COLLNET Journal of Scientometrics and Information Management
ISSN : 0973 – 7766 (Print) 2168 – 930X (Online)
Vol. 19(2) December 2025, pp. 229–253
DOI : 10.47974/CJSIM-2025-03005

Analysis of scientific productions regarding knowledge management with the open innovation approach

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Purpose: Societal and governmental evolution is strongly influenced by knowledge, information and communication technologies, innovation, and globalization. This study explores knowledge management through the lens of open innovation, using scientometric analysis and systematic review. It examines scholarly literature indexed in the Web of Science to uncover the critical dimensions and components of knowledge management within an open innovation framework.

Design/methodology/approach: This descriptive-applied research utilized both scientometric and systematic review approaches. In the scientometric phase, methods such as co-occurrence analysis, social network analysis, hierarchical clustering, and strategic diagram were applied. The systematic review employed PRISMA guidelines, content analysis, and coding strategies. Analytical tools included Excel, VOSviewer, UCINET, BIBExcel, and SPSS. The initial corpus comprised studies on knowledge management and open innovation (KMOI) indexed in Web of Science between 2006 and 2022. A total of 1,218 records were retrieved, from which 32 English articles and 29 Persian-language theses and papers were selected for review.

Findings: The mean growth rate of scientific productions during 2006 to 2022 was 24.829%, indicating a positive trend in scientific productions associated with KMOI. The keywords "performance, research and development, and absorptive capacity" had the most frequency and links and the keywords "manufacturing companies, open innovation methods and open source software" had the most citations; Following the co-occurrence analysis of 4187 keywords extracted from scientific publications by applying a co-occurrence threshold of 5, 8 clusters containing 367 topics and keywords were formed and identified.

Hierarchical clustering resulted in the formation of 5 clusters. Clusters of Knowledge management based on innovation and open innovation, and the requirements and consequences of open innovation are among mature clusters, clusters of innovation based on ecology and organizational performance based on knowledge and innovation are among developed clusters, and the cluster of knowledge management practices and processes with an open innovation approach has not yet reached maturity. A systematic review results led to the identification of 4 themes, 17 main categories and 316 subcategories. Among the identified codes, the codes "internal knowledge management capacity", "innovation capacity", "knowledge management capabilities", "information technology infrastructures", "innovative performance", "diversity in openness", "willingness to collaborate", and " Cooperation with suppliers and competitors" had the highest frequency, respectively.

Originality/value: This research has provided an overview of the important and growing issues in this field by drawing the existing knowledge related to knowledge management and open innovation. While creating a comprehensive perspective through the identification of the main topics and clusters discussed in this field, the research will be useful for those involved in the fields of research, education, and organizational managers. In other words, knowledge-based societies and organizations will be able to improve the level of learning, productivity, and create value by considering the concepts, themes, and categories identified in today's competitive environment.

Keywords: *Knowledge management, Open innovation, Open science, Knowledge-based, Scientometrics, Systematic review.*

1. Introduction

Knowledge management, information and communication technologies, innovation, globalization, and their interactions have been key contributors to societal and governmental advancement in the modern era. Similar to links in a chain, these factors have transformed the nature of competition for countries, organizations, and industries. Examples of this change are evident in the mechanisms of businesses, organizations, and many industries, such that the development of societies and organizations based on knowledge and technology, as well as the growth of societies and knowledge-based organizations in general, have accelerated tremendously over the past decade [1].

Innovation and creativity are two critical contributors to knowledge and, in turn, technology and knowledge management. Innovation involves the application of novel ideas arising from creativity, which may result in the development of a new product, technology, service, or solution. Innovation is crucial for organizations to generate value and sustain competitive advantage in the current complex and dynamic business landscape. Innovation is widely recognized as the primary driver of structural, content, and policy changes [2] Indeed, in the current era, where needs and the corresponding body of knowledge are in a constant state of flux, technologies are evolving and competition is growing. Organizations that consistently generate and implement innovative knowledge and technology are more likely to achieve success[3]. Knowledge is a necessary asset for enhancing an organization's innovation. Moreover, converting general knowledge into specific knowledge is imperative for attaining this objective. The analysis of internal and external knowledge flow can identify opportunities for organizational improvement and facilitate the generation of new ideas and knowledge.

Historically, the innovation process relied on internal intellectual resources. However, this process has undergone significant changes in recent years, particularly with the advent of smart technologies and digital transformation. As a result, a concept known as open innovation emerged, first put forth by Chesbrough in 2003 [4]. As defined by Chesbrough, open innovation involves utilizing knowledge inflow and outflow channels to expedite internal innovation and increase market reach for external benefits [4]. Open innovation refers to the notion that valuable ideas can come from both internal and external sources, and their commercialization can be facilitated by either internal or external means. Open innovation involves increasing transparency and permeability of organizational boundaries between organizations and the external world. Without question, open science is the foundation of open innovation. Open science encompasses practices such as freely publishing research, promoting open access, fostering open research, and disseminating scientific knowledge. Open science is a novel scientific approach that emphasizes collaboration and innovative methods of knowledge sharing facilitated by digital technologies and collaborative tools [5].

Open innovation requires organizations to identify, create, and utilize external knowledge sources as a core process because useful knowledge is vast and dispersed. Even highly capable organizations must engage in this process. On the other hand, the knowledge-based nature of digital transformation and its highly dynamic and variable characteristics necessitate modifications to the attitude toward and facilitation of knowledge management [6]. Optimizing the flow of knowledge within and outside an organization can be achieved through the precise design of knowledge management infrastructures and the appropriate utilization of its tools and mechanisms while adopting an open innovation approach. It is essential to consider the open innovation approach when developing an organization's knowledge strategy [7]. Recognition and integration of knowledge sources and strategic knowledge management are crucial principles in innovation. Organizations cannot solely depend on internal resources and research and development (R&D) due to the vast scope of science. They must also incorporate external resources, ideas, and technology [8]. It is vital to apply science-based knowledge management processes and open innovation approaches in modern times.

Numerous scientific publications have been produced and published about knowledge management and open innovation (KMOI) on reliable national and international databases. This topic has been explored from various perspectives across different fields. The co-occurrence technique, which examines the connection between words used in scientific productions, is a prevalent method for representing and analyzing knowledge structure in studies. Co-occurrence analysis is a prevalent scientometric technique that identifies thematic clusters, semantic and conceptual relationships, and knowledge structure in a research field [9].

Given the growing importance of open innovation and knowledge management in today's dynamic, knowledge-driven, and technology-centric landscape, there is a critical need to conduct scientometric analyses and systematic literature reviews of existing research. Although there is a considerable amount of literature on KMOI, it is scattered

and lacks a consolidated summary of findings. Therefore, a systematic review would help clarify the research status in this field and facilitate the categorization of research findings as to now.

The main objective of this study is to identify and analyze the concepts, themes, and categories of scientific publications concerning knowledge management that utilize an open innovation framework and are indexed in the Web of Science (WoS) database. The present study aims to address the following questions:

1. How has the number of publications and citations for scientific works pertaining to KMOI progressed over time?
2. What are the key concepts and topics most frequently discussed, have the greatest impact in terms of receiving citations, and are most commonly communicated in scientific productions related to KMOI?
3. What is the thematic approach and co-occurrence map of scientific productions pertaining to KMOI based on temporal overlap?
4. How does co-occurrence analysis contribute to the hierarchical clustering of scientific production topics related to KMOI?
5. What is the maturity and development status of the clusters derived from the co-occurrence analysis in the strategic diagram pertaining to scientific productions on KMOI?
6. What themes and categories result from the systematic review of scientific productions related to KMOI?

2. Literature Review

This section provides a comprehensive review of national (the context of Iran) and international research on KMOI. Notably, since the present study utilized a meta-study approach incorporating scientometric and systematic review methodologies, priority was given to identifying relevant research that employed these approaches.

2.1 *The Iranian Context*

Harouni, Farsani, and Sadeghi [10] conducted a survey to explore the mediating role of knowledge management processes in the relationship between open innovation and the implementation of knowledge management. The study population comprised managers and employees from the food industry within Shahrekord Industrial Town. The findings indicate that inbound open innovation does not significantly impact the internal knowledge management processes ($\beta = 0.084$, $p = 0.122$). Open innovation significantly impacts the external processes of knowledge management ($\beta = 0.164$, $p = 0.012$). Moreover, outbound open innovation significantly influences internal knowledge management processes ($\beta = 0.176$, $p = 0.008$). Balweh et al. [11] introduced a framework for knowledge management in

companies based on open innovation using the meta-synthesis method. This study extracted 55 codes, 16 categories, and 4 themes from a sample of 256 articles on the WoS database. The emerged categories encompass the establishment of technological infrastructures and knowledge management, the identification of a shared knowledge base and utilization of a reciprocal learning system, the promotion of intellectual property rights and safeguarding of common knowledge, and the ongoing enhancement of organizational performance in knowledge management. Farsani and Rahimpour [12] investigated the relationship between innovation and the implementation of knowledge management in gas transmission operations within Isfahan Province. They surveyed 84 managers and employees to gather data on knowledge management processes in this context. The study found that open innovation had a significant impact on knowledge management processes but a minimal impact on knowledge management implementation. The findings indicate that the gas transmission operations in the second zone of Isfahan province can effectively implement knowledge management by prioritizing internal and external ideas and knowledge management processes, as well as promptly responding to market demands (open innovation).

Yousufzadeh Konestani [13] investigated the influence of knowledge management systems on knowledge management capacity (KMC) within telecom companies, emphasizing the mediating effects of innovation capacity and open innovation.The study found a significant and positive correlation between the knowledge management system and KMC. The knowledge management system indirectly impacts KMC through the implementation of open innovation, which in turn contributes to KMC's development. Open innovation is directly related to innovation capacity and also indirectly and positively impacts innovation capacity through KMC. Asemani [14] conducted a survey-based study to examine the impact of KMOI on organizational sustainability in knowledge companies. The findings indicate a positive relationship between knowledge management and both open innovation and organizational sustainability. Additionally, a positive association was observed between open innovation and organizational sustainability. Knowledge management positively impacts organizational sustainability by fostering open innovation. Negarestani [15] conducted a survey to examine the role of open innovation in mediating the relationship between knowledge management systems and innovation capacity. The sample consisted of 177 managers from companies in Kerman's industrial town and Science and Technology Park. The study demonstrated a significant correlation between the knowledge management system and both open innovation and innovation capacity. According to Negarestani [15], effective measures to enhance innovation capacity include strengthening the knowledge management system through improved information technology infrastructure, employee training, and the employment of expert consultants. Additionally, fostering innovation can be achieved by engaging and promoting interaction between stakeholders, including customers, competitors, suppliers, stakeholders, and academic centers.

2.2 *International Context*

Oliva et al. [16] developed a model to analyze the risks associated with knowledge management in the context of open innovation. Through a systematic review of 72 articles complemented by interviews, they identified five principal risks: knowledge transfer inefficiency, value misappropriation, dependency (lock-in), and relationship-related risks. Furthermore, key barriers to effective knowledge management in open innovation were found to include motivational imbalances, mistrust and perceived injustice, cultural discrepancies, and overall complexity. The proposed theoretical model for knowledge management risks in open innovation is composed of four essential components: the identification of environmental factors, classification of relationship types, consideration of obstacles to knowledge management, and comprehensive risk assessment. Lam et al. [17] conducted a study titled "The Relation among Organizational Culture, Knowledge Management, and Innovation Capability: Implications for Open Innovation". The study utilized structural equation modeling to examine the impact of organizational open innovation culture on knowledge management practices and innovation capability. The findings revealed that a culture that fosters mutual trust, cooperation, and learning, facilitated by supportive and collaborative leaders, enhances the effectiveness of knowledge management practices and ultimately contributes to increased innovation capability within an organization. Santoro et al. [18] conducted a study titled "The Internet of Things: Building a knowledge management system for open innovation and KMC." The study used structural equation modeling on a sample of 298 Italian companies. The results indicated that a knowledge management system, achieved through internal KMC development, the creation of open and collaborative ecosystems, and the utilization of internal and external flows, facilitates knowledge transfer and enhances innovation capacity.

Wang and Xu [19] investigated the relationships between open innovation, customer knowledge management, and radical innovation. Furthermore, they examined the moderating effects of organizational learning capability on these relationships using structural equation modeling. The study sample comprised 165 service companies located in the Yangtze River Delta region of China. The results indicated that customer knowledge management exerts an indirect effect on radical innovation through the mediating role of organizational learning capability. Specifically, the effect of exploratory learning capability was found to be more significant. In their study titled "Knowledge-oriented leadership and open innovation: Role of knowledge management capability in France-based multinationals", Naqshbandi and Jasamuddin [20] utilized structural equation modeling to examine the relationships among knowledge-oriented leadership, knowledge management capability, and the resulting outcomes of open innovation. The findings suggest that higher levels of knowledge-oriented leadership are associated with enhanced knowledge management capability and improved open innovation results. Knowledge management capability serves as a mediator between knowledge-oriented leadership and open innovation. In their study titled "Knowledge Management, Knowledge Creation, and

Open Innovation in Icelandic SMEs", Grimsdottir and Edvardsson [21], while low-tech firms prefer outside-in strategies. This conclusion was drawn from semi-structured interviews with managers and employees, as well as field observation. In a survey conducted by Cui, Wu, and Tong [22], the researchers examined the impact of information technology-based absorptive capacity on new product development performance. They found that the combination of information technology-based absorptive capacity and idea openness positively influences new product innovation. Additionally, the interaction between absorptive capacity activated with information technology and open implementation speeds up the time it takes for products to reach the market. Lopes et al. [23] conducted an exploratory analysis to examine the relationship between organizational sustainability and KMOI. The study utilized informal observation, semi-structured interviews, and focus group discussions. The findings indicated that organizational sustainability is increasingly concerned with effectively managing new knowledge, ideas, and practices to enhance business growth. Open innovation is crucial for successful strategic sustainable management. It enables companies to implement knowledge management focused on assets that drive sustainable innovations impacting organizational sustainability. Last but not least, Natalicchio et al [24] conducted a systematic review entitled "*Knowledge Asset Management for Open Innovation*". This review examines open innovation processes and is structured into three sections: inbound open innovation processes, outbound open innovation processes, and the current understanding of open innovation processes.

2.3 *Summary of backgrounds*

The literature reviews, both domestic and international, indicate that the KMOI-related concepts and practices are effective and consistent ([25], [8]; [20]). Several studies ([15],[13]; [24]) have demonstrated the substantial impact of knowledge management systems on open innovation and innovation capacity. This impact enables knowledge exchange and promotes greater innovation capacity by fostering internal KMC, establishing open and collaborative ecosystems, and leveraging internal and external knowledge flows [18]. Meanwhile, enhancing the knowledge management system through measures such as bolstering information technology infrastructure, providing employee training, and engaging expert consultants can enhance innovation capacity. Additionally, fostering partnerships and interactions with customers, competitors, suppliers, beneficiaries, and academic centers can also be effective in promoting innovation. Companies and organizations adopt different strategies for knowledge management and open innovation based on their specific circumstances. Advanced technology companies tend to favor inside-out open innovation strategies, while low-tech companies prefer outside-in strategies. This is because internal open innovation positively impacts external knowledge management processes, while external open innovation positively influences internal knowledge management processes ([10]; [12]). From a different perspective, the three concepts of knowledge management, organizational innovation, and organizational sustainability have a positive feedback loop ([14]; [23]).

The research methodology review reveals that many studies have been conducted on KMOI using diverse approaches, methods, and tools from various dimensions and aspects. Most studies employ a quantitative approach, utilizing survey methods and structural equation modeling. Previous research differs from the current project in terms of methodology, purpose, and study population. Our study has identified the concepts, themes, and categories of KMOI through scientometric analysis and examination of scientific publications indexed in the WoS database. Moreover, a systematic review of reputable domestic and international scientific publications has also been conducted.

3. Research Method

A descriptive applied research study was conducted utilizing scientometric and systematic review methodologies. The scientometric phase incorporated co-word analysis, social network analysis, hierarchical clustering, and strategic diagram techniques. The systematic review phase was guided by the PRISMA framework and employed content analysis and coding methods. The initial study population comprised all relevant publications on knowledge management and open innovation (KMOI) indexed in the Web of Science (WoS) database between 2006 and 2022. WoS was used for scientometric analysis, as it is a comprehensive and valid database of scientific records. The database also employs strict criteria for evaluating and selecting journals[26]. The advanced search mode of the WoS database was used to retrieve related research. The search strategy employed in the topic field included the title, abstract, and keywords without language restrictions:

TS=((“Knowledge manag*” OR “knowledge creat*” OR “knowledge product*” OR “knowledge generat*” OR “knowledge acquisition” OR “knowledge storag*” OR “knowledge shar*” OR “knowledge transfer*” OR “knowledge exchange*” OR “knowledge disseminat*” OR “knowledge utiliz*” OR “knowledge extract*” OR “shar* of knowledge” OR “Experience* documenta*” OR “documenta* of experience*” OR “Knowledge retrieve *” OR “knowledge organiz*” OR “knowledge organis*” OR “Discover* of knowledge” OR “knowledge Discover*” OR “creat* of knowledge” OR “product* of knowledge” OR “generat* of knowledge” OR “ acquisition of knowledge” OR “storag* of knowledge” OR “transfer* of knowledge” OR “exchang* of knowledge” OR “disseminat* of knowledge” OR “utiliz* of knowledge” OR “extract* of knowledge” OR “retriev* of Knowledge” OR “organiz* of knowledge” OR “organis* of knowledge” OR “Experience* manag*” OR “ Knowledge Representative* OR “tacit knowledge” OR “implicit knowledge” OR “learn* lesson*” OR “lesson* learn*” OR “explicit knowledge” OR “Codified knowledge” OR “knowledge codificat*” OR “experience* transfer*” OR “ transfer* of experience*” OR “experience* transmission” OR “knowledge transmission” OR “learning experience*” OR “experience* shar*” OR “shar* of experience*” OR “teaching experience*” OR “knowledge documentat*” OR “document* of knowledge” OR “experience* exchange*” OR “exchang* of experience*” OR “experience* disseminat*” OR “disseminat* of experience*” OR “experience* utilize*” OR “experience* extract* OR “utilize* of experience*” OR “extract* of experience*” OR “data manag*” OR “data shar*” OR “data transfer*” OR “data exchange*” OR “data disseminate*” OR “shar * of data” OR “transfer* of data” OR “exchange* of data” OR “disseminat* of data” OR “data transmission” or “information manag*” OR “information shar*” OR “information transfer*” OR “ information exchange*” OR “information disseminat*” OR “shar* of information” OR “transfer* of information” OR “exchang* of information” OR “disseminat* of information” OR “information transmission” OR “data analysis” OR “ information analysis” OR “analysis of data” OR “analysis of information”) AND (“open innovation*”))

A total of 1,218 records were identified using the aforementioned search strategy. The records obtained from the WoS database were retrieved in plain text format. In the sciencemetric section, subsequent to retrieving relevant records and integrating the data,

data were analyzed using concordance analysis, social network analysis, and HistCite software. Furthermore, Excel, VOSviewer, UCINET, BIBExcel, and SPSS software tools were utilized to analyze and answer the first through fifth research questions. Co-occurrence analysis—a content analysis method—examines the co-occurrence of words with concepts in texts and documents. This approach enables the identification of key concepts within a scientific field. Such knowledge facilitates the identification of patterns and conceptual developments in a field, as well as the construction of the scientific structure, conceptual network, hierarchical relationships of concepts, and their application in the management of the field. In essence, word co-occurrence analysis serves as a tool for uncovering latent patterns and emerging conceptual events [27].

It is important to acknowledge that in the context of co-occurrence analysis, a terminology list was developed during the data pre-processing stage to regulate and standardize keywords. This involved removing similar or identical keywords, ensuring consistent plural and singular forms, and eliminating non-specialist keywords from the entire set of extracted keywords. Hierarchical clustering is commonly employed to conduct concordance analysis. It allows for the identification of clusters associated with each keyword and reveals the relationships between them. In this study, hierarchical clustering was conducted using SPSS. This method organizes data in a tree-like structure, where smaller clusters are progressively nested within larger clusters, ultimately merging into a single main cluster at the root of the hierarchy [28].

To analyze word co-occurrence, it is essential to first construct the necessary components, including the co-occurrence matrix. This matrix is then converted into a correlation matrix to facilitate further analysis. For matrix preparation, keywords occurring at least four times were selected, resulting in the creation of a 123-by-123 square matrix. The diagonal elements of the matrix were set to zero before transformation into correlation matrices. Concept clustering was subsequently carried out using SPSS statistical software (version 26).

The strategic diagram of thematic clusters was drawn as the next step. In order to create a strategic diagram, separate matrices were formed for the keywords of each cluster derived from the hierarchical diagram. Subsequently, the centrality and density of the clusters were assessed through the use of UCINET software. Finally, a strategic diagram was constructed. A strategic diagram depicts the interconnections and correlations among various thematic clusters. The diagram employs the horizontal axis to represent centrality, which measures the degree of cluster correlation. The vertical axis, on the other hand, represents density, which indicates the level of internal communication within each cluster. In co-occurrence analysis with VOSviewer software, clusters are formed based on similarity in connections and distance to different words. In hierarchical co-occurrence analysis, a word similarity index is used hierarchically, and the interpretation index line is drawn with input from a subject-matter expert. As such, in concordance analysis, the number of clusters is generally reduced, and the labels assigned to these clusters tend to be more general.

In the systematic review stage, 1,218 records were retrieved and examined. Specifically, scientific productions in the form of journal articles written in English were considered. Moreover, Persian keywords were employed alongside the English search strategy to

incorporate relevant Persian research into the systematic review section. Persian databases, including SID, Noor Mags, Magiran, Civilica, Ganj, National Library, and Elmnet, were searched using Boolean operators.

Subsequently, a decision was reached regarding the integration of scientific publications into the research community. This decision was based on the evaluation of the stages outlined in the PRISMA model and the relevance of the full text of these publications to the subject of the current research, i.e., KMOI. A total of 32 English articles and 29 Persian articles and dissertation theses were included in the systematic review. This study's analysis unit was the sentences included in the research under review. In order to extract related themes and components, the content analysis method and coding techniques were applied in addition to collecting bibliographic information. Subcategories (codes) relevant to the research topic were derived at the conclusion. Lastly, themes and main categories were identified through a two-step coding process.

4. Findings

This study analyzed scientific publications on KMOI to address the above research questions. Two approaches were used: scientometrics to answer the first to fifth questions and systematic review and content analysis to answer the sixth question.

Answer to the first research question. How has the number of publications and citations for scientific works pertaining to KMOI progressed over time?

A search of the WoS database using HistCite software identified 1,218 scientific publications indexed between 2006 and 2022. The figure presented below illustrates the growth of research in terms of the number of publications and citations over time.

As shown in Figure 1, the earliest KMOI-related research dates back to 2006. Research publications experienced steady growth until 2014, followed by a relatively upward trend

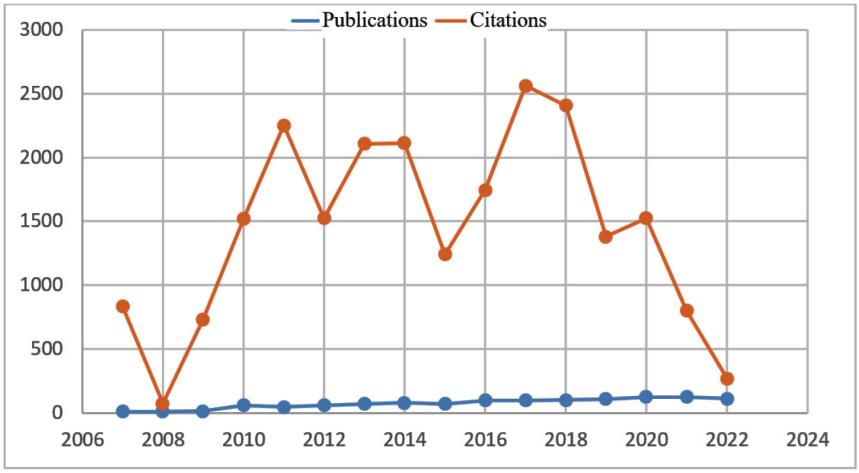

Figure 1

Growth based on the number of productions and citations by year

from 2015 to 2022. The publication peak occurred in 2020, 2021, and 2022, with 123, 121, and 110 scientific publications, respectively. The mean growth rate of scientific productions during this period was 24.829%, indicating a positive trend in scientific productions associated with KMOI. Moreover, the lowest number of citations was 73 in 2008, while the highest number amounted to 2,561 in 2017. The citation growth during this period was 67.119%, indicating the significant impact of scientific productions in this field.

Answer to the second research question. What are the key concepts and topics most frequently discussed, have the greatest impact in terms of receiving citations, and are most commonly communicated in scientific productions related to KMOI?

VOSviewer software was used to analyze the scientific records retrieved from Web of Science and to identify the predominant topics within the scientific literature related to knowledge management and open innovation (KMOI). We considered factors such as frequency (occurrence), impact (citation), and communication. A concordance analysis of 367 keywords from scientific productions in this field was conducted. Homogenization of topics and a co-occurrence threshold of 5 were applied. The most important topics were identified based on co-occurrence, communication, and impact (citation) indicators (Table 1).

Table 1 reveals that the keywords *performance*, *R&D*, and *absorption capacity* are the most prevalent in the field under investigation. This indicates that researchers have primarily focused on studying and examining these topics. Furthermore, these keywords exhibit the highest level of communication within the scientific research pertaining to KMOI. Consequently, these topics possess significant potential for communication and integration with other research areas in this field. Additionally, *manufacturing companies*, *open innovation methods*, and *open-source software* have garnered the highest number of citations in scientific production in this field.

Table 1

The most important topics in terms of co-occurrence, impact, and communication in scientific productions related to KMOI

Index	First rank (frequency)	Second rank (frequency)	Third rank (frequency)	Fourth rank (frequency)	Fifth rank (frequency)
Co-occurrence	Performance (319)	R&D (254)	Absorption capacity (226)	Innovation (189)	Management (162)
Communication	Performance (336)	R&D (308)	Absorption capacity (300)	Management (293)	Innovation (286)
Citation	Manufacturing companies (209)	Open innovation procedures (157)	Open-source software (148)	Organizational ambidexterity (86)	Local research (78)

Answer to the third research question. What is the thematic approach and co-occurrence map of scientific productions pertaining to KMOI based on temporal overlap?

In order to create a co-occurrence map of topics and analyze the thematic approach of scientific productions on KMOI, all relevant publications from WoS were inputted into VOSviewer software. Vocabulary co-occurrence techniques are widely used in scientometrics. The vocabulary co-occurrence technique can reveal the intellectual structure of a subject area. The frequency of co-occurrences indicates the scientific community's focus and identifies research hotspots within a given field [29]. A co-occurrence analysis was performed on 4,187 keywords extracted from scientific publications pertaining to knowledge management and open innovation (KMOI). A co-occurrence threshold of 5 was applied, resulting in the formation and identification of 8 clusters. These clusters contained a total of 367 topics and keywords. Figure 3 displays the co-occurrence map derived from time overlap. The size of the nodes represents the frequency of use of concepts in describing the works, while the color of the nodes indicates the clustering of concepts. In this map, the proximity and spatial arrangement of the keywords indicates the degree of conceptual interconnectedness.

On the other hand, based on Figure 3, KMOI-related scientific productions in the world cover a variety of topics. The topics can be categorized into 8 thematic clusters: business development through increased competitiveness and research and development procedures; open innovation procedures based on advanced technology; knowledge creation strategies based on innovation in industries and services, the perspective of the

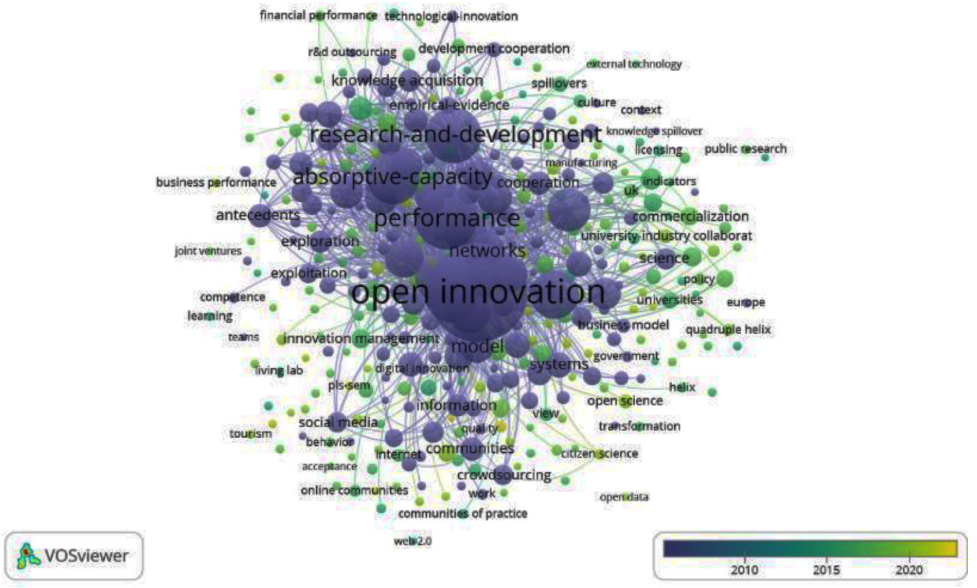

Figure 2

Co-occurrence map of vocabulary in scientific productions related to KMOI based on temporal overlap

Figure 3

Hierarchical clustering of KMOI-related scientific productions

knowledge-based economy, implementation of knowledge management with human and technological approaches, creating an innovation ecosystem in the industry, organizational factors affecting knowledge management with an open innovation approach, and the use of smart technologies in civil societies.

Figure 2 and the node coloring show that the majority of frequently used topics in scientific productions in this field originated prior to 2015. The thematic approach of the clusters has been determined based on the words within each cluster.

Answer to the fourth research question. How does co-occurrence analysis contribute to the hierarchical clustering of scientific production topics related to KMOI?

Hierarchical clustering was performed using SPSS software and calling of co-occurrence matrices. A dendrogram representing the hierarchical clustering of the topics was generated. Figure 3 displays the hierarchical clustering of scientific productions pertaining to KMOI. The clusters have been partitioned into multiple segments to enhance image clarity.

As displayed in Figure 3, the keywords of the examined scientific products have formed five clusters:

- **Cluster 1: Organizational performance based on knowledge and innovation.** Concordance analysis revealed that Cluster 1 involved keywords such as co-creation, dynamic capability, organization performance, human capital, innovation performance, and knowledge-based perspective.
- **Cluster 2: Knowledge management based on innovation and open innovation.** This cluster can be referred to as "innovation-based knowledge management" due to the presence of keywords such as innovation cooperation, innovation management, intellectual capital, knowledge absorption, knowledge exchange, knowledge management, knowledge sharing, knowledge transfer, learning, and wisdom foundations.
- **Cluster 3: Innovation based on ecology.** With topics such as innovation ecosystem, ecology, ecosystem, and creativity, it is fitting to entitle this cluster as "innovation based on ecology".
- **Cluster 4: Knowledge management practices and processes with an open innovation approach.** The concordance analysis revealed that Cluster 4 was involved with keywords such as absorption capacity, big data, blockchain, citizen knowledge, expert community, knowledge flow, open data, information technology, entrepreneurship, and customer knowledge management.
- **Cluster 5: Imperatives and implications of open innovation.** This cluster encompasses various keywords, including open science, social networks, patents, open source software, open innovation process, and technology transfer, which suggest the prerequisites of open innovation. The keywords knowledge creation, manufacturing and production, organizational learning, strategic management, technological innovation, value absorption, value creation, and sustainability highlight the impli-

Table 2

The density and centrality of the clusters resulting from the concordance analysis of KMOI-related scientific productions

Cluster number	Cluster title	Density	Centrality
1	Organizational performance based on knowledge and innovation	1.062	17
2	Knowledge management based on innovation and open innovation	1.038	27
3	Innovation based on ecology	1.167	7
4	Knowledge management methods and processes with an open innovation approach	0.811	28
5	Imperatives and implications of open innovation	1.032	32

cations of open innovation in organizations. Accordingly, this cluster may be referred to as "imperatives and implications of open innovation".

Answer to the fifth research question. What is the maturity and development status of the clusters derived from the co-occurrence analysis in the strategic diagram pertaining to scientific productions on KMOI?

Table 2 presents the scores related to the density and centrality of the clusters derived from the concordance analysis of scientific publications.

Cluster 5, with a value of 43, was found to have the highest centrality, while Cluster 3, with a value of 1.167, had the highest density. The strategic diagram employs a horizontal axis to represent centrality, which measures the degree of cluster correlation. The vertical axis, on the other hand, represents density, which quantifies the level of internal communication within each cluster. The graph's origin was set to 22 and 1.026 based on the average centrality and density of the clusters. The strategic diagram is constructed using the aforementioned scores.

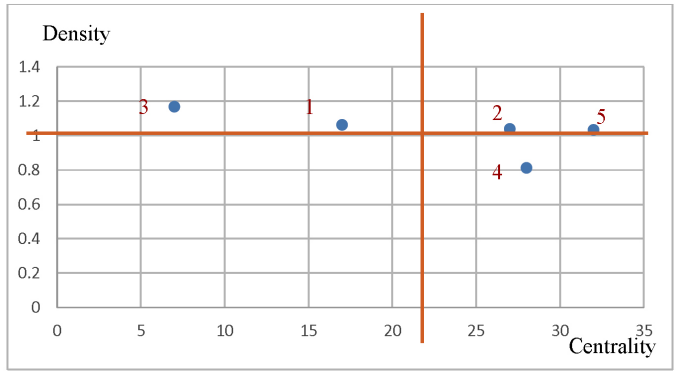

Figure 4

Strategic diagram of KMOI-related scientific productions

Based on Figure 4, the identified clusters are found in regions one, two, and four. Clusters 5 and 2 specifically occur in region one. Clusters 1 and 3 are situated in the second region. The clusters in the second region are not axial clusters but are well developed. However, these clusters are of lower rank than those in the diagram's first region, but they enjoy greater development capabilities. It is necessary to explain that the clusters positioned in the first region are mature clusters that are studied at the core of this research region. In contrast, Cluster 4, situated in the fourth region, is a central cluster that remains underdeveloped and has not yet reached maturity.

Answer to the sixth research question: What themes and categories result from the systematic review of scientific productions related to KMOI?

This study employed a systematic review approach, utilizing the content analysis method and open, central, and selective coding techniques to identify and extract themes, categories, and codes from scientific publications on KMOI.

A total of 316 codes were extracted from scientific publications. The most frequently identified codes were *internal KMC*, *innovation capacity*, *knowledge management capabilities*, *information technology infrastructures*, *innovative performance*, *diversity in openness*, *willingness to collaborate*, and *cooperation with suppliers and competitors*. As perceivable from the reviewed studies, organizations and businesses need to consider the primary themes of knowledge management, innovation, open innovation, and knowledge management based on open innovation to succeed.

- **Knowledge management:** The review of the studies and their results indicates that effective knowledge management in organizations requires consideration of the types of knowledge present both internally and externally, such as knowledge at the company or individual levels, knowledge as homogeneous or unique for individual actors, scientific and technical knowledge, market knowledge, external knowledge, knowledge and expertise of employees, shared knowledge, external knowledge sources, knowledge assets and types of work contents; providing necessary infrastructure, including knowledge infrastructure capabilities, human resource productivity, knowledge management system, information technology, organizational factors, knowledge sharing culture, trust between employees, knowledge sharing culture, sustainable strategic management, knowledge/resource-based perspective, resource allocation, organizational knowledge database, social ties, intellectual property rights, and learning and growth; and implementation of various processes of knowledge management, including knowledge acquisition, knowledge transformation, knowledge application, knowledge protection, knowledge sharing, documenting and maintaining experiences, knowledge transfer, knowledge creation, knowledge storage, explicit and implicit knowledge internalization, knowledge absorption, knowledge discovery, sharing ideas, exploitation of knowledge, dissemination of knowledge, exchange of knowledge, translation of knowledge, ability to acquire knowledge, ability to share knowledge, and integration of knowledge.

- **Innovation:** To foster innovation within an organization, it is crucial to consider various forms of innovation, including the development of new or enhanced products and services, the implementation of improved processes, the exploration of new markets, the pursuit of problem-solving initiatives, the acquisition of novel technologies, innovative process and products, technological innovation, product diversification, dual innovation, exploratory innovation, exploitation innovation, new thinking, inbound innovation, outbound innovation, structured innovation, professional innovation, organizational innovation, creation of specialized institutions, internal innovation by external enterprises (inside-out), external innovation (outside-in), knowledge-based innovation, market orientation, value innovations and internal innovation activities, provision of the necessary infrastructure including innovation capacity, fundamental innovation, innovation-supporting culture, technology development, technology capabilities, competence, culture and mindset, dynamic capability-based view or economy, economic performance, market focus and company communication view, innovation strategy, sustainable development innovation, innovation promotion, inter-organizational arrangements for innovation, innovation recombination (architecture) and innovation governance, the role of important actors such as innovation-related policymakers, intermediaries or facilitators with strong unbiased attitude, and technical leadership based on experience.
- **Open Innovation:** In order to implement open innovation in the organization, attention should be paid to the types of open innovation, including internal and external open innovation; preparing the necessary ground and platform such as collaborative capability, attention to internal and external ideas, interactive technologies, the multiplicity of partners, diversity in openness, readiness for cooperation, internal KMC, open ecosystems, open innovation environment, openness and organizational structure, open innovation communities, and competitive environment in society; development of perspectives such as the internal perspective of open innovation, governance of open innovation and competitive perspective (external perspective of open innovation); and designing effective processes, including internal processes, open innovation preparation, open innovation life cycle, outside-in process, inside-out process, coupled process, external process, and internal process.
- **Knowledge management based on open innovation:** In order to implement knowledge management based on open innovation in the organization, it is necessary to consider individual influencing factors including competence, culture and mindset, courage, ambiguity tolerance, risk-taking, self-confidence, motivation, professional improvement skills, and organizational citizenship behavior (interactive user behavior); organizational influencing factors such as participation in open innovation, organizational mechanism, company size, high-tech industries, company level, project level, organizational boundaries, and commitment-based human resource practices; influential inter-organizational factors including inter-organizational knowledge collaboration; the role of official organizations, the role of unofficial organizations,

participation in open innovation, communication function (linkage), company-to-company links, social links, informal links, external relations and networks of the organization, and more formal links. Among other issues that need to be considered are the formulation of a perspective centered on successful knowledge management in open innovation, market orientation, intensive use of information and communication technology, planning (resource deployment and time allocation), focus on sourcing, interdisciplinary adoption strategy, market focus and company communication perspective, a perspective based on dynamic capability or economy, knowledge/resource-based perspective, alliance strategies and knowledge and innovation management relationships, and consideration of potential barriers including the risk of innovative efforts, R&D costs, limitations on the use of company resources, risks from intellectual property failures, closed innovation systems, knowledge management barriers to innovation, relationship risk, dependency risk (lock-in), the risk of misuse of value, the risk of knowledge transfer inefficiency, failure to achieve the expected goal, and technological determinism. Other essential things that should be emphasized in the implementation of knowledge management based on open innovation are attention to important methods and considerations including resource integration, pragmatic mechanism, knowledge boundary management, contract projects, crowdsourcing, interaction with customers, commercialization of a unique idea, cooperation of the organization with capable research teams outside the organization, support provision for domestic scientists, cooperation with universities or research centers, clarification of measures of intellectual property protection, integration of intellectual property-aware employees, intellectual property gatekeepers, utilization of information technology in business operations, technology gatekeepers, collaborative processes, customer relations, supporting business processes, and application of information technology in business operations and its outcomes such as business services of open innovators, value absorption, value creation, economic performance, value co-creation, shared value creation, and optimization of the organizational model.

5. Discussion and Conclusion

The interplay between knowledge management, information and communication technologies (ICTs), innovation, and globalization has emerged as a critical catalyst for socioeconomic and institutional progress in the modern era. Scholarly attention has increasingly focused on knowledge management systems and open innovation paradigms, particularly examining how the dissemination of scientific knowledge, research outcomes, and technological advancements can optimize organizational performance and drive societal development. This research domain has attracted significant interest from academics, policymakers, and organizational leaders alike.

This study employed a dual-method approach, integrating scientometric analysis and systematic review, to investigate the conceptual framework, key themes, and categorical

dimensions of knowledge management within an open innovation paradigm. The scientometric analysis revealed that the emergence of open innovation theory has (1) established knowledge management as a critical enabler of open innovation processes and (2) underscored the imperative of incorporating open innovation principles into organizational knowledge management systems. Farsani and Rahimpour [12] found that incorporating open innovation practices, such as attending to internal and external ideas and promptly responding to market demands, along with effective knowledge management processes, can enhance the implementation of knowledge management. Lam et al. [17] found that an organization's open innovation culture, characterized by trust, cooperation, and learning and facilitated by supportive and collaborative leaders, enhances knowledge management practices and boosts innovation capability. According to Naqshbandi and Jasamuddin [20], higher levels of knowledge-oriented leadership are associated with improved knowledge management capabilities and enhanced open innovation outcomes. Knowledge management capability serves as a mediator between knowledge-oriented leadership and open innovation. As the issues covered indicate, KMOI procedures directly or indirectly support one another.

The average growth rate of scientific productions during this period was 24.829%, indicating a significant increase in attention and growth in the investigated field. Moreover, citations significantly increased during the studied period, with a growth rate of 67.119%. This indicates the substantial impact of scientific production in this field. The analysis revealed that the terms *performance*, *R&D*, and *absorption capacity* are the most frequently used and related keywords in scientific studies on KMOI. The topics of *manufacturing companies*, *open innovation methods*, and *open-source software* have garnered the highest number of citations and impact on scientific production. The high frequency of certain keywords in this field indicates the impact of R&D and absorption capacity on enhancing innovative organizational performance and related indicators. Ghorbanzadeh [8], found that managers in knowledge-based organizations can enhance the productivity of human resources by effectively managing knowledge transfer processes and promoting open innovation through organizational readiness, collaborative capability, and absorption capacity. Asemani's [14] study found that knowledge management positively influenced both open innovation and organizational sustainability. Additionally, open innovation was found to have a positive impact on organizational sustainability. Knowledge management positively impacts organizational sustainability by fostering open innovation. Lopes et al. [23] found that organizational sustainability is increasingly concerned with effectively managing new knowledge, such as innovative ideas and practices, to promote business growth. Open innovation is crucial for strategic sustainability management as it enables companies to effectively implement knowledge management focused on assets that drive innovations and impact organizational sustainability. This highlights the interdependence between KMOI initiatives and organizational performance indicators, as they mutually support and establish a basis for one another.

The significant influence of the identified keywords in this study highlights the crucial role of open-source software and technology development in fostering open innovation,

particularly in manufacturing companies. Cui, Wu, and Tong [22] found that the combination of IT-enabled absorptive capacity and idea openness positively influences new product innovation. Additionally, they observed that the combination of IT-enabled absorptive capacity and openness to implementation speeds up the process of bringing products to market.

Using the VOSviewer software, the concordance analysis of 4,187 keywords extracted from scientific publications pertaining to KMOI led to the formation of 8 clusters containing 367 concepts and keywords. The clustering centered on the following themes: business development through increased competitiveness and research and development procedures; open innovation procedures based on advanced technology; knowledge creation strategies based on innovation in industries and services, the perspective of the knowledge-based economy, implementation of knowledge management with human and technological approaches, creating an innovation ecosystem in the industry, organizational factors affecting knowledge management with an open innovation approach, and the use of smart technologies in civil societies. The co-occurrence analysis of words based on time overlap indicates that the majority of frequently used topics in scientific productions in this field were first discussed before 2015. The results of this study suggest that knowledge management is increasingly aligning with digital transformation and the application of smart technologies to facilitate the sharing and utilization of ideas, knowledge, technologies, and innovation. The alignment has resulted in adopting and accepting the open innovation approach by organizations that have not implemented formal knowledge management. On the other hand, using Ward's clustering method and SPSS software, five clusters were created in the concordance analysis of the studied scientific productions. As consulted with a subject matter expert, the clusters were labeled as *organizational performance based on knowledge and innovation* (Cluster 1), *knowledge management based on innovation and open innovation* (Cluster 2), *innovation based on ecology* (Cluster 3), *methods and processes of knowledge management with an open innovation approach* (Cluster 4), and *imperatives and outcomes of open innovation* (Cluster 5). Consistent with the third cluster identified in this study, Grimsdottir and Edvardsson [21]found that high-tech companies generally favor inside-out open innovation strategies, whereas low-tech companies tend to prefer outside-in strategies.

The strategic diagram of scientific productions related to KMOI demonstrated that Cluster 5, with a value of 43, had the highest centrality, while Cluster 3, with a value of 1.167, had the highest density. The study's results indicate that Clusters 5 and 2, situated in the first region, are mature clusters located at the center of the research area. Clusters 1 and 3 in the second region have the potential for further development and are not core clusters. However, Cluster 4 in the fourth region of the diagram is a core cluster that is still in its developmental stage. Indeed, it has not yet attained maturity. The findings suggest a requirement for researchers to identify and apply knowledge management methods and processes using an open innovation approach. This is necessary to enhance the knowledge and innovative performance of organizations, as well as foster innovation development aligned with the desired ecosystem characteristics. Natalicchio et al. [24] suggested

modifying open innovation processes based on three aspects: inbound open innovation, outbound open innovation, and existing knowledge about the open innovation process, as identified in the fourth cluster of the current research.

Four themes, 17 categories, and 316 subcategories emerged in the systematic review section of the current research. The subcategories with the highest frequency and theoretical support are *internal KMC*, *innovation capacity*, *knowledge management capabilities*, *information technology infrastructures*, *innovative performance*, *diversity in openness*, *readiness towards cooperation*, and *cooperation with suppliers and competitors*. Internal KMC refers to an organization's capacity to effectively design and implement knowledge management processes. This includes providing the necessary infrastructure and fostering innovation within the organization. Such capability enables the organization to engage in innovative activities, such as introducing new products, services, procedures, processes, or ideas. An analysis of the aforementioned codes and other codes with high frequency indicates that the key factors for establishing internal and external KMC with an open innovation approach include *diversity in openness*, *willingness to cooperate*, *innovative performance*, *information technology infrastructure*, and *collaboration with suppliers and competitors*. These factors are essential for an organization to implement knowledge management with an open innovation approach. Yousufzadeh Konestani [13] found that the knowledge management system indirectly impacted KMC through open innovation. Open innovation facilitates the development of KMC. It is directly related to innovation capacity and indirectly enhances it through KMC. Harouni, Farsani & Sadeghi [10] found that inbound innovation positively influenced external knowledge management processes, while outbound innovation positively influenced internal knowledge management processes. Negarestani [15] discovered a substantial influence of the knowledge management system on both open innovation and innovation capacity. The author suggests that enhancing the innovation capacity can be achieved by strengthening various components of the knowledge management system, such as improving the information technology infrastructure, providing employee training, and seeking expert consultation and support. Additionally, fostering innovation can be facilitated by engaging with multiple partners, including customers, competitors, suppliers, beneficiaries, and academic centers. Santoro et al. [18] discovered that the knowledge management system enhances knowledge transfer by promoting internal knowledge management capabilities, establishing open and collaborative ecosystems, and leveraging internal and external knowledge flows. Consequently, this results in an augmentation of innovation capacity. It is evident from the discussed topics that the strategies, procedures, and measures of knowledge management, innovation, and open innovation all contribute directly or indirectly to the organization's capacity building.

The review of scientific productions and integration of their findings in this study indicate that effective implementation of knowledge management in the present era requires both internal and external knowledge management practices. In this regard, it is necessary to identify and acquire the internal and external knowledge types and levels required by the organization. In addition, it is necessary to implement additional processes,

procedures, and knowledge management tools to establish the required infrastructure and facilitate the utilization of the needed knowledge. The organization should identify appropriate innovations for its field and enhance its innovative performance through infrastructure and effective role-playing of actors. It is crucial to prioritize the open innovation approach to enhance organizational performance through knowledge and innovation. This approach plays a significant role in developing the knowledge base and fostering improvement in the current era. In this context, it is crucial to identify examples of open innovation, establish the required background and platform, formulate an organizational vision, and design efficient processes. In order to effectively enhance organizational performance, it is crucial for organizations and businesses to adopt a comprehensive and integrated perspective on KMOI initiatives. Prioritizing the implementation of knowledge management with an open innovation approach should be based on careful consideration of the current situation and background conditions. To achieve this objective, it is crucial to consider individual, organizational, and inter-organizational influencing factors, the organization's perspective, existing obstacles, adoption methods, and other important considerations and their consequences. Balweh et al. [11] identified several thematic categories in their research, including the establishment of technological infrastructures and knowledge management, the identification of a shared knowledge base and utilization of a reciprocal learning system, the promotion of intellectual property rights and safeguarding of common knowledge, and the ongoing enhancement of organizational performance in knowledge management.

The current research identified several obstacles to implementing knowledge management with an open innovation approach. These obstacles include the risk associated with innovative efforts, R&D costs, limitations on exploiting company resources, risks related to intellectual property failures, closed innovation systems, and managerial obstacles. This study examines various factors related to innovation, including knowledge, relationship risk, dependency risk (lock-in), value misuse risk, knowledge transfer inefficiency risk, failure to achieve expected goals, and technological determinism. Alongside this, Oliva et al. [16] identified obstacles, specifically threats and risks, associated with open innovation and knowledge management. They emphasized the role of environmental factors, the identification of types of relationships, the consideration of knowledge management obstacles in open innovation and risk assessment, as well as the four major components of the theoretical model of knowledge management risks in open innovation.

The present study offers an overview of key and emerging issues in the field of knowledge management and open innovation (KMOI) by mapping the existing body of knowledge in this domain. The research seeks to establish a comprehensive understanding through the identification of major themes and conceptual clusters within KMOI. The insights generated are intended to benefit researchers, educators, and organizational managers, especially those operating in knowledge-based environments. By leveraging the identified concepts, themes, and categories, organizations and societies can enhance learning, productivity, and overall organizational performance, thereby creating added value in today's competitive landscape.

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