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Uncovering the Knowledge Networks in Innovation Research: A Topic Modeling Approach

Descobrindo as Redes de Conhecimento na Pesquisa sobre Inovação: Uma Abordagem de Modelagem de Tópicos

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Abstract: Over the years, research on knowledge and innovation networks has been conducted in various directions and from various perspectives. With the volume of published studies, especially in the last decade, the challenges of understanding the field as a whole have increased. The aim of this study was to identify research topics on knowledge and innovation networks using topic modeling. We derived 50 research topics by applying the Latent Dirichlet Allocation (LDA) model, which is the most popular topic modeling algorithm in scientific studies. Our sample consisted of the abstracts of 6,746 articles on networks, knowledge, and innovation, extracted from Scopus and Web of Science, and published from 1985 to 2021. From these data, we explored topic trends over the years, identifying 21 hot topics, 21 cold topics, and 8 steady topics that could help drive future studies on knowledge and innovation networks.
Keywords – Knowledge; Interorganizational networks; Innovation; Topic modelling; Latent dirichlet allocation (LDA).

Resumo: Ao longo dos anos, a pesquisa sobre redes de conhecimento e inovação tem sido conduzida em várias direções e a partir de diversas perspectivas. Com o volume de estudos publicados, especialmente na última década, os desafios para entender o campo

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como um todo aumentaram. O objetivo deste estudo foi identificar temas de pesquisa sobre redes de conhecimento e inovação utilizando modelagem de tópicos. Derivamos 50 tópicos de pesquisa aplicando o modelo de Latent Dirichlet Allocation (LDA), que é o algoritmo de modelagem de tópicos mais popular em estudos científicos. Nossa amostra consistiu nos resumos de 6.746 artigos sobre redes, conhecimento e inovação, extraídos da Scopus e Web of Science, e publicados de 1985 a 2021. A partir desses dados, exploramos as tendências dos tópicos ao longo dos anos, identificando 21 tópicos quentes, 21 tópicos frios e 8 tópicos estáveis que podem ajudar a orientar futuros estudos sobre redes de conhecimento e inovação.
Palavras-chave – Conhecimento; Redes interorganizacionais; Inovação; Modelagem de tópicos; Latent Dirichlet Allocation (LDA).

Introduction

The capacity to innovate has been seen in the literature as one of the competitive advantages of companies (Cefis et al., 2020). This capacity is a complex organizational resource with cumulative investment in various dimensions such as human capital, internal capital, and relational capital (Santos et al., 2018). Organizations that are better at searching for and integrating external and internal knowledge to create new knowledge develop advantages over other organizations (Belso-Martinez & Diez-Vial, 2018; Un & Rodríguez, 2018). In this sense, relationships and exchanges of knowledge seem to be important elements for the innovation and competitive advantage of companies.

In recent years, several studies have explored the role of knowledge networks and their relationship with innovation. For some authors, companies can accelerate capacity development and minimize their exposure to technological uncertainties by acquiring and exploiting the knowledge developed by third parties (Grant, 1996; Lane & Lubatkin, 1998). These alliances or learning networks represent an important antecedent to innovation, because the scope of knowledge that an organization can create, process, and use is limited, and what is useful is imperfectly dispersed among organizations (Kolloch & Reck, 2017).

Especially in the innovation literature, interorganizational networks are seen as a strategy of resource saving and risk sharing, in which small and medium-sized enterprises often do not have sufficient financial capacity or human resources (Kofler & Marcher, 2018). However, it is observed that large companies can also use networks formed with other partners or competitors as a way to support their research, development, and innovation areas (Vicente-Oliva et al., 2015). In addition, it is clear that the

relationships previously developed between the companies condition the structures of these networks and, for this reason, organizations that try to increase their ability to innovate should consider not only the type of relationships they currently have, but also how these relationships evolved (Ahuja et al., 2012; Belso-Martinez & Diez-Vial, 2018).

Although studies on the structure of the network at the organizational level have grown rapidly in the last decade, understanding of the topic remains fragmented and far from complete (Wang et al., 2019). For example, the literature on networks reports their role in promoting local development and innovation in organizations, but very few studies have evaluated the importance of networks between companies in the economic performance of organizations (Burlina, 2020). Although studies on this subject have advanced in the more than 30 years that have passed, there are still gaps that need to be explored. It seems that research on knowledge and innovation networks has grown in various directions and from various perspectives over the years. With the volume of published studies, especially in the last decade, the challenges of understanding the field as a whole increase. Identifying latent topics and tracking their scientific evolution can be of great interest and could contribute to government, industry, and academia. In this sense, the research question that guides the current study is: what are the research topics emerging from the literature of knowledge and innovation networks?

The aim of this study was to identify research topics in knowledge and innovation networks. To achieve this goal, we used topic modeling as a method to extract latent topics from the literature. We derived 50 research topics by applying the Latent Dirichlet Allocation (LDA) model, which is the most popular topic modeling algorithm in scientific studies. Our sample consisted of the abstracts of 6,746 articles on networks, knowledge, and innovation, extracted from Scopus and Web of Science, and published from January 1985 to December 2021. From these data, we explored topic trends over the years, identifying 21 hot topics and 21 cold topics that could help drive future studies on knowledge and innovation networks. We also found 8 other topics considered stable that may point to more recent themes in the literature.

Theoretical Foundations

The combination of resources and capabilities is considered essential to the organization's ability to innovate (Davids & Tai, 2009; Un & Rodríguez, 2018). Networks have been closely associated with a greater capacity to innovate, as they provide companies with greater access to valuable knowledge flows that allow them to improve their products and processes (Belso-Martinez & Diez-Vial, 2018; Santos et al., 2018). In particular, due to limited internal resources, organizations often use social networks to acquire external knowledge and control resources to increase their competitive advantage (Wang et al., 2019). The more extensive the collaborative innovation network of an organization, the more heterogeneous and diverse the knowledge it will have access to (Xu et al., 2019).

Organizations acquire knowledge from other organizations and, therefore, the exchange of knowledge through interorganizational networks can serve as a critical antecedent of the production of organizational innovation (Kolloch & Reck, 2017). Some authors also argue that networks have become a central governance model that organizations use to manage innovation (Cap et al., 2019). These networks can create an environment of innovation, increase the flow of knowledge, accelerate the knowledge transition of different attributes, increase the collision and frequency of knowledge integration from different sources, strengthen the organization's capacity for innovation, expand the effect of technological innovation, and eventually increase the overall level of innovation of all network participants (Xu et al., 2019). Thus, networks can result in innovations occurring less frequently within individual companies and, more commonly, through knowledge creation networks that integrate individuals, companies, universities, and other institutions (Hynes & Elwell, 2016).

In the literature, networks can emerge as interorganizational networks, innovation networks, or knowledge networks, and many authors end up adopting similar concepts with different names. For example, a knowledge network is defined as a connection between organizations in search of solutions to deal with complex and critical problems, in addition to the exchange of technical knowledge within the innovation process (Alberti & Pizzurno, 2015). An interorganizational network is seen as a form of interaction based on the reliable cooperation of autonomous but interdependent actors working on the goals of partners for a limited time (Kofler & Marcher, 2018). On the other hand, innovation networks are

interorganizational networks consisting of a defined set of actors that collaborate for innovation and are governed by the interests of the network (Cap et al., 2019). In this study, we considered the nomenclature "networks" to deal with any exchange of knowledge for the generation of innovation, since it is a cross-sectional term that does not delimit the level of analysis used by the analyzed studies.

Some theories are commonly used in research on interorganizational networks. While some authors offer different explanations for this process, they share a resource-based company vision as a conceptual basis for explaining why organizations participate in networks (Munoz & Lu, 2011). The networks complement the resource-based vision, arguing that focusing on the individual characteristics and capabilities of the company can explain the company (Crispeels et al., 2015). In addition, interorganizational networks can be considered synonymous with cooperation. These networks or other groupings of organizations may cooperate with the sharing of resources for mutual benefit as a logical response to resource shortages (Hynes & Elwell, 2016).

Knowledge-based vision is another theory used to explain these interactions, considered a consequence of resource-based thinking (Eisenhardt & Santos, 2002). Moreover, this theory argues that the main role of the organization is as an integrator of knowledge (Crispeels et al., 2015; Grant, 1996). Organizations that can research and integrate knowledge from sources within and between countries probably have superior innovative capabilities (Un & Rodríguez, 2018). Similar explanations can be found in the organizational learning literature, pointing out that organizations collaborate because they seek to explore and exploit new knowledge and develop the skills to use and build on such knowledge (Munoz & Lu, 2011).

From another perspective, the theory of social networks allows us to understand the behavior of networks under two characteristics: centrality of the network and structural holes (Wang et al., 2019). The centrality of the network, represented by the power of status, reflects the position and hierarchical advantage of the network (Ibarra, 1993). The central organization can enjoy a high advantage of position in the network and can respond more quickly to use potential network resources and take advantage of opportunities to increase its competitive advantage (Wang et al., 2019). A structural hole is formed when a node is connected to two other nodes between which there is no direct connection. Organizations with more structural holes can access more heterogeneous information and resources from different parts of the

network and, therefore, are more efficient in identifying threats and opportunities, and have the potential to offer better quality than other organizations (Xu et al., 2019).

Interorganizational networks are generally defined through different forms of business cooperation with variation in intensity, duration, and various motivations for collaboration (Kofler & Marcher, 2018). Interactions between the actors of these networks may be formal or informal. Formal are generally conducted under contracts and alliances, while information are based on private conversations between directors or pre-alliance relationships (Wang et al., 2019). The strength of these interorganizational networks is another characteristic that has been studied in recent decades. Granovetter (1973) argues that weak ties are more important to capture new information and resources, while strong ties need more time and attention. Weak relationships arise almost accidentally and through irregular contacts (Kofler & Marcher, 2018).

In particular, interorganizational networks as a means of granting access to knowledge can represent a critical basis for such innovative performance (Kolloch & Reck, 2017). These networks are increasingly recognized in the innovation management literature as 'access relationships' that allow partners to acquire non-redundant knowledge and capabilities that reside outside their organizational and technological limits (Zouaghi et al., 2018). The structure of these relationships within knowledge networks will determine the innovative capacity, along with how each company makes use of its position within them (Belso-Martinez & Diez-Vial, 2018).

In addition to the connection with interorganizational networks, the literature also points out the importance of absorptive capacity in the development of innovative capacity at the organizational level. A critical factor in the development of an organization's capacity is the balance and interaction between the construction of internal knowledge and the acquisition of external knowledge (Davids & Tai, 2009). In many cases, organizations do not have much incentive to transfer knowledge to the interorganizational level, as this knowledge could then be available to competitors (Bapuji & Crossan, 2005). However, companies transfer knowledge from the organizational level to the interorganizational level as this transfer is a way to legitimize and validate shared knowledge (Bapuji & Crossan, 2005).

In general, it is perceived that there are different perspectives and theories used to explore the phenomenon of knowledge networks to generate innovation. Some studies are bibliometric and all were

published in recent years, but these publications bring a specific view within the theme, such as open innovation (Gao et al., 2020), and do not cover the entire period in which there are publications (Agostini et al., 2020). Therefore, we argue that it is necessary to explore the literature of knowledge networks and innovation to promote an overview of the issues contained in this field and, from this, break with the frontiers of knowledge through the identification of opportunities for future studies.

Methodological Procedure

This section explains the methods and procedures adopted to identify research topics in knowledge and innovation networks. First, we briefly explore the method used in the study, after which we detail the methodological procedure, composed of four steps: (1) data analysis and sample definition, (2) LDA modeling, (3) textual preprocessing, and (4) trend identification.

Method

In recent years, there has been a significant increase in the volume of scientific content available in databases on various subjects. In parallel, we noticed the emergence of different methods of text analysis, starting from both qualitative and quantitative approaches. In addition, there are an increasing number of open source tools for text analysis (e.g. R and Python), although these tools are not easily leveraged by researchers, who probably have limited programming knowledge (Banks et al., 2018). In general, there is interest from the scientific community in discovering ways of analyzing the literature to summarize what has already been discovered on a given theme and indicate gaps that still need to be explored.

Topic modeling has attracted significant attention and can be successfully used in various text mining activities (Lee & Kang, 2018). Topic modeling algorithms are a set of machine learning methods for discovering hidden thematic structures in large document collections (DiMaggio et al., 2013). These algorithms assume that (1) each document is a mixture of topics and (2) each topic has its own probability distribution over words (Blei et al., 2010; Lee & Kang, 2018). Thus, the analysis of the texts is carried out

from the co-occurrence between words to determine the emerging topics. This method increases the interpretability of topics and the identification of outliers.

Topic templates allow researchers to code collections of text too large to be coded manually (DiMaggio et al., 2013). In addition, they do not require any prior labeling of the documents; the topics emerge from the analysis of the original texts (Lee & Kang, 2018). These topic templates can also serve the purpose of retrieving information, as documents are scored based on their similarity to the topic (probability) and therefore can be classified to identify the most representative documents (Banks et al., 2018). With topic models, researchers can discover new patterns in their text data and analyze much larger collections than would be possible manually (DiMaggio et al., 2013).

To obtain latent topics from the literature on knowledge and innovation networks, we used a probabilistic method of topic modeling known as Latent Dirichlet Allocation (LDA). LDA is a topic modeling algorithm widely adopted in academic studies, proposed by Blei et al. (2003). This Bayesian learning algorithm extracts "topics" from the text based on the co-occurrence of words (Toubia et al., 2019). The basic assumption of LDA is that each document is a mixture of topics, where each topic is a distribution in words. Each word that appears in the document can be attributed to one of the topics with some probability, and the meaning of the word may change with the association of other words within the document (Jeong et al., 2019).

Data Collection and Sample Definition

The first step of the methodological procedure was data collection and definition of the sample to be used in the study. We used the Scopus and Web of Science databases to search for publications related to the research theme. The searches were performed from the keywords "knowledge" AND "innovat*" AND "network*". We chose to delimit the sample to consider only English publications of the article type, because these publications have gone through blinded peer review processes. In addition, only articles published in the areas of business and management were kept in the sample. At the end of the searches, we found 8,030 articles, 2,849 articles in Scopus and 5,181 in the Web of Science.

We extracted the metadata related to these searches and created a database with the main information of these articles (authors, title, journal, year, and abstract). Some of the journals that publish

on this theme are indexed in the two databases and, therefore, the databases contain duplicate articles. In addition, some of the articles did not have a summary section, essential information for analysis through LDA. We excluded 1,265 articles from the sample due to duplication and 19 articles that did not present an abstract. No criteria were used to delimit the sample per year, since the dynamics of publications over time are also a target of this study.

The final sample was composed of a list of 6,746 articles. We noted that around 37% of the sample was published in a list of 20 journals in different fields, such as marketing, innovation, sustainability, entrepreneurship, management, and business (Table 1). As the abstract summarizes the general idea of the study, we chose to use only the abstract to represent the document to be analyzed by the LDA algorithm.

Table 1.
List of the top 20 main journals found in the sample

	Journal	Number of Articles	(%)
1.	Research Policy	331	(4.91%)
2.	Technological Forecasting and Social Change	267	(3.96%)
3.	Journal of Knowledge Management	182	(2.70%)
4.	Technology Analysis & Strategic Management	173	(2.56%)
5.	Technovation	154	(2.28%)
6.	Journal of Business Research	146	(2.16%)
7.	Industrial Marketing Management	140	(2.08%)
8.	Industry and Innovation	131	(1.94%)
9.	International Journal of Technology Management	127	(1.88%)
10.	R & D Management	98	(1.45%)
11.	Journal of Technology Transfer	94	(1.39%)
12.	Journal of Business & Industrial Marketing	93	(1.38%)
13.	Entrepreneurship and Regional Development	86	(1.27%)
14.	Organization Science	83	(1.23%)
15.	Management Decision	82	(1.22%)
16.	Journal of Product Innovation Management	78	(1.16%)
17.	Strategic Management Journal	78	(1.16%)
18.	European Journal of Innovation Management	77	(1.14%)
19.	International Journal of Innovation Management	70	(1.04%)
20.	IEEE Transactions on Engineering Management	66	(0.98%)
Other 786 Journals		4,190	(62.11%)

Textual Preprocessing

Once abstracts of the articles have been collected, some preprocessing is required before conducting LDA inference. We used the R package tm (text mining) to prepare the content. First, we standardized the form of writing of some words that often appear in the literature as synonyms. For

example, words such as "organizational" and "organisational" were standardized as "organizational". In addition, we removed the numbers, punctuations, blanks, and symbols for each document.

All the words are required to be lowercase. Next, we removed the words that are used to make the sentences grammatically correct (such as articles and prepositions), but that do not convey meaning to the subject when presented alone. These words are known as stop words and there is a list of pre-established words in the R tm package. It is also acceptable to use user-defined stop words for analytical purposes (Lee & Kang, 2018). Therefore, we created a list of the words that appear generally in the articles, such as "study", "paper", and "discuss", and removed these words from the text corpus.

After the removal of the words, the text corpus was lemmatized, seeking to reduce the total number of words available for analysis without losing information. Stemming finds the lemma (or expression) that preserves both the meaning and information of the part of speech that was originally used in the text (Lee & Kang, 2018). Other studies use derivation (or stemming) as a technique to more significantly reduce the size of the text corpus, but there is a risk of losing meaning and interpretation by displaying only the root of the words. For example, the words “innovative”, “innovation”, and “innovations” would become “innovat” when we use the derivation technique; in lemmatization, we would have “innovative”, “innovation”, and “innovation”. As the interpretation of the words contained in the topic is an important step in this study, we chose to use lemmatization.

Finally, the document-term matrix (DTM) was generated from the text corpus. The DTM is an array in which rows are each document in the sample, columns are each single word in the sample, and cells are the number of times each word occurs (Storopoli, 2019). This matrix was used as data entry in the inference of the LDA.

LDA Modeling

The third step was to perform the modeling of the LDA, at which time we decided the parameters and number of topics (K) to analyze the data sample. It was perceived that there is no consensus on how to define the parameters for the realization of LDA. Therefore, we tried to define the parameters for topic modeling based on the recommendations and good practices adopted by other studies that used the same method. Table 2 summarizes the parameters used in this stage.

Table 2.
Parameters for LDA inference

Component	Parameter
Sample size	6,746 abstracts
Number of topics K)	50, estimated with Griffiths and Steyvers (2004) metric
Inference algorithm	Collapsed Gibbs sampling
Gibbs sampling interaction	1,000
Dirichlet parameter α	50/K, being optimized each 10 iterations
Dirichlet parameter β	0.1 (default value)

The first parameter defined was the number of topics in the sample, performed from the R package LDATuning (Nikita, 2016). This package allows the use of the metric proposed by Griffiths and Steyvers (2004), which suggests the ideal number of topics for LDA based on a Markov Chain Monte Carlo algorithm. This suggestion is made from the selection of Bayesian models and the calculation of a posterior probability estimate, varying the topic values through running Markov chains. The highest value found is considered an indication of the number of topics able to summarize and explain the general corpus. Although the algorithm presented 100 topics as the best result to explain the data sample, we decided to go with 50 topics, since the model does not improve significantly enough after this amount to justify the analysis of a larger amount of content. In addition, we noticed that the greater the number of topics, the more difficult it becomes to interpret the data within the context of the literature studied.

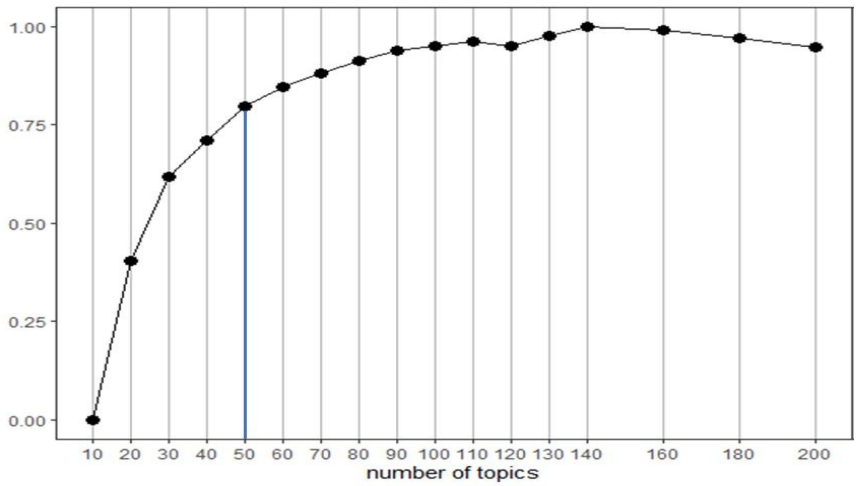

Figure 1. LDA tuning results.

The second parameter was the inference algorithm. The inference algorithm tries to collect samples from the posterior to approximate it with an empirical distribution (Blei et al., 2010). Generally, two inference algorithms can be employed: Variational Expectation Maximization (VEM) or Gibbs sampling (Gibbs). Mohammad Zubir et al. (2018) compared the results of the two algorithms and the results show that Gibbs, like the inference algorithm, provides a better prediction about the optimal number of topic data compared to VEM. In this sense, we chose to use Gibbs as the inference algorithm of this study.

The other parameters were defined according to the recommendation of Griffiths and Steyvers (2004). We used $\alpha = 50/K$ as the posterior value for topics about documents, and $\beta = 0.1$ as values for words about topics. Finally, the LDA was conducted by the FitLdaModel function in the TextmineR package (Jones, 2019) with 1,000 iterations, optimizing the value of α every 10 iterations of Gibbs.

Trend Identification

The fourth stage performed in this study was the identification of trends based on the topics generated in the LDA. Identifying hot and cold topics can be an attractive application of this type of model,

providing statistical measures related to the prevalence of these subjects in the sample. This identification can be useful to present the most relevant subjects to be explored in future studies. Generally, each scientific article addresses more than one subject in its content. While other methods of grouping or sample reduction can force the assignment of a document to a single subject, LDA allows the document to be assigned to all topics related to it, with their respective proportions. From the LDA results, we extracted the list of documents with their respective proportions assigned to each of the 50 topics, generating an array of documents.

The identification of trends in this study was a post hoc analysis, for which we used linear regression as a tool to identify topics that increased or decreased in popularity over the period from 1985 to 2021. Specifically, we used the year index as the input variable and the aspect ratio values assigned to the documents per topic as the response variable (Griffiths & Steyvers, 2004). The topics with regression coefficients presented as positive (negative) at a level of statistical significance of 0.05 were determined as hot (cold) topics. Thus, we consider hot topics as those that have shown, statistically, an increase in popularity over the years, while cold topics reflect the issues that have shown a decrease in popularity.

Once the topic trends were identified, we proceeded to read the first 10 abstracts of the articles that had the highest correlation with each topic (totaling 500 abstracts analyzed). We chose this quantity because it was the number of articles sufficient to reach theoretical saturation and translate the common subject of these articles of each topic. From this analysis, we proposed an overview of the literature based on the similarity between the sample's topics.

Results

The 50 topics drawn from the studies of knowledge and innovation networks are shown in Table 3, with the ten most frequent and relevant words. We defined the names (or labels) of these topics based on the interpretation of these words and the abstracts of the main articles related to each topic. The topics were numbered in descending order of proportions throughout the collection of articles, that is, we considered the percentage of participation of each topic within the sample to compose the ranking by

proportion. In addition, we considered the number of articles in which each topic was identified, also generating a ranking.

The difference between attributions by proportion and by number of articles is clearly noted in Table 3. There are some differences in topic classifications between the two types of attributions. For example, [T14] the Actor's role in innovation networks ranks fourteenth in terms of sample proportion, while this topic ranks twenty-fifth in the number of articles ranking. This may indicate that this subject is a topic that is being explored in many studies, but its position in the ranking related to the volume of articles is impacted as research on this topic ends up covering other topics as well. For Lee and Kang (2018), it is likely that analyzing only the volume of articles published on each theme prevents the capture of the real distributions of the older articles. Then, we employ the proportions as a common sharing measure to identify hot and cold topics using linear regression, as suggested by Griffiths and Steyvers (2004).

Table 3.
Topics of innovation and knowledge networks.

Topic		Frequent words	Share Rank			
			Proportion (%)			Number of articles
T1	Firm performance through knowledge networks	performance, relationship, impact, influence, positive, moderate, sample, hypo, investigate, affect	4.098	(1)	1,809	(1)
T2	Research design and network approach focused on empirical contribution	research, design, limit, practical, value, limitation, interview, publish, analyze, provide	3.538	(2)	1,398	(2)
T3	Network analysis in systematic literature reviews	research, literature, field, future, review, identify, area, current, contribution, researcher	3.390	(3)	1,159	(5)
T4	Practices to acquire and transfer knowledge	knowledge, share, transfer, flow, acquisition, base, exchange, tacit, acquire, intensive	3.155	(4)	1,209	(4)

T5	Alliances portfolio diversity influencing firm's absorptive capacity	firm, alliance, capacity, absorptive, benefit, partner, portfolio, interfirm, base, focal	2.900	(5)	1,216	(3)
T6	Network's structures and characteristics	network, tie, structure, position, centrality, strong, strength, structural, embed, weak	2.715	(6)	1,037	(7)
T7	Network influence in innovation processes	innovation, process, exploratory, innovate, activity, exploitative, link, explore, promote, focus	2.605	(7)	1,058	(6)
T8	Value co-creation networks	value, creation, framework, create, literature, perspective, develop, conceptual, understand, offer	2.450	(8)	656	(10)
T9	Knowledge network as learning strategy in complex systems	system, change, complex, term, dynamic, agent, transformation, long, environment, concept	2.376	(9)	713	(8)
T10	Theoretical and methodological models of networks	model, use, propose, technique, apply, term, tool, information, feature, evaluation	2.357	(10)	591	(15)
T11	Regional innovation and the role of public support	policy, development, public, regional, economic, government, support, region, sector, private	2.144	(11)	677	(9)
T12	Patents as a technological development spillover and inventors' network	technology, technological, patent, inventor, invention, citation, period, mobility, license, analyze	2.125	(12)	647	(11)
T13	R&D internationalization and the knowledge diffusion between local and subsidiary firms	international, subsidiary, global, local, foreign, embeddedness, multinational, country, internationalization, corporation	2.094	(13)	631	(14)
T14	Actor's role in innovation networks	role, actor, interaction, play, different, important, specific, exchange, context, focus	2.082	(14)	439	(25)

T15	Networks as a source of competitive advantage for small and medium-sized enterprises	smes, market, enterprise, small, competitive, size, advantage, medium, strategy, large	2.079	(15)	642	(13)
T16	Stakeholder engagement to address sustainability issues	challenge, stakeholder, face, sustainable, goal, build, require, action, involve, address	2.066	(16)	534	(18)
T17	Design practices and collaborative product development processes	process, product, development, develop, design, involve, market, lead, mean, exist	2.063	(17)	521	(19)
T18	Strategic management of networks and knowledge	management, strategy, strategic, manager, manage, managerial, process, practice, asset, factor	2.016	(18)	505	(21)
T19	Geographic scope of knowledge spillovers	cluster, industrial, proximity, regional, local, region, geographical, spillover, geographic, locate	2.004	(19)	644	(12)
T20	Knowledge diffusion and technology transfer focused on digital consumer behavior	information, technology, communication, user, diffusion, platform, digital, adoption, consumer, internet	1.976	(20)	543	(17)
T21	Organizational unit networks configuration and their knowledge processing	unit, outcome, across, benefit, individual, diverse, argue, large, likely, prior	1.976	(21)	420	(26)
T22	Institutional logic in global innovational networks	country, economy, institutional, global, national, develop, emerge, institution, sector, economic	1.925	(22)	499	(22)
T23	Social network brokerage and individual factor's behavior	factor, individual, influence, behavior, perceive, level, characteristic, important, perception, motivation	1.910	(23)	452	(23)

T24	Knowledge networks through the lens of social capital theory	social, capital, human, medium, dimension, relational, structural, cognitive, intellectual, impact	1.910	(24)	513	(20)
T25	Entrepreneurial universities and science parks spin-offs	university, research, science, academic, scientific, park, spin, institution, institute, scientist	1.904	(25)	564	(16)
T26	Capabilities and knowledge networks' role in business innovation model	business, model, company, market, develop, environment, create, element, focus, order	1.855	(26)	396	(28)
T27	Relationship between internal and external knowledge networks	external, open, source, internal, knowledge, search, strategy, openness, depth, breadth	1.793	(27)	452	(24)
T28	Organizational characteristics and ideation networks	different, type, idea, innovative, radical, generation, relation, individual, incremental, generate	1.772	(28)	342	(38)
T29	Organizational structures and employees' role in learning networks	organization, work, employee, organizational, organize, productivity, professional, worker, structure, self	1.733	(29)	404	(27)
T30	Rationalized logic and actor-centric ecosystems	practice, ecosystem, explore, perspective, emerge, understand, address, logic, good, offer	1.715	(30)	369	(32)
T31	Levels of organizational configurations in innovation networks and high-tech industry	level, high, tech, increase, degree, intensity, manufacture, output, low, potential	1.708	(31)	321	(40)
T32	Customer centric innovation and service organizations	service, customer, company, provider, operation, intensive, manufacture, involvement, solution, client	1.692	(32)	388	(30)

T33	Dynamic capabilities and buyer-supplier relationships	capability, supplier, dynamic, integration, base, develop, buyer, outsource, relational, resource	1.665	(33)	394	(29)
T34	Collaborative innovation networks and smart cities	decision, make, city, intermediary, energy, smart, support, plan, infrastructure, framework	1.660	(34)	355	(35)
T35	Startups and investment networks towards innovation	venture, start, growth, success, entrepreneur, experience, incubator, investment, woman, startup	1.637	(35)	342	(39)
T36	Networking across boundary spanning activities	activity, boundary, right, reserve, space, across, focus, ation, span, take	1.625	(36)	263	(45)
T37	Knowledge transfer network and industrial development history	industry, sector, biotechnology, industrial, lead, pharmaceutical, standard, manufacture, innovative, importance	1.624	(37)	320	(41)
T38	Online innovation communities and members behaviors through social network perspective	community, member, group, online, participation, software, good, family, support, participant	1.624	(38)	346	(37)
T39	Transformational leadership and organizational learning processes in innovation	learn, organizational, leadership, culture, organization, leader, interactive, mechanism, structure, japanese	1.616	(39)	353	(36)
T40	Strategies to manage quality, cost, and risk in knowledge flows and innovation processes	quality, cost, increase, risk, control, production, reduce, time, uncertainty, scope	1.589	(40)	277	(44)
T41	Teams and project organizations as sources for creativity and innovation	project, team, creative, creativity, diversity, construction, member, task, work, conflict	1.576	(41)	363	(33)

T42	R&D partnerships and collaborative network across industries and sectors for innovation	collaboration, partner, collaborative, partnership, collaborate, joint, benefit, research, increase, facilitate	1.566	(42)	370	(31)
T43	Education and professional development focused on innovation and industry's needs	education, skill, experience, exploration, competence, exploitation, competency, professional, student, train	1.549	(43)	280	(43)
T44	Entrepreneurial opportunity identification and development through social networks	entrepreneurial, entrepreneurship, opportunity, entrepreneur, orientation, role, develop, support, environment, play	1.496	(44)	356	(34)
T45	Supply network stability in dynamic environments	chain, supply, problem, efficiency, trade, improve, food, production, logistic, solve	1.490	(45)	291	(42)
T46	Evolution of innovation processes based on collaborative networks	stage, time, phase, early, evolution, life, cycle, dynamic, late, vertical	1.485	(46)	251	(46)
T47	Governance mechanism in the innovation and knowledge network	mechanism, governance, trust, power, configuration, mode, relational, coordination, contract, interfirm	1.476	(47)	244	(47)
T48	Collaborative networks with the triple helix actors	resource, access, helix, human, constraint, base, triple, financial, niche, facilitate	1.446	(48)	242	(48)
T49	Interorganizational cooperation and regional networks	interorganizational, cooperation, informal, core, inter, china, formal, structure, cooperative, competition	1.427	(49)	237	(49)
T50	Social networks in healthcare	healthcare, health, work, world, medical, clinical, care, hospital, patient, people	1.322	(50)	223	(50)

Linear regression was used to analyze the distribution of articles by topic over the years, identifying 21 hot topics, 21 cold topics, and 8 steady topics. These topics are presented in Table 4 with their respective regression coefficients in descending order, representing a ranking.

Table 4.
Hot and cold topics in networks of knowledge and innovation

N°.	Topic		Coefficient
(a) Hot Topics			
1	T1	Firm performance through knowledge networks	0.1560
2	T2	Research design and network approach focused on empirical contribution	0.1380
3	T23	Social network brokerage and individual factor behavior	0.0659
4	T7	Network influence in innovation processes	0.0548
5	T44	Entrepreneurial opportunity identification and development through social networks	0.0530
6	T10	Theoretical and methodological models of networks	0.0489
7	T3	Network analysis in systematic literature reviews	0.0379
8	T24	Knowledge networks through the lens of social capital theory	0.0359
9	T8	Value co-creation networks	0.0359
10	T30	Rationalized logic and actor-centric ecosystems	0.0359
11	T27	Relationship between internal and external knowledge networks	0.0333
12	T34	Collaborative innovation networks and smart cities	0.0314
13	T42	R&D partnerships and collaborative network across industries and sectors for innovation	0.0311
14	T45	Supply network stability in dynamic environments	0.0305
15	T15	Networks as a source of competitive advantage for small and medium-sized enterprises	0.0304
16	T49	Interorganizational cooperation and regional networks	0.0285
17	T35	Startups and investment networks towards innovation	0.0246
18	T43	Education and professional development focused on innovation and industry's needs	0.0211
19	T48	Collaborative networks with the triple helix actors	0.0160
20	T46	Evolution of innovation processes based on collaborative networks	0.0049
21	T38	Online innovation communities and members behaviors through social network perspective	0.0026

(b) Cold Topics

1	T32	Customer centric innovation and service organizations	-0.0024
2	T33	Dynamic capabilities and buyer-supplier relationships	-0.0034
3	T26	Capabilities and knowledge networks' role in business innovation model	-0.0081
4	T47	Governance mechanism in the innovation and knowledge network	-0.0097
5	T41	Teams and project organizations as sources for creativity and innovation	-0.0130
6	T22	Institutional logic in global innovational networks	-0.0153
7	T36	Networking across boundary spanning activities	-0.0198
8	T28	Organizational characteristics and ideation networks	-0.0215
9	T6	Network structures and characteristics	-0.0277
10	T5	Alliances portfolio diversity influencing firm's absorptive capacity	-0.0331
11	T19	Geographic scope of knowledge spillovers	-0.0433
12	T25	Entrepreneurial universities and science parks spin-offs	-0.0449
13	T40	Strategies to manage quality, cost, and risk in knowledge flows and innovation processes	-0.0456
14	T11	Regional innovation and the role of public support	-0.0514
15	T4	Practices to acquire and transfer knowledge	-0.0521
16	T29	Organizational structures and employees' role in learning networks	-0.0583
17	T39	Transformational leadership and organizational learning processes in innovation	-0.0606
18	T37	Knowledge transfer network and industrial development history	-0.0910
19	T18	Strategic management of networks and knowledge	-0.0974
20	T17	Design practices and collaborative product development processes	-0.1420
21	T9	Knowledge network as learning strategy in complex systems	-0.1570

(c) Steady Topics

1	T16	Stakeholder engagement to address sustainability issues	0.0137
2	T14	Actor's role in innovation networks	0.0036
3	T21	Organizational unit networks configuration and their knowledge processing	0.0030
4	T13	R&D internationalization and the knowledge diffusion between local and subsidiary firms	0.0028
5	T31	Levels of organizational configurations in innovation networks and high-tech industry	-0.0020
6	T12	Patents as a technological development spillover and inventors' network	-0.0123

7	T20	Knowledge diffusion and technology transfer focused on digital consumer behavior	-0.0182
8	T50	Social networks in healthcare	-0.2900

Discussions

After reading the 10 most representative abstracts of each of the 50 topics, we identified that some topics presented similarity and may reflect, in general, some of the evolution of the research in this field. We understand that there is a trend in studies that use an individual level analysis unit that may in some way impact the performance of the organization or innovation. This individual level appears in the topics of both the size of the companies and the concern for the individual. In addition, the issues that are on the rise seem to be related to practical issues and problems of organizations or environments. The similarity between the topics generated some perspectives that are presented in sequence.

Networking Outcomes

This perspective is related to the expected results from knowledge and innovation networks. We observed that the literature seems to demonstrate increasing interest in studying topics from the field of networks related to the performance of firms and co-creation of value, reflected in the hot topics T1 and T8. Although the topic of patents seems to have been explored over the years, its reflection through topic T12 emerged as a study trend that remained stable.

In T1 (Firm performance through knowledge networks), we observed that the literature was explored under different facets to understand how company performance is affected by networks to generate competitive advantages. In many studies, we observed that innovation performance (and possible variables that may affect it) appears as an antecedent of firm performance. In other studies, innovation performance seems to be used as a way of looking at firm performance. In addition, there is some interest in what can be considered as an antecedent of innovation performance.

In T8 (Value co-creation networks), we observed that the studies address how knowledge networks contribute to the creation of value by the companies involved. We also observed that the business model

and the characteristics of the environment in which the company is located are also factors that can influence the value creation processes. Part of the studies used the dominant service logic dominant theory and cost and transaction theory as lenses for these phenomena.

In T12 (Patents as a technological development spillover and inventors' network), we observed the presence of studies that started from the analysis of patents to understand the behavior of technological development in certain regions or industries. Patents were widely used to understand the flow of knowledge between inventors and how their mobility could influence the generation of inventions (often brought in as knowledge spillovers). In some studies, we identified the collaborative approach between industry and university, as well as the role of government, being mapped through patents. Most of the studies started with secondary data from patent databases, making use of quantitative techniques or network analysis to explore the topic.

5.2. Methodological aspects

This perspective reflects the findings regarding the methodological aspects of the analyzed articles, considering that in all abstracts there is a brief explanation of the methods used in the research. Topics T2, T3, and T10 emerged as hot topics and reflect the way networks have been used, increasingly, to translate both the literature in this field and to propose models and solutions that bring contributions to practice. As they contain similar terms, some topics ended up being divided into two groups, one more focused on the theoretical aspect and the other focused on the methodological aspect.

In T2 (Research design and network approach focused on empirical contribution), we identified two different themes. The first theme is related to research design, emphasizing research techniques and methods as a way to contribute with empirical studies in knowledge networks. The second theme is related to the use of the network approach as a theoretical lens or research design to analyze the phenomena, mostly dealing with value creation and the use of knowledge by companies (most of them in the tourism sector). In T3 (Network analysis in systematic literature reviews), we observed that there is a predominance of literature review studies, performed mostly through bibliometric techniques.

In T10 (Theoretical and methodological models of networks), we identified the presentation of two different groups of papers. The first group brought studies that proposed theoretical models as an attempt to translate and understand the dynamics of networks between companies. The second group sought to

present models, techniques, frameworks, and other solutions for the use of network analysis. In general, both groups present proposals for models that can bring contributions to network studies, whether in terms of method or theory.

Theoretical Aspects

In this perspective, we brought the topics that had, explicitly, the mention of theoretical lenses for the analysis of phenomena. We identified that the theories that emerge from the strategy line appear through the cold topics T5 (Absorptive capacity), T22 (Institutional logic), and T33 (Dynamic capabilities). Hot topics reflect the use of social capital theory (T24) and theories that serve as a lens for cognitive aspects (T30). It should be noted that these were not the only theories used in the surveys that were part of the sample. Some studies used a resource based view and service-dominant logic, for example. However, not all theories emerged as the main theme or as evidence to the point of assuming a leading role in the topics analyzed.

In T5 (Alliances portfolio diversity influencing firm's absorptive capacity), we identified studies that explored strategies for managing alliance portfolio diversity and partnerships between companies, mainly for the development of new products or technologies. Most of these partnerships are presented as ways to support the R&D departments of these companies, mostly large companies. Other studies argue that the way the diversity of these portfolios is managed makes a difference in the firm's absorptive capacity and in their innovation performance.

In T22 (Institutional logic in global innovation networks), we identified studies that sought to analyze the innovation networks formed between different countries from the perspective of institutional logic. For Dudukalov et al. (2016), global innovation networks play an important role in the development of the modern global economy because they stimulate international cooperation in the innovation sphere, the translation of knowledge in the global economic system, and general scientific and technological development and production development. Other authors, such as Genin et al. (2021), used institutional theory as a lens to explain how the different institutional aspects, networking characteristics, and the environment where they are inserted affect innovation results.

In T33 (Dynamic capabilities and buyer-supplier relationships), we identify how companies involved in buyer-supplier networks behave and benefit from the exchange of knowledge in innovation development processes. In some studies, there is the presence not only of the buyer and supplier actors, but also a role of the consumer contributing to these innovation processes. The argument used by some authors is related to the fact that these relationships help companies to develop or access the necessary capabilities to acquire a competitive advantage.

In T24 (Knowledge networks through the lens of social capital theory), we identified studies that used social capital theory as a lens to analyze knowledge networks. Part of the studies focus on the external perspective of organizations, exploring how the three dimensions of social capital (cognitive, relational, and structural) affect or are affected in interorganizational relationships. Other studies explore the same dimensions in the internal relationships of organizations in creative processes, focusing mainly on aspects related to trust.

In T30 (Rationalized logic and actor-centric ecosystems), we identified studies focused on the cognitive aspects of knowledge processing, often treated as translation logics or rationalized logic. These logics were constantly presented through metaphors or philosophical expressions as a way of translating the dynamics of ecosystems centered on different actors.

5.4 Practical contributions

In this perspective, we present the topics that addressed a theme directly linked to contributions to practice. We noticed that the topic becomes hotter as the contribution to the field becomes more specific or tangible. In addition, older themes or themes already extensively explored in the literature appeared as cold topics (T4, T9, and T37). Hot topics. on the other hand, focused on the clear contributions of the relationship between internal and external networks (T27), and collaboration networks focused on innovation and smart cities (T34). Issues focused on sustainability, customer behavior, knowledge diffusion, technology transfer, and stakeholder engagement appeared in topics T16 and T20, which remained stable over the years in this perspective.

In T4 (Practices to acquire and transfer knowledge), the analyzed studies point to several examples of practices to enable the transfer or sharing of knowledge. These practices, include the use of social

platforms, such as intranets, to encourage interaction between employees and companies, both externally or internally.

In T9 (Knowledge network as learning strategy in complex systems), we noted the presentation of studies that evaluated the knowledge networks formed between companies from different perspectives to understand how the exchange of knowledge occurs in complex systems. Some of the studies use actor-based approaches or co-evolutionary perspectives to understand the dynamics and interactions between those involved in a network. Apparently, this theme addresses the network as a strategic source of knowledge for companies to remain competitive. In addition, we observed the existence of studies bringing virtual platforms and environments as a way to promote interaction between network actors in complex systems, enabling greater reach between companies (for example, when accessing companies from other industries and ecosystems).

In T16 (Stakeholder engagement to address sustainability issues), we identified studies that addressed the use of networks as a way of bringing companies together to address sustainable problems, such as climate change. In T20 (Knowledge diffusion and technology transfer focused on digital consumer behavior), we observed the existence of studies focused on the use of platforms and other digital channels classified as information and telecommunication technologies in the innovation development processes focused on the consumer behavior of users.

In T27 (Relationship between internal and external knowledge networks), we identified studies that explore the relationship between internal and external networks under different aspects. These studies reinforce that the use of external networks as a source of knowledge is a strategy for solving company innovation problems. Although external networks play an important role in innovation outcomes, some important studies argue that internal networks play a role in that process. Studies started from the analysis of R&D studies or indicators, reflecting the networks between these large companies as objects of analysis.

In T34 (Collaborative innovation networks and smart cities), we identified studies that addressed the use of collaborative innovation networks to develop solutions for smart cities, often with a sustainable focus. We noticed that most of the solutions benefited cities in several aspects, but there is a predominance of studies that focused on solutions aimed at mobility, transport, and logistics. According to Leminen et

al. (2017), cities can benefit from innovation networks by simultaneously exploiting multiple platforms such as living labs for innovation.

In T37 (Knowledge transfer network and industrial development history), we identified studies that brought historical contexts as a way of presenting the scenario of specific sectors of the industry and used innovation networks as an argument or strategy for the industrial development in question. Parsons and Rose (2005), for example, explored both the legacy and the ways in which the networks of innovation functioned as the UK outdoor trade expanded. Bergquist and Söderholm (2011) argued that an examination of the innovation-system approach used to further the industry's environmental goals reveals that the knowledge and technology development underpinning the project depended on a network of diverse actors.

Structural Network Aspects

Regarding the structural aspects of the networks, we noticed that there was a predominance of cold topics related to the descriptive characteristics of the networks (T6 and T19). Themes related to the configurations of the organizations, as well as the roles of the actors in the networks, presented themselves as stable (T14, T21, and T31). Networking at the regional level emerged as the only hot topic linked to this perspective (T49).

In T6 (Network structures and characteristics), we identified studies that explore the influence of different structures and characteristics of a firm's relationships (e.g. size, quality, proximity, stability, and spatial aspects) on innovation generation and performance.

In T14 (Actor's role in innovation networks), we identified studies that address the role of different actors in innovation networks. Despite being part of a network with different actors (e.g. other companies, universities, government, and suppliers), having access to knowledge and resources is not enough for the company to succeed in its objectives related to generating innovation. Van de Ven (2005) argue that the role of the actor in this network and how knowledge and available resources are used has an influence on these results. For these authors, the actors do not play impartial roles; instead, they are active participants who become embroiled in diverse, partisan, and embedded issues of innovation development (Van de Ven, 2005).

In T19 (Geographic Scope of Knowledge Spillovers), we find studies based on the perspective of networks in terms of geographical structure. In this sense, issues such as distance or proximity between network companies were some of the aspects analyzed in these studies. We observed that the terms agglomeration and cluster were frequently used to analyze social behavior between companies at regional or global levels through a geographic view for the creation and use of knowledge directed to innovation.

In T21 (Organizational unit networks configuration and their knowledge processing), we identified studies that deal with the networks formed by companies and their different business units. The studies argue that the configuration of these networks of organizational units (e.g. distance, similarity, concentration, and dispersion) or idiosyncratic characteristics contained in these businesses (e.g. centralized versus decentralized R&D, specialist or generalist professionals) can influence how knowledge is processed and the expected results, whether they are focused on creativity, innovation performance, or company performance.

In T31 (Levels of organizational configurations in innovation networks and high-tech industry), we observed the approach of different levels of organizational configurations in the midst of networks. Part of these organizational configurations emerged as high and low levels of competences, entrepreneurial micro and macro level influences, higher education investment, and intellectual capital levels. We also noticed that most of the studies are related to the high-tech industry. In T49 (Interorganizational cooperation and regional networks), we identified studies dealing with cooperation between organizations and innovation networks formed at the regional level.

Strategic Management Level

In this perspective, we brought the topics that addressed themes related to the level of strategic management. We note that, as with the practical contribution perspective, there is heightened interest in studying topics that are more specific and tangible. Topics that addressed more general issues, such as the role of public support (T11), strategic management of networks (T18), capabilities (T26), strategies to manage quality, cost, and risk (T40), and governance mechanism (T47), were identified as cold topics. The hot topics that emerged brought up topics such as R&D partnerships and collaborative network across industries and sectors for innovation (T42), supply network stability in dynamic environments (T45), and

collaborative networks with the triple helix actors (T48). Topics such as R&D internationalization, the knowledge diffusion between local and subsidiary firms (T13), and social networks in healthcare (T50) have remained stable over the years.

In T11 (Regional innovation and the role of public support), we found studies that dealt with the development of innovation at a regional level and how the characteristics of the region influence the generation of innovation by companies inserted in this environment. Part of the studies focused on the role of public policies, government collaboration, and other types of public support to foster innovation at the regional level. For this, the networks were used as a way to understand the dynamics of these regions and how the government could support (or not) the innovation processes. In T13 (R&D internationalization and the knowledge diffusion between local and subsidiary firms), we identified studies focused on the R&D internationalization strategies of multinational companies and how knowledge is disseminated between local companies and their subsidiaries located in other countries.

In T18 (Strategic management of networks and knowledge), we identified studies that dealt with practices and techniques for strategic knowledge management and networks among companies for innovation generation. Some studies have brought the context of product development through R&D departments. Other studies have sought to understand how networks and knowledge management can be managed at a strategic level to reach competitive advantage. In T26 (Capabilities and knowledge networks' role in business innovation model), we identified studies focused on the use of knowledge networks as a strategy for accessing and developing the capabilities necessary for the (re)configuration of the business innovation model.

In T40 (Strategies to manage quality, cost, and risk in knowledge flows and innovation processes), we identified studies that sought to explore strategies to manage the cost, quality, and risks involved in innovation processes and knowledge flows. Authors such as Gupta et al. (2009) state that having knowledge networks external to the organization is a strategy to reduce the obstacles encountered throughout the innovation processes. On the other hand, other researchers bring the challenges of managing issues such as the high costs involved in these networks (since they often arise from the outsourcing of part of the process), risks of diffusion of strategic knowledge, and the impact on the quality of the products. The studies seem to try to balance mainly the aspects of quality, cost, and risk so that

companies can have the maximum advantage in the results without losing the dynamism of innovation and its positioning in the market.

In T42 (R&D partnerships and collaborative network across industries and sectors for innovation), we identified studies on partnerships formed between research and development departments as a strategy to accelerate and improve the product development process. In addition, we also found studies focused on interpersonal relationships generating collaborative networks to influence organizations' creative domains. Other studies have also addressed the behavior behind collaborative work in terms of authorship, exploring for example the impact of collaborator's quality and creativity on the outcomes (i.e. patents).

In T45 (Supply network stability in dynamic environments), we identified studies dealing with problems, solutions and strategies to help supply chain management remain stable and adapt quickly to the dynamics of the environment. Part of the studies brought up situations that forced companies to adapt, such as regulatory changes and the COVID-19 epidemic. Other studies used technology and pro-environmental activities as an argument for networks to make companies more efficient and sustainable, achieving their goals in an innovative way.

In T47 (Governance mechanism in the innovation and knowledge network), we identified studies that deal with governance mechanisms used by companies in knowledge and innovation networks. Although the literature deals more closely with the beneficial side of collaborative networks, studies on this topic bring up the concerns behind information protection and other mechanisms related to trust and social interaction between firms. In T48 (Collaborative networks with the triple helix actors), we identified studies dealing with networks formed with government, university, and industry. In T50 (Social networks in healthcare), we identified studies related to the use of social networks as a theoretical lens or method to explore problems related to the health sector.

Individual and Collective Level

Regarding the individual and collective levels, we found topics with research focused on exploring the role, characteristics, and behavior of individuals, leadership, and teams in networks. However, we noticed that while topics dealing with the individual level (such as community members and staff)

presented themselves as hot topics (T23, T29, T38, and T43). The themes focused on leadership and teams appeared as cold topics (T39 and T41).

In T23 (Social network brokerage and individual factor behavior), the studies seek to investigate how the characteristics and behavior of the individual factor affect the performance of innovation, as well as its interaction in the network. Research on social networks and innovation emphasizes that individuals spanning structural holes and crossing institutional boundaries have more opportunities for knowledge recombination and innovation involvement (Llopis et al., 2021). Occupying a brokerage network position provides the focal actor with structural opportunities to access non-redundant information and knowledge, which may result in enhanced innovative behavior (Nedkovski & Guerci, 2021). The identified studies seek to investigate how the characteristics and behavior of the individual factor affect the performance of innovation, as well as its interaction in the network.

In T29 (Organizational structures and employees' role in learning networks), we identified studies related to the influence of organizational structure and the role of employees in generating learning through knowledge and innovation networks. Some studies have focused on company assets, from hierarchical organization (e.g. traditional versus cellular) to the use of corporate social networks to encourage the exchange of knowledge. Other studies focused on the role of employees and how different employee profiles act in innovation-oriented learning processes.

In T38 (Online innovation communities and their members' behaviors through social network perspective), we identified studies that used the concept of communities of practice as a way to transfer knowledge among its members and generate innovative results. Due to the context of the digital economy, most studies deal with online or virtual communities and bring, in particular, the scenario of communities formed around open-source software projects. The behavior of the members of these communities, position of the members in the network, the role and formation of leaders in this environment, and the use of online communities as a form of spanning boundaries were other subjects addressed by studies on this topic.

In T39 (Transformational leadership and organizational learning processes in innovation), we found studies that addressed the different mechanisms involved in organizational learning processes towards innovation and how transformational leadership influences these processes. To de Weerd-

Nederhof et al. (2002), learning is an essential part of innovation, including the need to internalize and disseminate information and to reduce the duplication of research activities, both technological and organizational. According to García-Morales et al. (2008), organizations with greater organizational learning generate a network of learning that will make it easier for them to learn what they need to know and to innovate, enabling the organization to maintain its competitive position as a technological center. In some of the analyzed papers, aspects of transformational leadership were explored as a potential influence on these learning processes.

In T41 (Knowledge network influence on team diversity and team creativity), we identified studies related to the networks formed between teams and project organizations as sources of creativity and innovation for companies. According to Kratzer et al. (2010), since the creative product development task requires the teams to combine and integrate input from multiple other teams, the team's structure of interaction is an important determinant of their creativity. In addition, some studies present elements about the influence of team diversity on their creativity. For example, Bodla et al. (2018) explored conditions that leverage the positive and restrain the negative effects of team diversity on team knowledge sharing, which leads to team creativity.

In T43 (Education and professional development focused on innovation and industry's needs), we observed that the studies deal with the proposal or case studies of educational solutions for professional development, with a focus on the needs of industries. For example, Zaccarin and Silvestri (2011) state that universities play an important role in equipping students with suitable skills for developing research and innovation to identify the demand of firms in the sector. Hero, on the other hand, argues that universities play an important role in collaborating with industry, but the projects proposed by these institutions need to benefit student learning, not only the organizations looking for innovations.

Innovation Processes

In this perspective, we brought the topics directly linked to innovation processes. We observed that issues related to propositions of practices, activities, and models (often bringing case studies) presented themselves as cold topics (T17, T28, T32, and T36). The topics related to the specific search for

the influence of networks on innovation processes (T7) and the evolution of innovation processes from collaborative networks (T46) were presented as hot topics.

In T7 (Network influence in innovation processes), we identified studies focusing on activities related to innovation processes and how knowledge and collaboration networks can affect their results. Studies often address different types of innovation, stages of the innovative process, and how networks affect the exploration and exploitation of knowledge.

In T17 (Design practices and collaborative product development processes), we identified two complementary groups of articles. The first group included studies focused on the product development process being supported by the networks formed between companies, suppliers, and other actors. In the second group, there are studies that bring different techniques and approaches to the design of new products.

In T28 (Organizational characteristics and ideation networks), we identified studies related to ideation networks as part of innovation processes and how the characteristics of organizations influence these processes. In addition, we observed that part of the studies mention the use of platforms based on web or social media as tools for the exchange of knowledge between collaborators and other actors in the network, becoming the environment where the ideation process (or part of it) takes place.

In T32 (Customer centric innovation and service organizations), we identified studies focused on customer-centric solutions development practices and processes. Due to the degree of customization as a way of adding value to what is being delivered to the customer, these solutions appear in the studies as an innovation. We observed that these solutions are mostly delivered in the form of services, and not necessarily in the form of a tangible product. In this sense, the topic also addresses how organizations providing these services can better understand customer behavior, both for the development of new innovative solutions (services) and for the configuration of their business management strategies.

In T36 (Networking across boundary spanning activities), we identified studies focused on boundary spanning activities to promote interactions at the intra-organizational level in such a way that it can benefit companies' innovation processes. For Huo (2021), for example, knowledge search spanning organizational boundaries is believed to be essential to innovation but is often technologically, geographically, and socially bounded in the inter-firm co-innovation processes. Furthermore, given that

spanning any type of boundary may lead to both decreased learning and increased creativity, its influence on co-innovation success remains unclear (Huo, 2021). In T46 (Evolution of innovation processes based on collaborative networks), we identified studies that deal with the evolution of innovation processes and the life cycles of collaboration networks between actors for the development of new solutions.

Size of the Firm

In this perspective, we identified aspects related to the size of companies as an unexpected result of the analysis of the topics. Although most of the studies analyze the networks between large companies and institutions such as government and universities, the literature seems to be directed to explore phenomena of smaller companies. We found topics related to small and medium enterprises (T15) and startups (T35). These findings may point to aspects of the networks that work differently for these companies, as they have different challenges compared to multinationals.

In T15 (Networks as a source of competitive advantage for small and medium-sized enterprises), we identified studies that addressed how small and medium-sized companies benefit from networks to gain competitive advantage. Part of the studies argue that networks are strategic for companies of this size because they have different challenges in comparison with large companies and because this is a way to allow them entry into different markets. In addition, other studies argue that networks help small and medium-sized companies to fill their gaps (considering that they are companies with limited resources), especially in terms of coopetition, as they benefit from networks both to cooperate and to compete with other companies.

In T35 (Startups and Investment Networks for Innovation), we identified articles related to the influence of investment networks on startup innovation outcomes. As an investment network, we noticed the presentation of different actors such as universities, venture capital, crowdfunding, and incubators. While some studies argue that these investment networks are useful for providing physical spaces and funds, other studies suggest that entrepreneurs may prefer, for example, incubator collaboration because of business and network knowledge. Although most studies are presented at the organizational level, we observed the existence of studies that explored the characteristics of founders or investors as something that can also influence the innovation results of these startups.

5.10. Entrepreneurship

Another unexpected finding was reported in this perspective, which brought up topics related to entrepreneurship. We noticed that themes related to universities and technology parks as environments that foster entrepreneurship were presented as cold topics (T25). On the other hand, studies that seek to understand how to identify and develop business opportunities through networks emerged as a hot topic for future research (T44).

In T25 (Entrepreneurial universities and science parks spin-offs), we identified studies focused on knowledge networks involving universities and technology parks for technological development. Universities, as providers of knowledge and technology, have a key role in society based on knowledge (Marques et al., 2019). Science parks have been crucial elements of innovation systems both in developed and developing countries because of their role in bridging the gap between academia and business through knowledge spill-overs and spin-offs (Fikirkoca & Saritas, 2012). In this sense, access to academic knowledge and expertise by businesses located on site is a key principle of Science Parks (Lindelof & Lofsten, 2005). Some studies suggest that companies that form networks with universities and technology parks benefit both in terms of technological development and in aspects related to entrepreneurship. Hansson et al. (2005), for example, argue that the new role of science parks may be to cater for the development of the social capital necessary for enabling and facilitating entrepreneurship in networks. Other studies used academic entrepreneurship literature to show how universities can supply support for the development of firm competencies, either directly or indirectly (Rasmussen & Wright, 2015).

In T44 (Entrepreneurial opportunity identification and development through social networks), we identified studies that explored how the characteristics of entrepreneurs and the networks in which they are inserted influence business identification and development. Part of the studies analyzed these networks between entrepreneurs in a broad way, dealing with the characteristics of the entrepreneurial ecosystem and physical spaces (such as coworking spaces). Shu 2018, for example, argues that social networking is increasingly important to entrepreneurs because it can help them to recognize valuable opportunities. In this sense, some other studies were identified dealing with the alertness, personality traits, and interaction mechanisms among entrepreneurs, that precede the identification of a business opportunity. Others argue that these same traits are valid for driving businesses to success.

Final Considerations

We identified 50 topics from studies on knowledge networks and innovation, applying the method of modeling topics in a text corpus containing more than five thousand articles published in the period from January 1985 to December 2021. Among the findings, we identified 21 hot topics, 21 cold topics, and 8 steady topics that may support the direction of future studies.

The results seem to point to studies that seek to explain the phenomena within the context of innovation and knowledge networks in more detail. We noticed that many studies that appear as cold topics addressed issues at a macro level or in a generic way. Matters related to practical problems and clear results were presented as hot topics. The clearest contribution among the topics is precisely the hottest topic: T1 - Firm performance through knowledge networks. This is perhaps the topic that sums up the interest behind all the other topics found in topic modeling. In addition, the interest in studying networks in smaller companies was also a finding that deserves further investigation in future studies, as well as the convergence with the field of entrepreneurship.

Although an attempt has been made to converge the themes, there are opportunities for improvements to be implemented. One possible improvement is an in-depth discussion of the hot and cold topics found and the presentation of propositions that better guide researchers in future studies. Furthermore, research into topics that have not been identified as hot (cold) may suggest recent topics that do not yet have a sufficient volume of publications. In this sense, an analysis of these emerging topics could also bring contributions to research on this topic. Another limitation of this study is the fact that the literature on internal networks and external networks was not disassociated. A complete mapping of all theories used as a lens for both different types of networks was also not provided. Future studies can explore these opportunities and provide further insights for researchers in this field.

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Submetido:

Aceito:

Comentado [A1]: Inserir as informações