, and competitive advantage appear, indicating an examination of the essential characteristics that organizations must possess to cultivate technological and innovative capabilities. It is evident that the intent of the documents comprising this repository substantiates, tests, and advances the theory of resources and capabilities.

Figure 11. Co-occurrence Graph under FP Approach.

In the technology transfer approach, there is a clear interest in developing technological capabilities. This interest translates into assessing technology performance and analyzing the changes and improvements achieved through innovation. Furthermore, decisions and resources are scrutinized to manage technological change in processes and products.

Figure 12. Co-occurrence Graph under TT Approach.

Under the knowledge management framework, two clusters of terms are discernible. The blue cluster implies a focus on talent management and relationships for cultivating innovation capabilities, as well as the formulation of methodologies for assessing and quantifying the relationship between talent and innovation. In the red cluster, the perspective highlighted by the network emphasizes a systemic assessment of knowledge management, establishing a correlation between the knowledge harnessed for method and artifact creation and its enhancement of global societal and technological levels (Kongsvik et al., 2020).

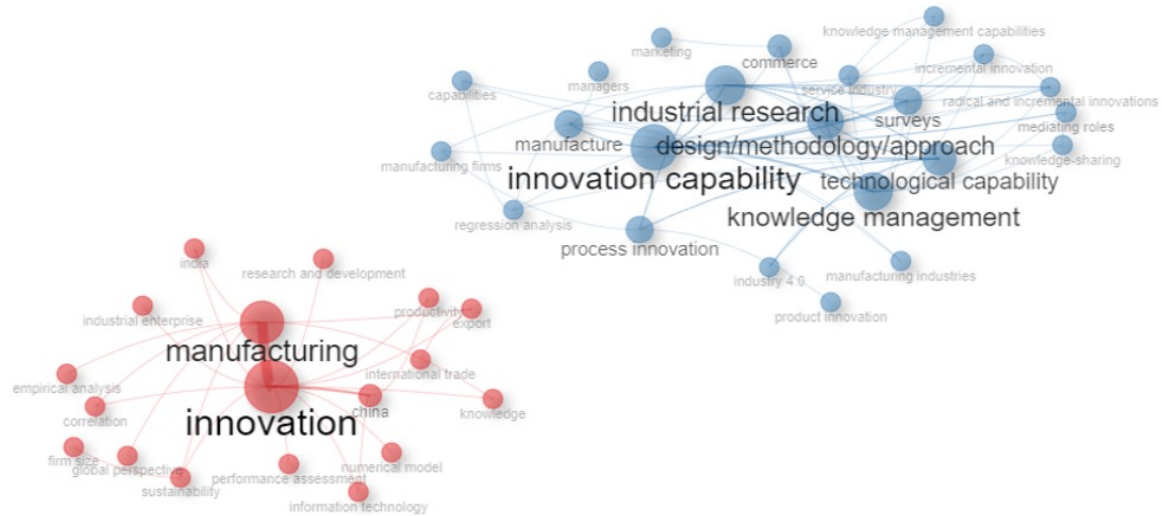

Figure 13. Co-occurrence Graph under KM Approach.

Figures 14, 15, 16, and 17 present science trees for the respective thematic approaches. The various trees clarify key terms that may be challenging to visualize in co-occurrence networks and in the word clouds presented earlier. Within the sustainability (SD) approach, new documents emphasizing the significance and benefits of the environmental perspective in business were observed (Porter & Van Der Linde, 1995).

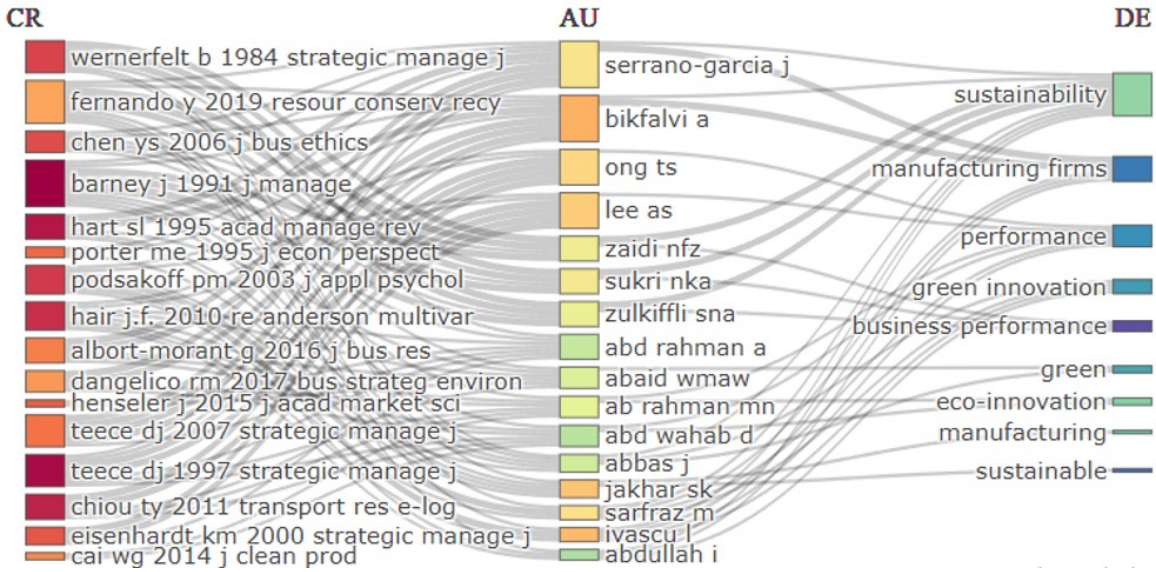

Figure 14. Science Tree under the SD Approach.

In Figure 15, the firm performance approach (FP) displays key terms associated with technology and innovation and the theory of capabilities and resources. The references align with those found in search equation 3 (Eq. 3), suggesting that this line of research is the primary focus of studies on innovation capabilities. Under this approach, the theory and its empirical testing methods for innovation capabilities are developed, although the results apply to the broader spectrum of industries and professional activities.

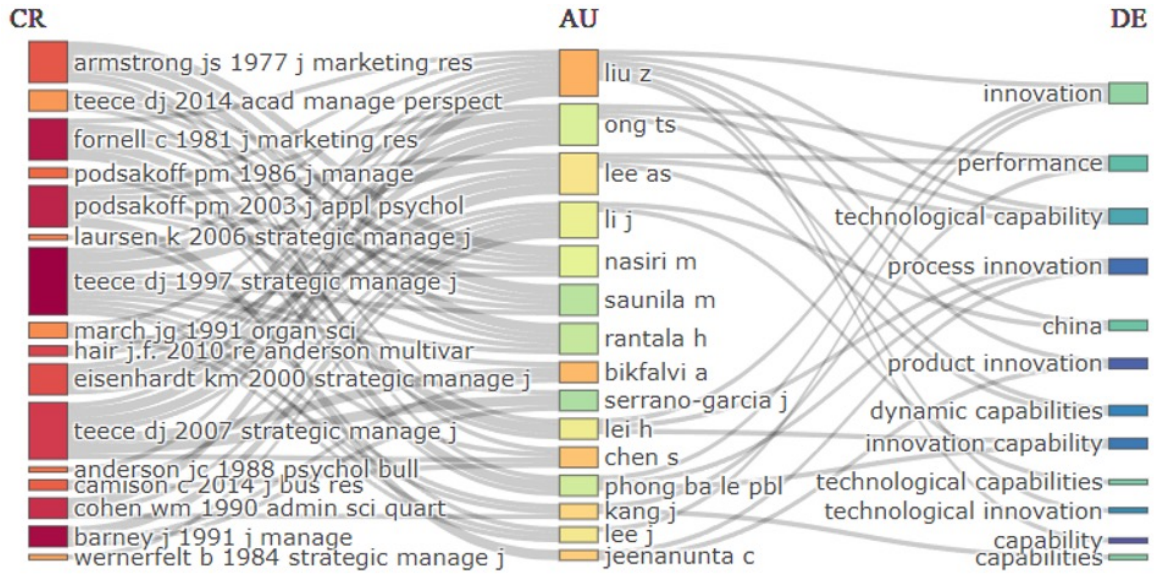

Figure 15. Science Tree under the FP Approach.

Regarding technological transfer (TT), the keyword "Industry 4.0" emerges as a current case study illustrating technological growth in societies. Other key terms, such as eco-innovation and resilience, can be observed, and these terms also encompass the study of processes and products susceptible to innovation. Regarding theoretical references, new documents like those by De Marchi (2012) and Haque et al. (1996) appear, focusing on studying technological transfer as

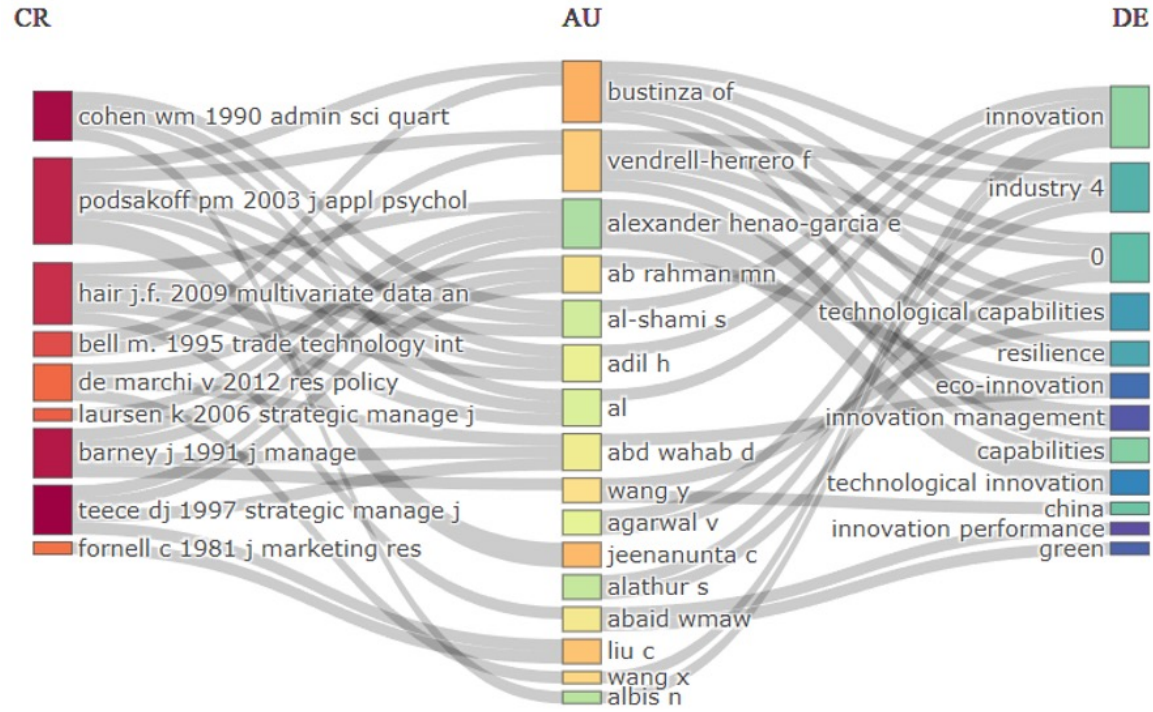

Figure 16. Science Tree under the TT Approach.

a transformative process for societies and emphasizing the need for diverse actors in innovation generation.

In the knowledge management (KM) approach, the innovative process and knowledge sharing are critical and significant. Regarding theoretical references, new documents such as those by Grant (1996) and Calantone et al. (2002) emerge, aiming to investigate innovation from the perspective of knowledge management and human talent. This establishes human talent as the most important resource for managing change and competitiveness.

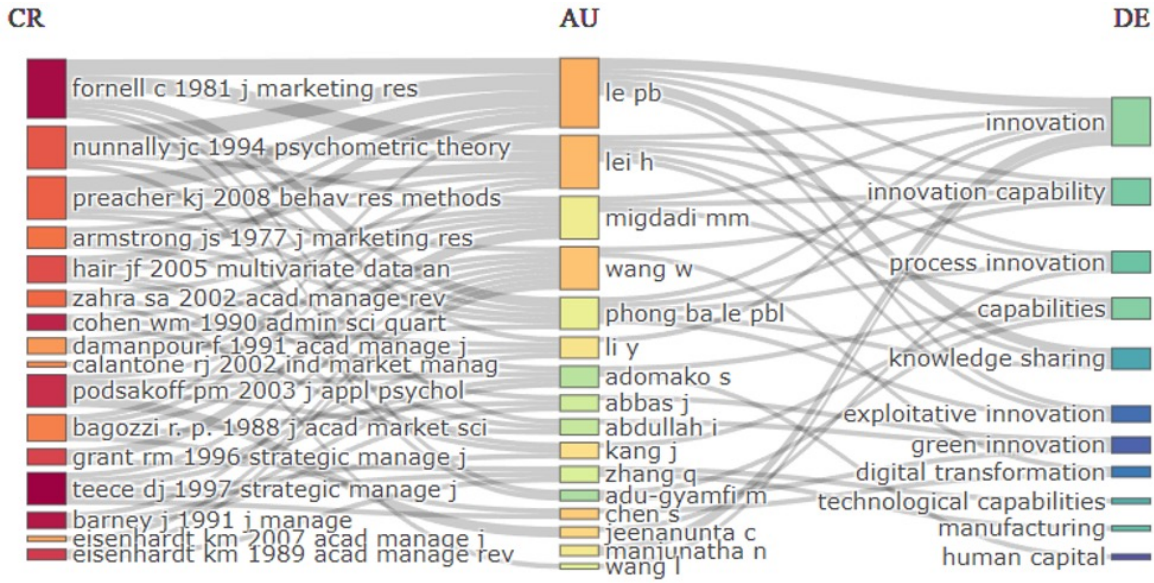

Figure 17. Science Tree under the KM Approach.

In Table 6, the most cited references by analytical approach are observable. Not all references appear in the science trees shown in the previous figures.

Table 6. Most cited references in document repositories by identified thematic approach.

Cites	Authors	Title	Year	Publisher	App
8	Grant, R. M.	Toward a knowledge-based theory of the firm,	1996	Strategic management journal	KM
7	Nelson, R.R. and Winter, S.G.	An Evolutionary Theory of Economic Change.	1982	Harvard University Press	TT
6	Bagozzi, R. P., & Yi, Y.	On the evaluation of structural equation models	1988	Journal of the academy of marketing science	KM
6	Haque. I.U., et al.	Trade, technology, and international competitiveness.	1995	World Bank Publications	TT
6	Calantone, R. J., Cavusgil, S. T., & Zhao, Y.	Learning orientation, firm innovation capability, and firm performance.	2002	Industrial marketing management	KM & SD
5	Baron, R. M., & Kenny, D. A.	The moderator–mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations.	1986	Journal of personality and social psychology	KM
5	Çakar, N. D., & Ertürk, A.	Comparing innovation capability of small and medium-sized enterprises: examining the effects of organizational culture and empowerment.	2010	Journal of small business management	KM
5	Chen, C.-J., & Huang, J.-W.	Strategic human resource practices and innovation performance—The mediating role of knowledge management capacity.	2009	Journal of business research	KM
5	De Marchi, V.	Environmental innovation and R&D cooperation: Empirical evidence from Spanish manufacturing firms.	2012	Research policy	TT
5	Frank, A. G., Dalenogare, L. S., & Ayala, N. F.	Industry 4.0 technologies: Implementation patterns in manufacturing companies	2019	International journal of production economics,	TT

Cites	Authors	Title	Year	Publisher	App
5	Fu, X., Pietrobelli, C., & Soete, L.	The role of foreign technology and indigenous innovation in the emerging economies: technological change and catching-up.	2011	World development	TT
5	Hart, S. L.	A natural-resource-based view of the firm.	1995	Academy of management review	SD
5	Horbach, J.	Determinants of environmental innovation—New evidence from German panel data sources	2008	Research policy	TT
5	Penrose, E.T.	The Theory of the Growth of the Firm.	1995	Oxford University Press	TT
4	Chen, Y.-S., Lai, S.-B., & Wen, C.-T.	The influence of green innovation performance on corporate advantage in Taiwan.	2006	Journal of business ethics	SD
3	Chiou, T.-Y., et al.	The influence of greening the suppliers and green innovation on environmental performance and competitive advantage in Taiwan.	2011	Transportation research part E: logistics and transportation review	SD
3	Day, G. S.	The capabilities of market-driven organizations.	1994	Journal of marketing	SD
3	Porter, M. E., & van der Linde, C.	Toward a new conception of the environment-competitiveness relationship	1995	Journal of economic perspectives	SD

Finally, Table 7 presents the most cited documents for the study period addressing innovation capabilities in manufacturing companies. The repository of Eq. 3 was utilized to extract these documents, which were identified within the document repositories derived through the various analytical approaches outlined.

Table 7. Most Referenced Research Papers

Cites	Authors	Title	Year	Journal	App
255	Najafi-Tavani, S., et al.	How collaborative innovation networks affect new product performance: Product innovation capability, process innovation capability, and absorptive capacity.	2018	Industrial marketing management	FP & KM
210	Dubey, R., et al.	Big data analytics and artificial intelligence pathway to operational performance under the effects of entrepreneurial orientation and environmental dynamism: A study of manufacturing organizations.	2020	International journal of production economics	FP & TT
113	Jakhar, S. K., et al.	When stakeholder pressure drives the circular economy: Measuring the mediating role of innovation capabilities.	2019	Management Decision	SD
108	Gupta, H., et al.	Barriers and overcoming strategies to supply chain sustainability innovation.	2020	Resources, Conservation and Recycling	SD & TT
88	Salim, N., Ab Rahman, M. N., & Wahab, D. A.	A systematic literature review of internal capabilities for enhancing eco-innovation performance of manufacturing firms.	2019	Journal of cleaner production	SD, FP & TT
87	Du, J., Liu, Y., & Diao, W.	Assessing regional differences in green innovation efficiency of industrial enterprises in China.	2019	International Journal of Environmental Research and Public Health	SD & KM
87	Ramanathan, R., Ramanathan, U., & Bentley, Y.	The debate on flexibility of environmental regulations, innovation capabilities and financial performance–A novel use of DEA.	2018	Omega	FP & SD
84	Peng, B., et al.	The cultivation mechanism of green technology innovation in manufacturing industry: From the perspective of ecological niche.	2020	Journal of Cleaner Production	SD

Cites	Authors	Title	Year	Journal	App
63	Zhang, M., et al.	Manufacturing practices and servitization: The role of mass customization and product innovation capabilities.	2020	11th International Conference on Operations and Supply Chain Management	TT
61	Wu, Y., et al.	Technological capability, eco-innovation performance, and cooperative R&D strategy in new energy vehicle industry: Evidence from listed companies in China.	2020	Journal of Cleaner Production	SD & FP

Taking into account the results obtained, each of the mentioned approaches is then addressed in detail:

3.2.1. Sustainability Approach

In the results by thematic areas, it is evident that sustainability is a critical approach. The keywords observed in Figure 9 and Figure 10 highlight the imperative for sustainable development, encompassing not only the creation of cleaner technology with reduced impacts but also linking to the concern of improving the living conditions of the civilian population. However, given the magnitude of the concepts and the volume of records observed, technology development through innovation capabilities aims to minimize impacts and conserve resources.

The references identified in Table 6 and Figure 14 establish the shift in the business environment due to concerns about sustainability in business activities. They emphasize the advantages of incorporating an environmental approach to work (Porter & Van Der Linde, 1995), the development of innovation capabilities to achieve cleaner technology (Dangelico et al., 2017), and the adjustment of the RBV to technological changes in favor of environmental protection with the Natural Resource-Based View (Hart, 1995).

In Table 7, identified and designated with the initials "SD" in the "App" column. The documents identified in the analysis period conduct empirical research linking firm performance to environmentally focused innovations from the perspective of capabilities. The authors of this document consider this thematic approach to have great potential for exploration and research. This is because innovation trends now involve addressing the reduction of environmental impacts in the design of products and processes driven by the climate crisis. Linked to environmental protection, there is a push for companies to incorporate corporate social responsibility as part of their organizational culture and image, reinforcing its significance in research.

3.2.2. Firm Performance Approach

Due to the differential quantity of articles highlighted in Figure 1, this research line can be considered the primary study objective related to the research topic. Market orientations of innovations serve as the primary analytical vehicle for measuring innovation capability, with its application evident in business management. In Figure 9 and Figure 11, concepts such as management, R&D, strategy, firm performance, dynamic capabilities, competitive advantage, and absorptive capacity, among many others, can be observed. In Figure 11, uniformity around the highlighted concepts is evident, and despite identifying word clusters, the connection between

different concepts is evident. Relevant areas of study for business management, such as investment, product development, and the supply chain, can also be observed.

A limited presence of new authors is identified when exploring seminal authors, and most cited references are observed in the scientific tree of the approach in Figure 15. This suggests a focus on the theoretical development of DC and RBV for the measurement and comparison of innovation capabilities across different organizations. Figure 15 also displays keywords that complement the analysis developed in the previously mentioned figures, such as various capabilities, innovation, small and medium-sized enterprises (SMEs) about manufacturing, and product innovation, which are the differential study objects concerning the development of innovation capabilities in diverse contexts.

The key documents are presented in Table 7 under the business performance focus "FP." These documents contribute to the theory by providing empirical evidence linking the development of dynamic capabilities and innovation capabilities with financial or product performance across various contexts and company sizes. They often extend beyond performance studies to connect with other approaches such as knowledge management, technology transfer, and sustainability.

3.2.3. Technology Transfer Approach

This approach examines innovations from the challenging technology component, where the knowledge of company-owned artifacts is explicitly expressed, known in detail, documented, and measurable using physical and economic indicators (Castellanos Domínguez, 2007). In Figure 9, the keywords used in this research approach include industrial research, technological capability, innovative performance, R&D, investment, and technological innovation, among others.

In Figure 12, different clusters of words related to manufacturing concerning sustainability, business models, and R&D are evident. A relevant field of study is the development of technological capabilities around Industry 4.0, where ordinary capabilities in artifacts emerge, such as vertical integration, virtualization, automation, traceability, flexibility, and energy management (Frank et al., 2019). In Figure 16, a sizable word cluster evaluates technological capabilities from multiple perspectives related to technology transfer, such as knowledge management, green manufacturing, innovation performance, trade-in manufacturing equipment, and market dynamics, composing the study of technology transfer. In the scientific tree of Figure 16 and Table 7, new reference documents are presented under this approach categorized with the initials "TT."

This research approach aims to measure the impact of complex technology on manufacturing companies and study the phenomenon of technological transfer from Industry 4.0, focusing on sustainability. A cursory reading of the documents in the respective repository addresses technology as a process that emerges from the business and social environment in which the artifact is launched. This fact establishes that the adoption or transfer of technology highlights organizations' innovation capabilities, whether formal or informal. It approaches the measurement of innovation capabilities according to the resources available to the organization (Market actors, artifacts, human capital, intellectual capital, technological systems) and the actors' decisions (Dubey et al., 2020; Qi et al., 2020). However, the authors' fundamental interest lies in understanding how innovation arises for technology creation, which factors influence changes in artifacts, and how these changes impact societies and their dynamics, excluding the analysis of ordinary capabilities obtained due to the innovation process. Technical studies on ordinary capabilities interest the literature within their respective knowledge areas. However, the topic of innovation capabilities has a distinctly managerial focus.

3.2.4. Knowledge Management Approach

This research approach examines innovations from the soft component of technology related to human resources and its expression of tacit knowledge (organizational structure and culture, planning, marketing, information management, talent management) (Castellanos Domínguez, 2007).

In Figure 13, two disconnected clusters of words are evident. The upper cluster addresses the innovation capacity within organizations focused on knowledge management. The lower cluster discusses innovations as a phenomenon that links actors from a global perspective, emphasizing a systemic exchange phenomenon. This approach highlights that human talent is essential for knowledge within the organization and monitoring the environment, aiming to focus strategy and resources on innovation in changing environments to make informed decisions (Vu, 2020).

In the science tree presented in Figure 17 and Table 6, the referenced documents in this approach are identified. These documents develop the theory around knowledge management for business performance and the means of evaluation to measure this human resource capacity. In Table 6, documents with the initials KM are shown as the most referenced. In Table 7 , the most cited documents analyzed in the current research are presented.

The documents presented in Table 7 focus on the concept of innovation capability, linking the role of top management, decision-making, organizational infrastructure, work methodologies, and individual capabilities and relationships in various contexts during work development (Du et al., 2019; Le, 2020). These studies are not confined to large organizations; evidence has also been examined regarding innovation capabilities in SMEs that have developed innovation due to market opportunities and their knowledge-intensive approach (Chu et al., 2019). This further underscores the interest in the technology transfer approach, where human relationships and knowledge utilization are essential for technology adoption and study. The authors of this research consider this thematic approach to be of great research interest. This is because working with the human factor, developing relationships within and between organizations, and talent management are fundamental axes for innovation and decision-making.

4 Discussion

The theoretical study of innovation capabilities emerged in the 1990s with the Resource-Based View (Barney, 1991; Wernerfelt, 1984). However, the concept of innovation capability surfaces in studies concerning the technological evolution of societies. Therefore, this capability is a technological capability that nations aim to develop to protect sovereignty and achieve international competitiveness (Lall, 1992; Rana, 1980). The authors of this document consider this initial approach to innovation capabilities appropriate, as changes occur within technological artifacts, enhancing their utility in problem-solving and subsequently transforming societies.

Regarding its definition, innovation capability is the capacity of an entity to generate and capitalize on ideas and knowledge (Dangelico et al., 2017; Lawson & Samson, 2001), materialized in the enhancement of technology applied to processes, operations, and products (Jakhar et al., 2019), and adapted to the changing conditions of the environment (Ramanathan et al., 2018; Salim et al., 2019). This definition is expected to be found in literature searches for the concept. However, related studies directly engage with dynamic capabilities, which offer greater clarity for observation due to the necessity of measuring organizational capacity.

The study of work is essential for the development of innovations (Salvato, 2009). This activity applies knowledge from a specific field of study, endowing it with ordinary characteristics that are explored in the search for improvements. Delving into the study of work broadens the

perspective, as it requires the consideration of the multidisciplinarity of the activity, integrating different fields of knowledge into the review of problems and the search for solutions. Cohen and Levinthal acknowledge that absorptive capacity is crucial for innovation, as it allows assimilating multidisciplinary knowledge to achieve radical and necessary changes in artifacts (Cohen & Levinthal, 1990). However, companies require more than the mere integration of knowledge to achieve innovation. Teese et al. assert that adaptability and learning capabilities are essential for change management and decision-making, thus establishing the three dynamic capabilities within the theory of resources and capabilities (Teece et al., 1997). As mentioned in the introduction, these three dynamic components of innovative capacity are sought to be measured to assess the likelihood of change that an organization can undertake to improve its competitive position.

The documents reviewed show a significant interest in developing measurement instruments for dynamic capabilities. Due to their tacit knowledge expression, establishing objective and replicable indicators to measure and compare innovative capacity within organizations presents challenges. Seminal documents identify quantitative measurement models for this purpose (Anderson & Gerbing, 1988; Fornell & Larcker, 1981; Hair JR et al., 2010; Podsakoff et al., 2003). One alternative to measurement involves considering financial indicators and comparing them with investments in human talent or patent production (Najafi-Tavani et al., 2018). The designed instruments are primarily aimed at enhancing competitiveness among companies in dynamic environments. Nevertheless, innovation capabilities encompass technical approaches related to the technological application of trending issues, such as sustainability or Industry 4.0.

5 Limitations and directions for future research

One of the significant limitations of the research is the difficulty in consolidating a document repository that includes other academic search engines. As specified in section 2, only Scopus and WoS were considered, as they are the only search engines that allow easy extraction of metadata contained in the found records. In academic search engines hosting scholarly publications, such as Redalyc, Scielo, Google Scholar, or JSTOR, the absence of a dedicated tool for information extraction can pose a challenge to data retrieval. This can lead to biases in the results, favoring documents published in the specifically selected engines.

While there was an intention to export documents published on other search engines to bibliographic managers for a more comprehensive and exhaustive analysis, these bibliographic managers need more features to achieve the objectives set in this research. This includes the absence of citation and reference tracking and compatibility with analysis software such as VOSviewer and Bibliometrix. Another approach could have involved manually extracting information from the records found across multiple search engines. However, this was not pursued due to the size of the results and the difficulty of accessing the content of different publications.

Regarding future work, it is suggested that the challenges encountered in using scientometric techniques be investigated and solutions developed that enhance the analysis through third-party software linking different search engines, bibliographic managers, software tools, and analysis instruments.

Concerning the research content, each of the identified thematic lines presents more specific approaches that could not be fully addressed in this document due to the scope and length of the research. It is suggested that each thematic line be explored individually or collectively using scientometric techniques or literature reviews to understand the applied concept according to the specific analysis context. Additionally, further investigation could delve into the connection

between the concept studied and uncovered in this research and different theories that study innovation, such as the helix theory or contingency theory.

6 Conclusions

The technological innovation capabilities in the manufacturing industry are a topic of great academic interest. Although no principal authors who explored and developed the literature were identified, multiple studies have been conducted linking different fields of knowledge, especially management. The studied concept aims to dimension, compare, and measure the innovative activity specific to an organization or system.

In this research, it has been found that the theme around innovation capabilities has evolved to identify four main research lines: sustainability, business performance, technology transfer, and knowledge management. These four lines are addressed from the Theory of Capacities and Resources, which examines the innovation process based on organizational characteristics linked to activities, human personnel, knowledge, and artifacts that organizations or systems possess.

This scientometric analysis provides a general overview of academic progress and serves as a guide for exploring innovation capabilities through the knowledge produced today. It is evident that innovation is not limited to the development of organizational capabilities but is also grounded in the study of the environment in which organizations are immersed, linking systematic and sectoral perspectives.

Acknowledgments

This research is part of the ECOTEA project— Development of an eco-friendly electric watercraft within the energy transition framework for inland waterway transportation of cargo and passengers on the ATR River—code 2243-914-91527. The authors express gratitude for the support provided by Minciencias in the development of this project.

Conflicts of Interest

The authors declare no conflict of interest.

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