Revista Ibero-Americana de Estratégia
Iberoamerican Journal of Strategic Management

e-ISSN: 2176-0756
doi.org/10.5585/riae.v21i1.21165
Received: 25 Nov. 2021 / **Approved:** 22 Set. 2022
Evaluation Process: Double Blind Review
Editor in Chief: Heidy Rodriguez Ramos
Co-editor: Ivano Ribeiro
Associate Editor: Marcelo Roger Meneghatti

COPE JM14473

TECHNOLOGICAL COOPERATION NETWORKS AND PATENTS IN BIOTECHNOLOGY: IDENTIFICATION OF CONCEPTUAL BASES

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Abstract

Objective of the study: This article seeks to explore from bibliometrics with factor analysis, the conceptual bases of the thematic networks of technological cooperation and patents in biotechnology.
Methodology: We performed an exploratory factor analysis (EFA) for quantitative analyses, using the BibExcel software and the Kaiser-Meyer-Olkin test (KMO) (SPSS software). The matrix of citations and quotations resulted in 86 articles, distributed in three factors, according to similarity analysis (Iramuteq software).
Originality/relevance: The term "technological cooperation networks" is increasingly becoming widespread in academia and in the biotechnology sector. However, its concept comes from different theoretical fields, and in the literature, there is still a lack of convergence.
Main results: The matrix of citations and quotations resulted in 86 articles, distributed in three factors, according to similarity analysis (Iramuteq software). The main contribution of the research was the identification of three converging factors, namely: 1) the central role of the biotechnology firm in articulating the knowledge, innovations, and technologies produced and disseminated in the technological cooperation networks; 2) the patent as a valuable resource that concentrates and highlights knowledge, innovations, and technological routes for the firm, its networks, and the industry; and 3) research conceived as a networked activity that promotes the intersection between science produced in universities, technologies conceived in firms, and the dissemination to industry and society of articles, patents, and innovations.
Theoretical/methodological contributions: This study can contribute to the advancement of scientific knowledge by identifying the converging factors of the conceptual field of technological cooperation networks in biotechnology.

Keywords: Innovation. Biotechnology. Bibliometry. Analysis of social networks.

REDES DE COOPERAÇÃO TECNOLÓGICA E PATENTES EM BIOTECNOLOGIA: IDENTIFICAÇÃO DAS BASES CONCEITUAIS

Resumo

Objetivo do estudo: Este artigo busca explorar, a partir da bibliometria com análise fatorial, as bases conceituais das redes temáticas de cooperação tecnológica e patentes em biotecnologia.
Metodologia/abordagem: Foi realizada uma análise fatorial exploratória (AFE) para análises quantitativas, utilizando o software BibExcel e o teste Kaiser-Meyer-Olkin (KMO) (software SPSS). A matriz de menções e citações resultou em 86 artigos, distribuídos em três fatores, segundo análise de similaridade (software Iramuteq).
Originalidade/relevância: O termo "redes de cooperação tecnológica" está se difundindo cada vez mais na academia e no setor de biotecnologia. No entanto, seu conceito vem de diferentes campos teóricos e, na literatura, ainda falta convergência.
Principais resultados: A matriz de citações e citações resultou em 86 artigos, distribuídos em três fatores, segundo análise de similaridade (software Iramuteq). A principal contribuição da pesquisa foi a identificação de três fatores convergentes, a saber: 1) o papel central da empresa de biotecnologia na articulação do conhecimento, das inovações e das tecnologias produzidas e disseminadas nas redes de cooperação tecnológica; 2) a patente como um recurso valioso que concentra e destaca conhecimentos, inovações e rotas tecnológicas para a empresa, suas redes e a indústria; e 3) pesquisa concebida como uma atividade em rede que promove a intersecção entre a ciência produzida nas universidades, as tecnologias concebidas nas empresas e a divulgação para a indústria e a sociedade de artigos, patentes e inovações.
Contribuições teóricas/metodológicas: Este estudo pode contribuir para o avanço do conhecimento científico ao identificar os fatores convergentes do campo conceitual das redes de cooperação tecnológica em biotecnologia.

Palavras-chave: Redes de Cooperação Tecnológica. Patentes. Biotecnologia. Bibliometria. Análise de Redes Sociais.

REDES DE COOPERACIÓN TECNOLÓGICA Y PATENTES EN BIOTECNOLOGIA: IDENTIFICACIÓN DE LAS BASES CONCEPTUALES

Resumen

Objetivo del estudo: Este artículo busca explorar, a partir de la bibliometría con análisis factorial, las bases conceptuales de las redes temáticas de cooperación tecnológica y patentes en biotecnología.
Metodología: Fue realizado un análisis factorial exploratorio (AFE) para análisis cuantitativa, utilizando el software BibExcel y el test Kaiser-Meyer-Ohlin (KMO) (software SPSS). La matriz de menciones y citaciones resultó en 86 artículos distribuídos en tres factores, según el análisis de similaridad (software Iramuteq).
Originalidad/relevancia: El término "redes de cooperación tecnológica" se está difundiendo cada vez más en la academia y en el sector de biotecnología. Sin embargo, su concepto viene de diferentes campos teóricos y en la literatura aún falta convergencia.
Resultados: La principal contribución de la pesquisa fue la identificación de tres factores convergentes, a saber: 1) el papel central de la empresa de biotecnología en la articulación del conocimiento de las innovaciones y de las tecnologías producidas y diseminadas en las redes de cooperación tecnológica; 2) la patente como un recurso valioso que concentra y destaca conocimientos, innovaciones y rutas tecnológicas para la empresa, sus redes y la industria; 3) pesquisa concebida como una actividad en red que promueve la intersección entre la ciencia producida en las universidades, las tecnologías concebidas en las empresas y la divulgación para la industria y la sociedad de artículos, patentes e innovaciones.
Aportes teóricos/metodológicos: Este estudio puede contribuir para el avance del conocimiento científico al identificar los factores convergentes del campo conceptual de las redes de cooperación tecnológica en biotecnología.

Palabras llave: Patentes. Biotecnología. Bibliometría. Análisis de Redes Sociales.

Cite as / Como citar

American Psychological Association (APA)
Almeida, J. M. S., Costa, P. R., Kniess, C. T., Cirani, C. B. S., & Vils, L. (2022). Technological cooperation networks and patents in biotechnology: identification of conceptual bases. *Iberoamerican Journal of Strategic Management (IJSM), 21*, 1-34, e21165. https://doi.org/10.5585/riae.v21i1.21165.

(ABNT – NBR 6023/2018)
ALMEIDA, João Marcos Silva de; COSTA, Priscila Rezende da; KNIESS, Cláudia Terezinha; CIRANI, Claudia Brito Silva; VILS, Leonardo. Technological cooperation networks and patents in biotechnology: identification of conceptual bases. *Iberoamerican Journal of Strategic Management (IJSM),* v. 21, p. 1-34. 2022. https://doi.org/10.5585/riae.v21i1.21165.

1 Introduction

The importance of cooperation mechanisms between companies in the face of the dynamics of technological innovations has been more explored in recent studies. Research has shown that approaches focused exclusively on the internal competencies of companies, especially activities of greater scientific and technological complexity and with a frequency of innovation, do not fully explain the results (Côrtes, Pinho, Fernandes, Smolka, & Barreto, 2005).

The interaction between the various actors that comprise the cooperation can be analyzed from different perspectives. This research observes that under the paradigm of open innovation, the players seek to favor the acquisition of new knowledge and access to complementary resources (Guan, Zhang &Yan, 2015; Marquardt, 2013), improve investment allocation (Chesbrough & Appleyard, 2007; Guan & Wei, 2015), and the innovative performance of participants (Sampson, 2007).

The cooperating associates consist of companies (Da Costa, Porto, & Feldhaus, 2010), universities (Santana & Porto, 2009), research institutes (Oliveira & Telles, 2011), technological innovation centers (Desiderio & Zilber, 2014; Dias & Porto, 2014), scientific parks (Novelli & Segatto, 2012), regional innovation systems (Santos, Sbragia, & Toledo, 2012), and national innovation systems (Lopes, 2007; Da Cunha & Cario, 2017).

Cooperation requires developed and commonly accepted management procedures which are implemented and made more flexible by partners, resulting in skills and not only technological competences, but also of relational capacity management (Da Costa, Porto, & Feldhaus, 2010). According to Dyer and Singh (1998), interfirm connections can be a source of relational gains and competitive advantage. For Lado, Paulraj and Chen (2011), obtaining relational gains and competitive advantage depends directly on the development and maintenance of relational skills.

To enhance technological innovation and expand cooperation horizons beyond companies, Leydesdorff and Etzkowitz (1997) broaden the scope of cooperation and propose the concept of the Triple Helix, in which cooperation between industry, government, and university plays a fundamental role in societies based increasingly on knowledge (Etzkowitz & Leydesdorff, 2000). The Triple Helix model is a proposal that recommends an interrelation between the free market and centralized planning (Etzkowitz, 2013). According to this proposal, the economic growth of the future is not dependent on just innovation cycles, but on a new structure, which aims to bring basic and applied research closer (Leydesdorff & Meyer, 2006).

University-company cooperation (U-C) can be defined as a set of interactions aimed at the production of knowledge, involving direct relationships between companies or a group of companies and universities, such as technological cooperation networks (Schartinger; Rammer & Fröhlich, 2012). Santoro and Gopalahrishnam (2000) emphasize that it is necessary to institutionalize knowledge in cooperative relationships to achieve a continuous flow in the acquisition of this knowledge, as the processes of exchange and acquisition are influenced both by the organizational aspects (organizational structure and culture), as well as the characteristics of knowledge, such as appropriation and network transfer from tacit to explicit knowledge.

The biotechnology sector is a fortuitous analysis context for the formation of cooperation networks, due to the specific characteristics the segment presents. Among which Powell, Koput and Smith-Doerr (1996) observed in their research that the development of innovations in the biotechnology sector is directly related to the establishment of inter-organizational partnerships and the formation of innovation networks. This occurs in the transformation of biotechnological scientific research knowledge into new technologies based on cooperability, as well as the multi-disciplinarity of knowledge that is necessary for the development of biotechnological products and processes, culminating in the technological and socioeconomic growth of several nations. The Biotechnology sector has industries that are founded on multidisciplinary knowledge and retains characteristics of networking and expansion in the international market and the sources of expertise. These industries are widely dispersed, and in these cases, innovation will be found in the form of cooperation networks, more than in individual organizations (Powell, Koput, & Smith-Doer, 1996).

Biotechnology companies tend to develop a complex and dynamic system of cooperation networks, formed by universities, research institutes, investment funds, government agencies, pharmaceutical laboratories, and other biotechnology companies (Estrella & Bataglia, 2013). Frenken, Ponds and Van Oort (2010) utilized patent counting in their research to characterize cooperation networks between companies and universities. The authors found that the impact of this cooperation on innovation is not only mediated by the proximity of the actors, but also by the networks resulting from the cooperation between university and industry. Hall, Jaffe and Trajtenberg (2005) concluded that patents are indicators of technological production and a window for technological change.

Given the above, it is noted that, among scholars, the term Technological Cooperation Networks (TCN) in Biotechnology has been increasingly widespread. However, the concept comes from different theoretical fields, and in the literature, there is still a lack of convergence on its use. Thus, the following question emerges: what are the conceptual bases of the thematic networks of technological cooperation and patents in biotechnology? Therefore, based on bibliometrics with factor analysis, this article seeks to explore the conceptual bases of the thematic networks of technological cooperation and patents in biotechnology. To accomplish this, the bibliometric method was used, from the survey of the scientific production of the most influential authors and their respective correlations, identifying the main conceptual bases that helped in the formation of the conceptual field on technological cooperation networks and patents in biotechnology.

This work aimed to contribute to the conceptual congruence of the field of technological cooperation networks in biotechnology, through the classification of the main congruent factors, assisting researchers in the identification of the main schools of thought that built the theoretical-conceptual basis. It is also expected that future researchers will find in this work an orderly and systemic research structure for subsequent replication, providing direction for future research.

This article is structured as follows: the first section is the introduction which covered the main characteristics of technological cooperation and networks. In the second section, the theoretical framework is contemplated, with the foundations of technological cooperation networks, the biotechnology sector, and bibliometrics. The third section examines the methodology and the fourth presents the discussion and analysis of the results. The fifth and last section is the conclusion with its implications for the theory, identifying the limitations of the study, and possible paths for future investigations.

2 Theoretical framework

Technological cooperation networks emerge as an essential element, which allows organizations to share their skills and contribute quickly and intensively to the development of technologies (Balestrin & Verschoore, 2016).

The studies by Bengtsson and Sölvell (2004) have shown that the intensity of interaction in a network is positively correlated to the generation of innovations. Evidence indicates that companies not engaged in cooperation and knowledge exchange limit their knowledge bases and reduce their ability to participate in interorganizational relationships (Pittaway, Robertson, Munir, & Denyer, 2004).

Cooperation networks emerged in the organizational field with the aim of gathering attributes that allow companies to adapt to the competitive and dynamic environment (Thompson & Thompson, 2003), contributing to combining and integrating complementary knowledge and skills (Ahuja, 2000), and gain competitive advantage (Arya & Lin, 2007).

Belderbos, Carree and Lokshin (2006) observed that the engagement of companies in multiple cooperation networks can represent a complementarity of projects, to benefit companies' strategic choices for innovation. The cooperation in this sense refers to the concept of Open Innovation developed by Henry Chesbrough in 2003 as part of a process for the acquisition of external resources, helping in the efficiency of the innovation process. Open innovation also allows access to complementary resources (Guan et al., 2015; Marquardt, 2013) which contributes to the participants' innovative performance (Sampson, 2007).

The open innovation paradigm based on cooperation has led to a growing interest in understanding the structure of networks belonging to knowledge flows and possible established standards (Sebestyén and Varga 2013; Bogers et al. 2017; Roper and Love 2018), and the influences of the structures of these formed networks that can result in innovation (Broekel and Hartog 2013; Boschma, Heimeriks & Balland, 2014). Definitions by Chesbrough and Bogers (2014) emphasize that the main characteristic of innovation is the organizational capacity to manage knowledge flows so that the nature of network innovation can be defined.

The Triple Helix model, developed by Etzkowitz (1993) and Etzkowitz and Leydesdorff (1997), is applied in this context of cooperation, as it has demonstrated a new understanding about the relationship between companies and universities, placing the government as another actor in the network. The integration between these actors proposes a dynamic relationship between the State, science performed in universities, and technology developed in companies (Etzkowitz & Leydesdorff, 2000, p.112). This theory emphasizes that a certain level of interaction between these three actors (universities, industries, and government) can create an effective system for the development of innovations (Ivanova & Leydesdorff, 2014).

The biotechnology sector in this context is, therefore, a fertile ground for the formation of technological cooperation networks. Powell et al. (1996) also observed in their research that the development of innovations in the biotechnology sector is directly related to the establishment of inter-organizational partnerships and the formation of innovation networks. This causes this sector to assume an important role in the point of view of the consolidation strategies of the knowledge-based economy, for promoting competitiveness, leveraging network growth, and creating specialized jobs (Barbosa & Paula, 2016).

The heterogeneity of the network's knowledge, based on the different characteristics of the integrating actors and the strength of the relationships between them, directly affects the performance of innovation in biotechnology companies (Demirkan & Demirkan, 2012). Powell et al. (1996) observed the same phenomenon, that is, the different types of agreements or relationships established by companies in the biotechnology sector directly affect the performance of innovation.

Technological cooperation networks are essential for companies in the biotechnology sector, given the competitive and intensive nature of knowledge, making the network one of the main sources of new knowledge (Pisano, 2006). Biotechnology is characterized as a sector in which scientific and product development processes are collaborative (Oliver, 2004). In addition, scientific research in biotechnology companies is increasingly driven by network-based relationships (Katz & Hicks, 1997).

3 Method

Bibliometry can be defined as the application of statistical and mathematical methods in the analysis of literary works (Groos; Pritchard, 1969), which aims to present indexes of production and dissemination of scientific knowledge (Araújo, 2006). Such methods can collaborate with the task of systematizing research in an area of knowledge and directing problems to be investigated in future research (Chueke & Amatucci, 2015).

In the field of applied social sciences, bibliometric studies also seek to examine the production of articles in a specified field of knowledge, mapping academic communities and identifying the networks of researchers and their motivations (Okubo, 1997). Therefore, it is a research technique that allows the measurement of scientific production (Nederhof, 2006), making it possible to count, based on analysis of publications, citations, and quotations (Cronin, 2001).

The author conducted numerous researches to perform this study and to systematically analyze the scientific field, trace its historical evolution, map its intellectual structure, and evaluate its strengths and weaknesses (Nerur, Rasheed, & Natarajan, 2008; Shafique, 2013; Pilkington & Meredith, 2009). Bibliometric techniques have previously been used to perform studies of this nature.

The analysis of authors' quotations reveals patterns of association between authors, based on their frequency of quotations, which advances the understanding of the evolution of an academic discipline (White & McCain, 1998). Furthermore, this type of analysis can also indicate research groups, which tend to share common theoretical and methodological themes (Small & Garfield, 1985). Citations by seminal authors provide a basis for unraveling the complex patterns of associations that exist between them, detecting changes in intellectual currents that occur over time (Nerur et al., 2008).

The study of citations, while retrieving the sources of consultation regarding previous works, has become a method of mapping for the development of science. However, to understand bibliometric research, it is essential to know the three main characteristics of these studies: 1) Lotka's Law: which refers to the authors' productivity calculation; 2) Bradford's Law: which refers to the dispersion of authors in different journals; and 3) Zipf's Law: which refers to the frequency of words in a given text (Nerur et al., 2008).

It is also crucial that the researcher has knowledge of the research topic, so that he can properly define the "search expression". Finally, it is necessary to define the search filters: search period (year), area and subarea, if only articles published in journals or not will be searched and, finally, the language of the publication.

The most used databases for bibliometric research are Web of Science (Thomson Reuters) and Scopus (Elsevier), both of which have practically the same coverage and are prepared for bibliometric research, presenting the main information. Both bases contain relevance of journals, number of citations for each article, most cited authors, etc. In this research, we chose to use the Web of Science database, since it contemplates the Administration journals with the greatest impact factor and uses the normalization of authors.

Therefore, this article was developed from a bibliometric study, a statistical tool that allows mapping and generating different indicators of treatment and management of information and knowledge (Guedes & Borschiver, 2005). Bibliometrics proved to be appropriate for this research, as it allowed the identification of the main publications, considering the field of knowledge researched over the determined period, demonstrating the main congruent factors of a given conceptual field and the relationships between them (Pilkington & Meredith, 2009).

Following the protocol of Quevedo-Silva, Santos, Brandão and Vils (2016), a search was completed on the Web of Science journals portal, between the months of January and February 2019 with the following search terms: ("cooperat * or collabor * or network * or technol *") or patent *) and biotec *. The keywords that formed the search expression were chosen as they represent the conceptual field that was intended to be researched, being: "technological cooperation networks" in the biotechnology sector. Due to this objective, the word "biotechnology" was placed at the end of the expression with the Boolean "and" to cover the biotechnology segment. Another component was the use of the word "patent" as this term is an important element in this segment, due to the intellectual protection it provides to companies in this sector. However, the author employed "patent" with the Boolean "or" because when they performed searches with the Boolean "and", the search was very restricted and obtained few results. This fact could make the research unfeasible, thus, using the Boolean "or" offered more possibilities. Based on this adopted premise, the results acquired a specific article by Murray (2001), mentioning the importance of the Bayh-Dole law on the patenting of research in American universities. Other segments, especially high technology, such as semiconductors and nanotechnology, also have bases for cooperation with universities and research centers.

The decision process to determine the best search expression aimed to return articles that best addressed the selected conceptual field. As a tool to support the choice of words, terms, and expressions, we used the Linguee dictionary, which presents characteristics that distinguish it from a traditional dictionary, as it shows not only the entries and their respective translations, but also generates a Parallel Corpus, containing the word or the searched expression. The phrases that compose the corpus are found by programs called network crawlers (web crawlers). The trackers allow the dictionary to constantly have new data. When selecting words, phrases, or expressions, bilingual sites are searched, including those translated by professionals, universities, and organizations (Mikhailov & Cooper, 2016).

Another critical factor for the success of defining the search expression is the conceptual domain of the authors. However, before defining the final search expression, it is also important that the sentences found are analyzed by peers from the academy and experts in the field. In this specific research, meetings were held with research colleagues and professors who had expertise in the field of knowledge. Once we defined the search expression, it was necessary to place the search parameter filters. In this stage, the following filters were used: "Years of Publication": from 1988 to 2019; "Web of Science Categories": Management and Business, and "Types of Documents": Articles.

The search resulted in 365 articles, allowing for the extraction of the most cited articles, most important authors, and periods of greatest influence. In addition, the author prepared the matrix of citations and co-citations, using the BibExcel software to perform exploratory factor analyses. In this stage, specifically, for the articles to be exported from the Web of Science to the BibExcel software, the 365 articles were "marked" and added to the Marked List. It was also necessary to place filters in this process: "authors", "summary", "title". In this stage, it is of special importance to mark the fields: "cited references" and "number of citations". After this step, we generated a TXT file, which was then inserted into the BibExcel software, to elaborate the matrix of citations and quotations. 86 articles distributed in 86 lines and 86 columns represented the matrix resulting from citations and co-citations from this process, also called the quadrangular matrix. At this juncture, the articles identified by the quadrangular matrix obtained citations among the related authors. From this, the data were ready for exploratory factor analysis.

Exploratory factor analysis is a data reduction technique based on the correlation between cases or observations to common factors. The factors found indicate the convergence of authors for a given theme, subject, or problem. In the analysis of the co-citation matrix, the authors who cite and correlate form a factor that can determine a field of study (Quevedo-Silva et al., 2016).

Following the procedures recommended by Hair, Babin, Money and Samouel (2005), with the support of the SPSS software, three main factors were extracted, with 86 authors correlating, as shown in Table 1. All authors involved in this extraction had a KMO above 0.5. The Kaiser-Meyer-Olkin test (KMO) is a statistical method that indicates the proportion of data variance that can be considered common to all other variables, that is, it can be attributed to a common factor.

After reading the 86 articles that composed the matrix of citations and co-citations, and to assist in the analysis of each of the three identified factors, we used the Iramuteq software to identify the possible relationships between words and concepts from the lexicometry that could assist and improve the interpretation of the results of the content analysis conducted by reading the 86 articles. The results of the Iramuteq software enable different types of analysis of textual data, from very simple, such as basic lexicography (calculation of word frequency), to multivariate analyses (descending hierarchical classification, similarity analyses). This organizes the distribution of vocabulary in an easily understandable and visually clear way (similarity analysis and word cloud) (Camargo & Justo, 2013). The Iramuteq (R Interface for Multidimensional Analysis of Texts and Questionnaires), developed by Professor Pierre Ratinaud, from the laboratory of studies and research in applied social sciences (LERASS) of the University of Toulouse, has as a principle the lexicometry, which constitutes the organization and summarization of the structures of the texts, broken down into words. The distances between these words also allow for lexical analyses, such as descending hierarchical grouping (Reinert, 1987) and analysis of similarity of text segments (Benzécri, 1973). For this step, the author introduced titles, abstracts, and keywords into the Iramuteq software for each of the three identified factors, with 32 articles representing factor 1, 34 articles representing factor 2 and, finally, 20 articles representing factor 3. At the end, Iramuteq was used for a general view and evaluation of the 86 articles with their titles, abstracts, and keywords.

Through this software, the different types of textual data were observed and analyzed, which contributed significantly so that the three factors that would represent the convergence of concepts between the authors could be definitively named. The Iramuteq analyses used the titles and abstracts of the 86 articles, with each factor being rotated independently.

4 Data analysis and interpretation

The 31-year chronological analysis (from 1988 to 2019) of the conceptual field on technological cooperation networks was appropriate. Although the term was devised in seminal studies by Stepanenko (1959), who explored scientific and technological development between socialist countries, and with

Pfaltzgraff and Deghand (1968), who studied technological collaboration between European countries, it was only from the 1990s that the first studies with the current contemporary perspectives on cooperation networks began to emerge. The theory on strategy for inter-organizational cooperation proposed by Hagedoorn (1993) stands out, in which the author states that the cooperation between companies is primarily motivated by interests in basic and applied research or is associated with a networked strategy for accessing markets. Considering the scientific evolution of the conceptual field on technological cooperation networks over 31 years, Table 1 shows the sum of the number of citations and average per item of the authors.

Table 1 shows the number of publications per year and is expanded in Figure 1, which displays the period from 1999 to 2018, which has the highest conceptual production on technological cooperation networks. Finally, in Figure 2, it is possible to see the number of citations per year, particularly in the period from 2000 to 2019, the period with the highest number of citations in the conceptual field of the research.

Table 1

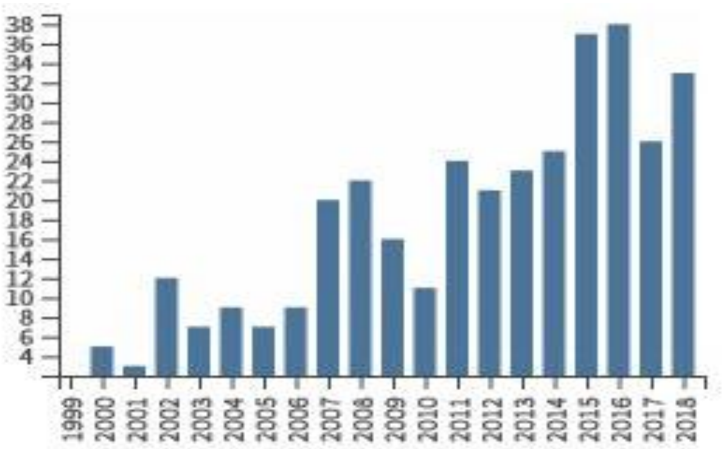
Summarized research data

Scientific evolution of the conceptual field on Technological Cooperation Networks (from 1988 to 2019)	Quantity.
Results found (number of articles)	365
Sum of number of citations	14,342
Average citations per item	39,19
h-index	55

Source: Authors elaboration.

Figure 1

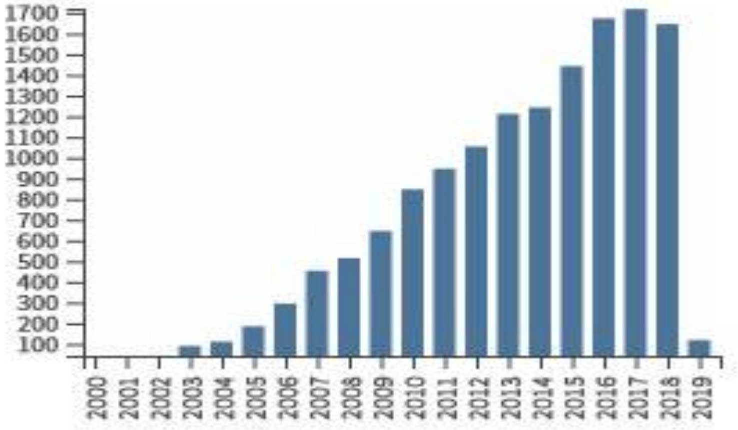
Articles published by year, considering the conceptual field on TCN (from 1999 to 2018)



Source: Authors elaboration.

Figure 2

Citations by year, considering the conceptual field on TCN (from 2000 to 2019)



Source: Authors elaboration.

Based on Figure 1, we can see a relative growth of publications over the years (1999 to 2010) in the conceptual field on technological cooperation networks, which, even after some fluctuations, has grown again in a new cycle (from 2011 to 2018). Regarding the number of citations established per year (Figure 2), a growth trajectory is observed, demonstrating the growing impact and relevance of scientific research on technological cooperation networks, with emphasis on the period from 2003 to 2018.

In addition to the scientific evolution of the conceptual field on technological cooperation networks (from 1988 to 2019), regarding the growing number of published articles, as well as their citations, the matrix of citations and co-citations was also elaborated (Table 1), using BibExcel software for exploratory factor analysis. Thus, three main factors were extracted, with 86 authors correlating, as shown in Table 2. All authors involved in this extraction had a KMO above 0.5.

Table 2

Factorial Matrix

	Matrix (authors)	Factors		
		1	*2*	*3*
1	Ahuja G, 2000	.809		
2	Ahuja G, 2001	.761		
3	Almeida P, 1999	.698		
4	Arora A, 1990	.810		
5	Baum J, 2000	.825		
6	Burt R, 1992	.690		
7	Decarolis D, 1999	.740		
8	Dosi G, 1988	.507		
9	Dyer J, 1998	.791		
10	Griliches Z, 1990	.651		
11	Hagedoorn J, 1993	.859		
2	Hausman J, 1984	.680		
13	Henderson R, 1996	.661		

	Matrix (authors)	Factors		
		1	*2*	*3*
14	Jaffe A, 1986	.673		
15	Jaffe A, 1993	.556		
16	Lane P, 1998	.814		
17	Levin R, 1987	.719		
18	Levitt B, 1988	.716		
19	Mowery D, 1996	.818		
20	Owen-Smith J, 2004	.650		
21	Penrose E, 1959	.741		
22	Pisano G, 1990	.680		
23	Powell W, 1996	.640		
24	Rosenkopf L, 2003	.647		
25	Rothaermel F, 2004	.758		
26	Schilling M, 2007	.684		
27	Schumpeter J, 1934	.639		
28	Shan W, 1994	.834		
29	Stuart T, 1999	.740		
30	Stuart T, 2000	.813		
31	Teece D, 1986	.500		
32	Teece D, 1997	.721		
33	Ahuja G, 2001		.854	
34	Albert M, 1991		.799	
35	Alcácer J, 2006		.730	
36	Alcácer J, 2009		.855	
37	Barney J, 1991		.636	
38	Chesbrough H, 2003		.509	
39	Cohen W, 1990		.558	
40	Dosi G, 1982		.634	
41	Fleming L, 2001		.775	
42	Fleming L, 2004		.630	
43	Grant R, 1996		.628	
44	Hall B, 2005		.731	
45	Harhoff D, 1999		.671	
46	Henderson R, 1990		.676	
47	Henderson R, 1994		.613	
48	Jaffe A, 2002		.762	
49	Katila R, 2002		.788	
50	Kogut B, 1992		.638	
51	Lanjouw J, 2004		.811	
52	Laursen K, 2006		.565	
53	Leonard B. D, 1992		.713	
54	Lerner J, 1994		.735	
55	Levinthal D, 1993		.651	
56	March J, 1991		.733	
57	Nelson R, 1982		.700	
58	Phene A, 2006		.861	
59	Rosenkopf L, 2001		.735	
60	Rothaermel F, 2008		.732	
61	Sorensen J, 2000		.793	
62	Stuart T, 1996		.705	
63	Trajtenberg M, 1990		.698	
64	Trajtenberg M, 1997		.808	
66	Tushman M, 1986		.675	
66	Zahra S, 2002		.635	
67	Arora A, 1994			.644
68	Audretsch D, 1996			.746
69	Cockburn I, 1998			.788

	Matrix (authors)	Factors		
		1	*2*	*3*
70	Cohen W, 2002			.779
71	Dasgupta P, 1994			.866
72	Gittelman M, 2003			.547
73	Hicks D, 1995			.837
74	Jensen R, 2001			.833
75	Liebeskind J, 1996			.660
76	Mansfield E, 1991			.703
77	Mansfield E, 1995			.761
78	Mcmillan G, 2000			.793
79	Mowery D, 2001			.699
80	Murray F, 2002			.782
81	Narin F, 1997			.621
82	Stern S, 2004			.791
83	Thursby J, 2002			.763
84	Zucker L, 1998			.695
85	Zucker L, 1998			.598
86	Zucker L, 2002			.764

Source: Authors elaboration.

4.1 Factor 1: The firm and its capabilities and resources in alliances, agreements, and cooperation networks

The first factor, resulting from the EFA, was named “The firm” and its capabilities and resources in alliances, agreements, and cooperation networks. During the reading process of the 32 articles, which represent factor 1, there were some interesting aspects. First, there were two seminal pieces in this block of articles: 1) Penrose, 1959 “A Theory of the Growth of the Firm” and 2) Schumpeter J, 1934 “Economic Development Theory”. In this group of authors, there are 22 articles from the 1990s and 10 from the 2000s.

In this factor, it is important to draw attention to the author, who appears twice on the list with two theoretical essays that had a predominant contribution to the concepts of collaboration and mainly to Dynamic Capabilities, first in 1986 “Profiting from Technological Innovation: Implications for Integration, Collaboration, Licensing, and Public Policy” and second in 1987 with “Dynamic Capabilities and Strategic Management”. Still regarding authors who appear more than once in this group, the following stand out: Ahuja, 2000 and 2001; Jaffe, 1983 and 1993; Levitt, 1987 and 1988; Stuart, 1999 and 2000, which are therefore the most productive, according to Lotka’s law.

Observing factor 1 and considering Bradford’s law, it is possible to observe that authors who appeared on the list more than once published in different journals, that is, there was a dispersion of authors in different journals and, coincidentally, all four recurring authors are in this same situation. In this block, the first related article that appears on the list of Web of Science, is by the authors Owen-Smith and Powel (2004), “Knowledge Networks as Channels and Conduits: The Effects of Spillovers in The Boston Biotechnology Community”.

Among the journals, the one that published the most research by authors of this factor was the Strategic Management Journal, with eight publications, followed by the Administrative Science Quarterly, with five publications and Management Science, with two publications. The journals cited represent two thirds of the total of the 32 publications of factor 1, being the Strategic Management Journal responsible for nearly one third of the publications. There are two books in this block, by the two seminal authors, Penrose and Schumpeter.

Regarding the articles that comprise factor 1, it is possible to identify that the authors' research efforts were basically directed towards developing their research considering the quantitative aspects. The universe of work was the firms, including those from other segments, in addition to the biotechnology sector.

Ahuja, who was listed twice in factor 1 (2000 and 2001), developed his work in the chemical industry, and his 2001 work listed 97 companies from the United States, Western Europe, and Japan. Schilling (2007) is another author who stands out in his research for having as work field 1,106 high-tech companies in the automotive, computers, doctors, aerospace sectors, among others.

Constructs have guided the construction of the concept of cooperation over the 31 years. Over time these were worked on and improved by the researchers. The article by Dyer (1998) "The Relational View: Cooperative Strategy and Sources of Inter-organizational Competitive Advantage" is significant as this work develops the cooperation strategy, using Barney's "Resource-Base View" (1991) as the theoretical framework.

Pisano (1990), in "The R&D Boundaries of the Firm: An Empirical Analysis", is another author who uses seminal concepts in this area. In his article, Pisano tests his hypotheses in 92 projects of biotechnology companies and highlights, in his theoretical framework, Williamson's "transaction costs" (1975 and 1982).

In general, the authors listed in this first factor develop their research focusing on constructs such as: innovation (Arora, 1990), cooperation networks, strategic alliances (Baum, 2000), dynamic capacity (Teece, 1987), absorptive capacity (Mowery D, 1996), knowledge base and transfer and organizational learning (Ahuja and Katila, 2001, Rosenkopf and Almeida 2003; Schilling and Phelps 2007).

Ahuja and Katila (2001) note that, in cooperation networks, the knowledge base acquired with other partners improves the innovation performance in the firm. Mowery, Oxley and Silverman (1996), also members of factor 1, concluded that the "wisdom received" by the firm contributes to promoting greater knowledge transfer in the network. The findings of Schilling and Phelps (2007) revealed that networks influence the creation of knowledge in the firm and Rosenkopf and Almeida (2003) found that the formation of networks facilitates information and forces knowledge flow within the firm. Therefore, throughout the readings, it was possible to verify the firm's evident role in the construction of the factor, regardless of the follow-up as a protagonist for cooperation research.

Among the diverse contributions of researchers in this block, a significant one is that by Arora (1990), and the other is by Dosi G (1998) in the article "Complementarity and External Linkages: The Strategies of the Large Firms in Biotechnology", which states that the center of innovation in the field of biotechnology should be thought of as a "network of interorganizational relations". In "Don't Go It

Alone: Alliance Network Composition and Startups Performance in Canadian Biotechnology", Baum (2000), notes the importance of biotechnology companies setting up alliance networks, as they increase their performance compared to the beginning operations.

Finally, it can be ascertained that factor 1 shares themes and concepts that are correlated with the conceptual bases on the central role of the biotechnology firm in articulating the knowledge, innovations, and technologies produced and disseminated in technological cooperation networks, which meets what this research is proposing from the stated theoretical framework. Table 3 presents a conceptual-descriptive summary of the 32 authors belonging to factor 1.

Table 3

Conceptual-descriptive summary of the 32 authors of factor 1

Authors-*KMO*	Theoretical foundation	Results and contributions
1- Ahuja G, (2002) *C.F.* (0,809)	Organizational Networks: (Powel, Koput, & Smith-Doerr, 1996). Structural Holes: (Burt, 1992, Hargadon & Sutton, 1997). Direct and Indirect Ties: (Berg, Duncan, & Friedman, 1982)	Direct and indirect ties positively influence the production of innovation, but the impact of indirect ties is moderated by the company's level of direct ties. An important detail is that the link between patents and innovation is likely to be stronger in sectors where patents provide companies with fair protection of their assets.
2- Ahuja G, (2001) *C.F.* (0,761)	Knowledge Basis: (Griliches, 1984, 1990; Pakes & Griliches, 1984; (Henderson & Cockburn, 1996)	I identified that within technological acquisitions, the absolute size of the acquired knowledge base improves the performance of innovation. Non-technological acquisitions have no significant effect on the subsequent exit from innovation.
3- Almeida P, (1999) *C.F.* (0,698)	Dissemination of Knowledge: (Jaffe et al., 1993; Zucker et al., 1994; Leslie & Kargan 1996)	By analyzing the data on the inter-company mobility of patent holders, it was possible to empirically demonstrate that the inter-company mobility of engineers influences the flow and transfer of knowledge from the local market. Statistical results derived from patent citations indicate that technology transfers are not uniformly created in all regions, nor are they natural by-products of specific technologies.
4- Arora A, (1990) *C.F.* (0,810)	Complementary Strategies: (Bulow et al., 1985). Innovation: (Imai, 1980; Vacca, 1986).	The results showed that the strategies aim at distinct and complementary sets of resources. In biotechnology, large companies are no longer the only "locus" of innovative activity. The "locus" of innovation must be thought of as an interorganizational "network of relationships".
5- Baum J, (2000) *C.F.* (0,825)	Strategic Alliances: (Gulati, 1998; Teece, 1992). Features and Competitive Advantage: (Dyer & Singh, 1998)	The results demonstrate that the diversity of alliance networks configured at the time of its foundation produces significant differences in its initial performance, directly contributing to an explanation of how and why the age and size of the company affect the company's performance.
6- Burt R, (1992) *C.F.* (0,690)	Structural Holes: (Burt, 1992). Social Structure: (Colemam, 1990; Bourdieu & Wacquant, 1992)	Social capital is created by a network in which people can mediate connections between disconnected segments. For the theory of structural holes, social capital is created by a network of strongly interconnected elements.
7- Decarolis D, (1999) *C.F.* (0,740)	View Based in Knowledge: (Demsetz, 1991; Grant, 1996; Nonaka, 1994; Spender, 1996)	Expenditure on R&D is representative of knowledge flows, while products in progress, citations, and patents are indicative of knowledge stocks. The company's geographic location, knowledge generation, accumulation, and

Authors-*KMO*	Theoretical foundation	Results and contributions
		application are a source of superior performance in the biotechnology sector.
8- Dosi G, (1988) *C.F.* (0,507)	Innovation and Knowledge: (Griliches, 1984; Nelson & Winter, 1977, 1998; Dosi 1982, 1984)	Private agents, in search of profits, will allocate resources for R&D or new production techniques, if they believe in the existence of some type of scientific activity or opportunity not yet explored, as they expect some type of economic benefit and net of costs incurred, arising from the innovation process.
9- Dyer J, (1998) *C.F.* (0,791)	Relational Capacity: (Hamel, 1991; Harrigan, 1985; Shan, Walker, & Kogut, 1994; Teece, 1987) Resource-Based View: (Barney, 1992)	The relational view can offer normative prescriptions for company strategies that contradict the prescriptions offered only by the resource-based view. Collaboration between companies can generate relational gains through a specific list of assets, sharing knowledge of routines, allocating complementary resources and more effective governance.
10- Griliches Z, (1990) *C.F.* (0,651)	Spilllovers in R&D (Griliches, 1979; Jaffe, 1988, 1989; Norton & Davis, 1981)	Overflows of R&D are an important potential source of companies' endogenous growth.
11- Hagedoorn J, (1993) *C.F.* (0,859)	Transaction Costs: (Williansom, 1985). Strategic Alliances: (Teece, 1987)	According to the survey, the two main factors that lead companies to cooperate with their efforts for innovation are: Market and Technology.
12- Hausman J, (1984) *C.F.* (0,680)	Econometrics (Patents)	The results showed a significant discovery: there is a negative interactive trend in the relationship between patents and R&D. That is, companies are receiving less patents from their most recent investments in R&D, which implies a decline in "effectiveness" or R&D productivity.
13- Henderson R, (1996) *C.F.* (0,661)	Spillovers in R&D: (Spence, 1984; Dasgupta & Stiglitz, 1980)	In their enormous R&D efforts, large companies, are more productive, not only because they enjoy economies of scale, but also since they achieve economies of scope supporting various research project portfolios that capture overflowing internal and external knowledge.
14- Jaffe A, (1986) *C.F.* (0,673)	R&D Spillovers: (Griliches, 1979) Technological Position: (Jeff, 1984)	Companies that have a positive interaction with their R&D departments produce far more patents per dollar than their competitors and benefit more from Spillovers in R&D. It was possible to find clear evidence that companies adjust their technological positions in response to profit possibilities.
15- Jaffe A, 1993) *C.F.* (0,556)	Spillover of Knowledge: (Romer 1986, 1990; Gross-Man & Helpman, 1991).	Despite the invisibility of knowledge overflows, they leave a paper trail in the form of quotes. We found evidence that these trails, at least, are geographically located, but there is evidence that the geographic location decreases over time.
16- Lane P, (1998) *C.F.* (0,814)	Absorptive Capacity: (Cohen & Levinthal, 1990). Organizational Learning: (Hamel, 1991; Hamel, Doz, & Prahalad, 1989).	Companies should pay as much attention to the management of their resources as to the management of their physical assets. Companies that are able to develop a greater understanding of their processes for converting into knowledge are those that are most successful in interorganizational learning.
17- Levin R, (1987) *C.F.* (0,719)	Patents: (Griliches, Ariel Pakes, & Bronwyn). Appropriability: (Cohen, Levin, & Mowery, 1985)	Patents do not confer absolute appropriability. The research results demonstrate that patents are important as a barrier to entry into the semiconductor industry, as they provide an obstacle for potential new entrants.
18- Levitt B, (1988) *C.F.* (0,716)	Organizational Learning: (Starbuck, 1976; Hedberg, 1981; Fiol & Lyles, 1985)	Organizations learn by learning, 2) learn by doing, 3) learn by the experience of others, and 4) learn "ecologically" by behavior and the environment. Organizational learning can be interpreted as a form of intelligence.

Authors-*KMO*	Theoretical foundation	Results and contributions
19- Mowery D, (1996) *C.F.* (0,818)	Absorptive Capacity: (Kogut, 1988; Doz & Prahalad, 1989; Cohen, & Levinthal, 1990). Knowledge Transfer: (Mowery, Oxley, & Silverman, 1992)	"Absorption capacity" helps to explain the extent of the transfer of technological capabilities in strategic alliances, but joint ventures appear to be more effective channels for transferring complex capabilities than contract-based alliances.
20- Owen Smith J, (2004) *C.F.* (0,650)	Strategic Alliances: (Shan et al. 1994; Walker et al. 1997); Spillovers Knowledge: (Almeida & Kogut, 1999)	The geographical proximity and institutional characteristics of the key members of a network transform the position of these members within a larger network resulting in an advantage. When analyzed together, geographical proximity and centrality result in information overflows that turn into economic gains.
21- Penrose E, (1959) *C.F.* (0,741)	Firm Theory: (Coase, 1937)	Penrose conceptualizes the firm as a set of human and non-human resources that has competencies, is under administrative coordination, and produces goods and services for sale on the market, with the objective of making a profit. The growth of the firm is like an evolutionary process, and through resources and capacities, it evolves and increases in size.
22- Pisano G, (1990) *C.F.* (0,680)	Theory of Transaction costs: (Williamson, 1985)	The results demonstrate that rapid and radical technological changes force companies to change the locus of R&D from internal to external.
23- Powell W, (1996) *C.F.* (0,640)	Relationship Networks: (Powell & Brantley, 1992). Organizational Learning: (Nelson, 1990; Stinchcombe, 1990).	The results demonstrate that in a sector of rapid technological development such as biotechnology, the "locus" of innovation is found in the networks of interorganizational relationships that support a fluid and evolving community. Alliances and mobility serve as bridges allowing companies to overcome the constraints of contextually located research.
24- Rosenkopf L, (2003) *C.F.* (0,647)	Learning Networks: (Gulatti, 1995; Eisenhardt & Schoonhoven, 1996). Alliances: (Doz, 1996; Dyer, 1997)	The alliances and mobility of the inventors are two mechanisms that serve as bridges to geographically distant contexts allowing companies to overcome their restrictions on localized research.
25- Rothaermel F, (2004) *C.F.* (0,758)	Allianvces: (Koza & Lewin, 1998; Rothaermel, 2001) Exploration and Exploitation (Levinthal & March, 1993).	The development of new products depends on the type of alliance. The results showed that biotechnology companies are much more involved in "exploitation" alliances than in "exploration" alliances.
26- Schilling M, (2007) *C.F.* (0,639)	Stretegic Alliances: (Shan et al. 1994) and structures of Network Cooperation (Ahuja, 2000; Baum et al. 2000).	Dense local agglomeration provides the ability to transmit information on the network, promoting communication and cooperation. Companies integrated in alliance networks that exhibit high agglomeration and high reach (short average distances for a wide range of companies) will have more innovative production than companies in networks that do not exhibit these characteristics.
27- Schumpeter *C.F.* (0,639)	Alfred Marshall	The main contribution was to demonstrate that the economy creates cycles that destroy one current structure to create another, what he called "creative destruction".
28- Shan W, (1994) *C.F.* (0,834)	Inter-organizational Cooperation Networks: (Kogut, Shan & Walker,1992) and (Granovetter, 1985)	The results demonstrate that cooperation affects innovation. The study found that small business innovation production and its cooperation agreements with large companies are not mutually related: innovation is explained by agreements, but not the other way around.
29- Stuart T, (1999)	Inter-organizational Cooperation Networks: (Granovetter, 1973, 1985)	The results demonstrate that young biotechnology companies supported by venture capital from traditional companies go to IPO more quickly and gain better

Authors-*KMO*	**Theoretical foundation**	**Results and contributions**
C.F. (0,740)		valuations than companies that do not have these connections (or endorsements).
30- Stuart T, (2000) *C.F.* (0,813)	Strategic Alliances: (Nohria & Garcia-Pont, 1991; Gulati, 1995; Eisenhardt e Schoonhoven, 1996; Walker, Kogut, & Shan, 1997).	The results demonstrate that alliances are access relationships and that the advantages derive from a portfolio of strategic coalitions dependent on the profiles and resources of their partners in the alliance. Young and small companies benefit more from innovative strategic alliances than old and large organizations.
31- Teece D, 1986) *C.F.* (0,501)	Appropriability: (Teece, 1986; Levin et al, 1984). Dominant Paradigm (Albernathy & Utterback, 1978; Dosi, 1982). Complementary Resources: (Teece, 1986)	When imitation is easy, markets do not work well, and the profits from innovation can accumulate for owners of complementary assets, not for developers of intellectual property. The developed framework indicates that the boundaries of organizations (with their complementary, specialized, and co-specialized assets) are an important variable in companies' strategy for innovation.
32- Teece D, (1997) *C.F.* (0,721)	Competitive Forces: (Porter, 1980), Business Strategy: (Shapiro, 1989) RBV: (Barney, 1986, 1994)	Companies have dynamic resources that see the creation of competitive advantage resulting from high performance routines operating within the company shaped by processes and positions. Path dependencies and technological opportunities mark the way forward.

Note: (*) means that the research was “quantitative”, (**) means “qualitative” and (***) means “book”. Factorial Load (F.L.).
Source: Authors elaboration.

4.2 Factor 2: The patent as evidence of the flow of knowledge, innovation, and technological change

The second factor of the research is called “The patent as evidence of the flow of knowledge, innovation, and technological change”. In this group, the authors that appear more than once are Alcácer (2006 and 2009), Fleming (2001 and 2004), Henderson (1990 and 1994), and Trajtenberg (1990 and 1997). This demonstrates a strong correlation of co-authorship with the other authors belonging to this group, since these authors research jointly and collaboratively. Consequently, according to the results and according to Lotka’s law, culminates in those authors being more productive as well.

Another indication of the strong correlation between these authors (and at this point the articles that were extracted by factoring are indicated) is that some also appear in the list of factor 1 authors, such as: Ahuja, Jaffe, Rosenkopf, Rothaermel, and Stuart, demonstrating strong productivity (Lotka’s law). Considering Bradford’s law, for this block, authors who appear more than once published in different journals, that is, there was a dispersion of journals for these four authors.

In general, the main constructs that comprise the connection between researchers in this block are mainly centered on patents, patent citation, innovation, knowledge, and technology. These constructs represent a line of research that built the conceptual basis for this theme. In this factor, the journal with the largest number of publications remains the Strategic Management Journal, with 10 publications; the second administrative journal is also the Administrative Science Quarterly, which appears with four publications and, with three publications, in third place, is the Research Policy. All these journals represent 50% of the total publications of factor 2, which contains 34 publications. Additionally, there is a book in this block, by authors AB Jaffe and M Trajtenberg (2002), published by The MIT Press of Cambridge, Massachusetts London-England.

In the factor 2 articles, it is observed that the methodological research effort of the authors was to predominately develop quantitative research. However, there are also theoretical essays and case studies, and the universe of work was high-tech companies, such as semiconductors, pharmaceuticals, and the biotechnology sector.

The authors listed in this block develop their research with a focus on patents, but also focusing on the constructs that support this conceptual line. These constructs are: overflow and flow of knowledge, absorptive capacity, and organizational learning.

In this block, the following authors broke conceptual paradigms with their articles: Barney, the most cited of all authors, with 64,604 citations, with the seminal 1991 article “Firm Resource and Sustained Competitive Advantage”. The article deals with the firm’s resources to obtain a sustainable competitive advantage. Chesbrough H. (2003), with “Open Innovation”, presents, in this book, a paradigm shift for the concept of innovation, which the biotechnology sector has used in its innovation processes. Throughout the readings, it was possible to verify that the relevant role of the patent became increasingly evident. In this factor, some authors are prominent, such as Hall (2007), who in his research concluded that patents are indicators of technological production of a network. The findings of Jaffe and Trajtenberg (2002) indicated that patents are a window for technological change for actors who are part of a network.

Albert, Avery and McAllister (1991) concluded that the most cited patents are of technological importance, have greater scope in a network, and can indicate promising technological routes. In this perspective, Harhoff, Scherer and Vopel (1999) also concluded that the most cited patents are more valuable. Additionally, Alcácer, Gittelman and Sampat (2009) concluded that the aforementioned patents improve the flow of knowledge. Fleming and Sorenson (2004) claim that from the analysis of patents, it is possible for the inventors of a network to alter their searches and their future searches.

Another compelling study, due to the large time frame followed, was the one developed by Hall (2005), entitled “Market Value and Patent Citations”. In this work, the author conducted a 30-year longitudinal study with 4,800 American companies, and aimed to explore the economic significance generated by patents. The result made it clear that the patents that are cited have a much more positive economic impact, increasing the valuation of companies in the market. The author concluded that the cited patents provide a proxy for knowledge stock for companies.

Thus, it can be verified that factor 2 shares themes and concepts that are correlated with the conceptual bases of the patent, which presents itself as a valuable resource that provides knowledge evidences, technological transformations, and innovations for companies and their cooperation networks corroborating with the aspects raised within the theoretical framework in attention to the open innovation constructs and cooperation networks. Table 4 presents a conceptual-descriptive summary of the 34 authors belonging to factor 2.

Table 4

Conceptual-descriptive summary of the 34 authors of factor 2

Authors-*KMO*	Teorethical framework	Results and Contributions
1- Ahuja G, (2001) *C.F.* (0,854)	Knowledge Base: (Griliches, 1984, 1990; Pakes & Griliches, 1984; Henderson & Cockburn, 1996)	It was found that within technological acquisitions, the absolute size of the acquired knowledge base improves the performance of innovation. Non-technological acquisitions do not have a significant effect on the subsequent exit from innovation.
2- Albert M, (1991) *C.F.* (0,799)	Patents: (Narin, Rosen, & Olivastro, 1989)	It can be concluded directly from this study that highly cited patents are of significantly greater technological importance than patents that are not cited or cited infrequently. The fact that these patents are so often cited has been interpreted as an indicator of the high quality of the technology embedded in these patents.
3- Alcácer J, (2006) *C.F.* (0,730)	Knowledge Overflows: (Jaffe, Trajtenberg, & Henderson, 1993). Patents: (Cockburn, Kortum, & Stern 2004; Lemley, 2005; Sampat, 2005	A substantial proportion of citations contain no sign of knowledge of the inventor and approximately 40% of the cited patents have all citations imposed by the examiners. Only 8% of patents have no citations added by the examiner. The results indicate that inferences about the inventor's knowledge using grouped citations may suffer from overinflated bias or levels of significance.
4- Alcácer J, (2009) *C.F.* (0,855)	Patent and Knowledge Transmission: (Jaffe & Trajtenberg, 2002).	It can be seen those patents citing the prior art have become a popular measure of patent quality and knowledge flow between companies. Interpreting these measures is, in some cases, complicated, because citations from the prior art are added by patent examiners, as well as by patent applicants.
5- Barney J, (1991) *C.F.* (0,636)	Strategy and Competitive Advantage: (Porter, 1980, 1990).	Four potential factors were presented that contribute to the company obtaining competitive advantage: value, rarity, not imitable, and not substitutable.
6- Chesbrough H, (2003) *C.F.* (0,509)	Capabilities: (Teece, 1986). Disruptive Innovation: (Christensen, 1995, 1996)	This case study developed at Xerox Company; the author developed the term “Open Innovation”.
7- Cohen W, (1990) *C.F.* (0,558)	Knowledge Acquisition: (Bower & Hilgard, 1981). Knowledge Transfer: (Ellis, 1965; Estes, 1970)	The results showed that firms are in fact sensitive to the characteristics of learning in the environment in which they operate. Thus, absorption capacity is part of a company's decision to allocate resources for innovative activities.
8- Dosi G, (1982) *C.F.* (0,634)	Innovation: (Nelson and Winter, 1977). Technological Development: (Clark, Freeman, & Soete, 1980). Paradigm (Kuhn, 1962)	The paradigms of technological trajectories are between continuity and rupture in the process of incorporating knowledge and technology in growth environments. The emergence of a new technological paradigm is often related to new “Schumpeterian” companies, while its continuity often demonstrates a “oligopolistic” stabilization process.
9- Fleming L, (2001) *C.F.* (0,775)	Knowledge of Technological Changes: (Rosenberg, 1996) Dominant Design: (Anderson & Tushman 1990; Klepper 1997).	On average, experimenting with new components and new combinations leads to less useful inventions. Patent citation data shows that new combinations are actually more variable.
10- Fleming L, (2004) *C.F.* (0,630)	Innovation: (Trajtenberg, Henderson, & Jaffe, 1997).	This article really demonstrated that science alters inventors' search processes, taking them directly to more useful combinations. Science has no apparent effect when inventors work with relatively independent parts; it only

Authors-*KMO*	**Teorethical framework**	**Results and Contributions**
		appears beneficial when inventors seek to combine compatible components.
11- Grant R, (1996) *C.F.* (0,628)	Knowledge Base: (Grant, 1996)	The main role of the organization is to apply knowledge, rather than to create knowledge. The manager plays a fundamental role in the coordination of knowledge.
12- Hall B, (2005) *C.F.* (0,731)	Patents: (Hall, Jaffe, & Trajtenberg, 2001).	The greater the stock of patents, the greater the market value of these companies. If the patents are cited the value is even higher. The cited patents provide a proxy for the company's stock of knowledge greater than if it were a simple patent.
13- Harhoff D, (1999) *C.F.* (0,671)	Patents: (Trajtenberg, 1990; Hall et al., 1998)	Patents reported as relatively valuable by the companies that own them are most cited in subsequent patents.
14- Henderson R, (1990) *C.F.* (0,676)	Conceptual Design: (Clark, 1985). Dominant Design: (Abernathy & Utterback, 1978; Sahal, 1986)	We found a new category of innovation in addition to the radical and incremental that we call “Architectural innovation” that takes place from the reconfiguration of the components belonging to the product, that is, the architecture of a product is changed without changing its components.
15- Henderson R, (1994) *C.F.* (0,613)	Capabilities: (Barney, 1986; Dosi & Teece, 1993). Competitive Advantage: (Porter, 1980). Competence: (Burgelman, 1994; Iansiti, 1993; Leonard-Barton, 1992),	Companies that maintain links with the wider scientific community through the use of publications and companies that manage the allocation of key research resources through collaborative processes are significantly more productive in drug discovery. The focus on the "architectural" or "integrative" characteristics of organizations can provide valuable information on the source of lasting differences in company performance.
16- Jaffe A, (2002) *C.F.* (0,762)	Patents: (Hall, Griliches & Housman, 1986) Overflow of Knowledge: (Jaffe, 1986)	The use of patent and citation data is really a window on the process of technological change and a powerful tool for research on the economy of innovation. Patent registries contain a wealth of information, including the inventors' identity, location and employer, as well as the technological field of the invention. Patents also contain citation references from previous patents, which allow you to track links between inventions.
17- Katila R, (2002) *C.F.* (0,788)	New Products: (Saviotti & Metcalfe, 1984; Helfat, 1994. Knowledge Base: (Martin & Mitchell, 1998).	Companies' R&D efforts vary in two distinct dimensions: The depth of the search, or how often the company reuses its existing knowledge, and the scope of research, or how widely the company exploits new knowledge.
18- Kogut B, (1992) *C.F.* (0,638)	Knowledge: (Rogers, 1983; Winter, 1987). Organizational Knowledge: (March & Simon, 1958; Cyert & March, 1963)	It has been demonstrated that knowledge (transferred) consists of information (who knows what) and know-how (how to organize a research team). What is central to our argument is that knowledge is individual, but it is also expressed in regularities by which members cooperate in the community (be it by group, organization or network).
19- Lanjouw J, (2004) *C.F.* (0,811)	Patents: (Choen et al, 2000); Griliches, 1990)	We found three determinants, demand, the quality of patents and technological depletion. Research productivity is inversely related to the quality of patents and the level of demand, as the expected quality is positively associated with the stock of patents
20- Laursen K, (2006) *C.F.* (0,565)	Open Innovation Aberta: (Chesbrough (2003) Innovation (Katila & Ahuja, 2002).	Companies are increasingly attracting knowledge from outside sources in their innovative activities. Modern innovation processes require companies to master highly specific knowledge about different users, technologies and markets, we found that research is broad and deeply curvilinear (taking an inverted U shape) related to innovative performance.

Authors- *KMO*	Teorethical framework	Results and Contributions
21- Leonard Barton D, (1992) *C.F.* (0,713)	Basic Capabilities (Zucker, 1977) Competences: (Thusman & Anderson, 1986) Knowledge: (Henderson & Clark, 1990).	Basic capabilities are a collection of joint knowledge, which is distributed and constantly improving. However, while allowing innovation, they can prevent it. The role of the manager is fundamental to the changes and leadership of the paths
22- Lerner J, (1994) *C.F.* (0,735)	Patent and Innovation: (Green & Scotchmer (1990); Matutes, Regibeau & Rockett (1992)	It was found that the scope of the patent has a significant impact on the company's value, in a manner consistent with theoretical suggestions. This article also highlights the importance of the scope of patents as a political instrument.
23- Levinthal D, (1993) *C.F.* (0,651)	Learning: (Senge, 1990; Stalk, Evans & Shulman, 1992).	Three limiting elements were found: Temporal Myopia, Spatial Myopia and Failed Myopia. All three types compromise the effectiveness of learning. In particular, they complicate the problem of maintaining an appropriate balance between "Exploitation" and "Exploration".
24- March J, (1991) *C.F.* (0,733)	Organizational Learning: (Winter 1971; Levinthal & March 1981). Organizational Knowledge: (Whyte, 1957) and (Maanen, 1973)	Learning, analysis, imitation, regeneration and technological change are important components of effort to improve organizational performance and strengthen competitive advantage. Each involves adaptation and a trade-off to maintain an appropriate balance between exploration and exploitation.
25- Nelson R, (198) *C.F.* (0,700)	Knowledge and Technological Innovation: (Sahal, 1981 and Gibbons, 1974) P&D Griliches (1979).	There is a private and public aspect to technological knowledge and although the lines between them are unclear, it is important to recognize both, as they influence the allocation of resources in R&D.
26- Phene A, (2006) *C.F.* (0,861)	Knowledge basis: (Cohen & Levinthal, 1990). Patent: (Jaffe et al. (1993). Innovation: (Ahuja & Lampert, 2001).	The findings demonstrate that technologies far from knowledge do not guarantee their usefulness, on the contrary, it is the interaction of technological space and geographical origin that allows companies to create radical innovations, that is, exploration in geographic areas or technology parks can be much more valuable. to achieve revolutionary innovations.
27- Rosenkopf L, (2001) *C.F.* (0,735)	External source of knowledge: (Nonaka & Takeuchi, 1995); Leonard-Barton, 1995). Capabilities: (Teece, Pisano, & Shuen, 1997),	In the optical disc segment, technological evolution is greater when exploration extends beyond organizational limits. Exploration that does not exceed organizational limits consistently generates less impact on technological evolution.
28- Rothaermel F, (2008) *C.F.* (0,732)	Strategical alliances: (Arora & Gambardella, 1990; Teece, 1992; Rothaermel, 2001).	In younger companies the motivating factor for forming alliances is in the complementarities of resources. In older companies, on the other hand, the motivation factor is due to similarities.
29- Sorensen J, (2000) *C.F.* (0,793)	Organizational competence: Barron, West & Hannan (1994) Innovation: Cohen & Levinthal (1989, 1990); (Dosi, 1982).	Our evidences show that as organizations age, they generate more innovation. The skills to produce innovations - or at least patents - have improved with age, but as companies get older, they become more and more likely to generate innovations (Exploitation) from previously existing skills.
30- Stuart T, (1996) *C.F.* (0,705)	Organizational Trajectory (Nelson & Winter, 1982; Winter, 1984).	A component of the dynamics of technological change in this segment is that companies do not research in isolation, they research as members of a population of organizations that research simultaneously. The whole trajectory goes through the creation of knowledge.
31- Trajtenberg M, (1990) *C.F.* (0,698)	Patents: (Griliches Z, 1984 e 1986); Innovation: (Trajtenberg M, 1990)	The results presented suggest that patent citations can be indicative of the value of innovations and that they contain the key to unlocking the wealth of information contained in patent data.

Authors-*KMO*	**Teorethical framework**	**Results and Contributions**
32- Trajtenberg M, (1997) *C.F.* (0.808)	Patents: (Griliches Z, 1981, 1986 e 1990) Knowledge: (Jaffe A; Trajtenberg & Henderson, 1993)	We find two key aspects that occupy a prominent place in the technological changes that are: "basicity", which refers to fundamental characteristics of innovations such as originality and "Appropriability" which refers to the ability of inventors to reap the benefits of their own. An important finding is that universities prioritize basic research.
33- Tushman M, (1986) *C.F.* (0,675)	Organizational environment: (Millera e Friesen, 1984; Tushmana & Romanelli,1985),	The study showed that discontinuities that destroy skills are initiated by young companies and are associated with increased environmental turbulence. Discontinuities that increase competence are initiated by existing companies and are associated with a reduction in environmental turbulence. Companies that initiate major technological changes grow faster than other companies.
34- Zahra S, (2002) *C.F.* (0,635)	Innovation and Learning: (Cohen & Levinthal, 1989) Absorptive Capabilities (Cohen & Levinthal, 1990)	From the perspective of the company's dynamic resources, it is possible to observe that a company's potential capacity and realized capacity can directly influence the creation of sustainable competitive advantage.

Note: In the "objective" field, the symbol (*) means "quantitative" research, (**) means "qualitative" and (***) means "book". Factorial Load (F.L.).
Source: Authors elaboration.

4.3 Factor 3: Research as a guide for science and technology in companies, universities, and society

In this factor, there are authors who appear more than once: Mansfield (1995 and 1998) and Zucker (1998 and 2000). Consequently, these authors become the most productive authors, according to Lotka's law. As these two authors also published in different sources, we can observe that there was a dispersion of journals. Therefore, at this point, these authors also comply with Bradford's law.

The journal with the largest number of publications in this factor is Research Policy, with six publications, followed by Management Science, with three publications. These two journals represent 45% of the 20 total publications in this block.

It can be identified that factor 3 shares themes and concepts that are correlated with the conceptual bases on the conceived research, as a networked activity that promotes the intersection between the science produced in the universities, the technologies conceived in the firms, and the dissemination for industry and society for articles, patents, and innovations. Some authors who correlated in this block, used the quantitative and qualitative methods.

The findings of Jensen and Thursby (2001) revealed that the industrial use of government-funded research would be less without the licensing of patents by universities. Additionally, Zucker, Darby and Armstrong (2002) concluded that basic research contributed to the performance of firms that operate in networks and that the research performed in a collaborative way, evidenced by leading publications from universities and scientists, also has a significant effect on the performance of companies (Zucker, Darby, & Armstrong, 1998).

In a complementary way, Narin, Hamilton and Olivastro (1997) concluded that when there is government support for scientific research, there is an increase in the level of patenting. In the research of the referred authors, it was verified that 77% of the articles cited by patents in the industries of the United States are authored by universities or other governmental institutions, while only 23% are authored by researchers belonging to the industry.

The study by McMillan, Narin, and Deeds (2000) also revealed that the biotechnology industries are more dependent on public scientific research than other industries. Relatedly, Cohen, Nelson, and Walsh (2002) evaluated the role public research conducted by Universities and Institutes of Science and Technology (IS&T) plays in industrial development, as well as the ways in which this effect is exercised. It was found that public research is critical and has a strong impact on the R&D of industries. Cockburn and Henderson (1998) also established a significant connectivity between public and private research and that private research, in turn, also brings returns for public research.

Two authors Jensen (2001) and Thursby (2002) directly dealt with the impacts of the Bayh-Dole law in their articles, which became a turning point for investments in R&D, for the intellectual production of researchers and, mainly, for licensing and patenting efforts in the United States. The results showed that the Bayh-Dole law did not result in a significant increase in licensing or patenting, but contributed significantly to facilitate marketing efforts, creating a safer institutional environment, and defining clearer and more objective rules regarding the responsibilities of researchers. Table 5 presents a conceptual-descriptive summary of the 20 authors belonging to factor 3.

Table 5

Conceptual-descriptive summary of the 20 authors of factor 3

Authors-*KMO*	Theoretical framework	Results and contributions
1- Arora A, (1994) *C.F.* (0,644)	Collaboration: (Arora & Gambardella, 1990) Capabilities: (Nelson, 1990; Teece, 1986)	We found two ways that companies use information to innovate: the ability to use (which increases the number of partnerships to innovate) and to evaluate (which is more selective but creates more valuable links with other companies).
2- Audretsch D, (1996) *C.F.* (0,746)	Overflow of Knowledge: (Jaffe, 1988; Feldman, 1994)	The innovative activity tends to group itself more in sectors in which the knowledge spillovers play a decisive role, even after controlling the degree of geographical concentration of the companies. The results suggest that the propensity for innovative activity in the cluster is more attributable to the role of spillovers of knowledge and not only to the geographical concentration of production.
3- Cockburn I, (1998) *C.F.* (0,788)	Absorptive Capacity: (Cohen & Levinthal, 1989)	The companies maintain intensive connections based on scientific co-authorship between scientists from pharmaceutical companies and public funds. The 'connection' is correlated with performance in discovering new drugs.
4- Cohen W, (2002) *C.F.* (0,779)	Connection between Public and Private Research: (Narin, 1997)	Public research significantly affects industries' R&D. The results also indicate that the main channels through which university research affects industrial R&D include published articles, reports, public conferences and meetings, information exchange, and consultancy.
5- Dasgupta P, (1994) *C.F.* (0,866)	Technological Transfer: (Arora, 1991); Public and	The institutions and norms that govern the conduct of open science do not produce an optimal allocation of research efforts, but they function properly by maximizing the long-

Authors-*KMO*	Theoretical framework	Results and contributions
	Private Technology: (Nelson, 1990)	term growth of the stock of scientific knowledge. The existing symbiosis between public and private research in the modern era has benefited society in general and the institutional machine that performs these vital functions for our society.
6- Gittelman M, (2003) *C.F.* (0,547)	Productivity in scientific research: (Cockburn et al., 2000; Gambardella 1995; Powell et al., 1996; Zucker et al., 2002).	Scientific knowledge and patents are related, but good publications and good patents are not. This can be easily explained, by remembering that the two points are not chosen by the same evolutionary logic of selection. The results point to conflicting logics between science and innovation, and scientists must contribute to both while they inhabit a single intellectual community.
7- Hicks D, (1995) *C.F.* (0,837)	Research Innovation: (Freeman, 1991; Rothwell, 1992). Knowledge Base: (Cohen & Levinthal, 1989)	Articles are essential for knowledge transfer: they not only transmit formalized information, but also seek to develop new knowledge. Academic and industrial researchers distinguish between public and private knowledge in such a way as to give them the maximum advantage, but companies can publish more precisely since they can choose which information to make public.
8- Jensen R, (2001) *C.F.* (0,833)	University Research: (Jaffe, 1989; Nelson, 1982). Licensing and Royalties: (Caves, Crookel, & Killing, 1984)	There is still an embryonic state in most licensed technologies. In most university inventions, there is a problem of moral hazard with the inventor's effort. In the debate over the Bayh-Dole Act, proponents argue that unless universities have the right to license faculty inventions, there are many results of federally funded research that remain in the research laboratory awaiting application industrial.
9- Liebeskind J, (1996) *C.F.* (0,660)	Scientific Knowledge (Irvine & Martin, 1985; Zucker, Darby, Brewer & Peng, 1995) Social Nets: (Granovetter, 1985)	It has been observed that industrial scientists perform a large number of collaborative research efforts with scientists from other organizations and in particular from universities. The results indicated that the use of social networks increases both learning and flexibility in obtaining knowledge in a way that would not be possible if the work was done in isolation.
10- Mansfield E, (1991) *C.F.* (0,703)	Research (Ben Martin & John Irvine, 1986) Industrial Innovation: (Mansfield, 1971, 1977, 1980)	The results provide compelling evidence that, particularly in industries such as pharmaceuticals and IT, the contribution of academic research to industrial innovation has been considerable. This does not mean that other inputs such as facilities and equipment, labor or administration are not important, but while the contribution of these other inputs is generally taken for granted, the role of academic research is considered uncertain.
11- Mansfield E, (1995) *C.F.* (0,761)	Academic Research: (Jaffe, 1989 and Pool, 1991). Academic Research and Industrial Innovation: (Mansfield, 1971, 1977, 1980 and 1987)	A substantial proportion of industrial innovations were based on recent academic research, although in many cases the invention itself did not originate from universities. The extent to which a university is credited for these innovations tends to be directly related to the quality of the university's faculty, the size of R&D expenditures, and the proportion of industries located nearby.
12- Mcmillan G, (2000) *C.F.* (0,793)	Public Science and Technology: (Narin, 1997) Intellectual capital: (Zucker, 1995)	The results indicate that the biotechnology industry depends more on basic public science than other industries. The main reason is that they trust public science and because of this they are increasingly looking for university alliances for their basic research.
13- Mowery D, (2001) *C.F.* (0,699)	Science and Innovation: (Gambardella, 1995) Patents: (Trajtenberg, Henderson, & Jaffe, A., 1994)	The results show that for the universities surveyed, the Bayh-Dole law did not result in an increase in licensing or patenting but contributed to and facilitated marketing efforts.
14- Murray F, (2002) *C.F.* (0,782)	Social Organization, Science and Technology: (Dasgupta & David, 1994)	"Science and Technology" are of a different nature, but there is an overlap between them that has a strong influence on the innovation process. Companies that manage the balance

Authors-*KMO*	Theoretical framework	Results and contributions
	Technological Process (Dosi, 1982)	between science and technology both internally and externally will gain a significant advantage over their competition. In particular, this means developing new strategies that incorporate academic scientists as important players in the commercialization process.
15- Narin F, (1997) *C.F.* (0,621)	Academic Research and Industrial Innovation: (Mansfield E, 1991) Basic Research (Martin B 1996) Patents and citation: (Narin, 1988, 1991 and 1995)	73% of the articles cited by US industry patents are authored by academic, governmental, or other public institutions; only 27% are authored by industrial scientists. Public science plays an essential role in supporting US industry. All areas of industry linked to science, between large and small companies, is a fundamental pillar of the advancement of American technology.
16- Stern S, (2004) *C.F.* (0,791)	Technological Innovation: (Cohen & Levinthal, 1990; Rosenberg, 1990).	There is a strong negative relationship between wages and science. Companies that allow their employees to publish, on average, extract a 25% salary discount. The conclusion of the article is that, conditional on scientific capacity, scientists pay to be published scientists.
17- Thursby J, (2002) *C.F.* (0,763)	Technological Knowledge: (Dasgupta & David, 1994).	The results demonstrate that the increase in licensing is mainly due to a greater willingness of the faculty and administrators to license and increase the business in R&D, instead of a restructuring in the faculty. This increase in licensing reflects the effect intended by the legislation (Bayh-Dole law).
18- Zucker L, (1998) *C.F.* (0,695)	Knowledge Spillovers: (Griliches, 1982) (Jaffe, Trajtenberg & Henderson, 1993)	It was found that there is a positive impact of university research with companies located geographically close to each other, due to the exchange in the market of university scientists between companies, favoring knowledge overflows.
19- Zucker L, (2002) *C.F.* (0,764)	Human intellectual capital: (Di Gregório & Shane, 2000). Knowledge: (Nelson & Winter 1982).	Basic knowledge has an impact on the performance of the biotechnology industries and intellectual human capital in the role of teachers is a key resource in the creation and transfer of knowledge between the academic and private sectors.

Note: In the "objective" field, the symbol (*) means "quantitative" research, (**) means "qualitative" and (***) means "book". Factorial Load (F.L.).
Source: Authors elaboration.

5 Discussion and conclusions

The objective of this research was to explore the conceptual bases of the thematic networks of technological cooperation and patents in biotechnology, based on bibliometrics with factor analysis. The results presented by this research demonstrate evidence that supports the congruence of research fronts in the conceptual field of technological cooperation networks.

The main contribution of this article was the identification of three converging factors in the conceptual field of technological cooperation networks in biotechnology, namely: factor 1 - the central role of the biotechnology firm in articulating knowledge, innovations, and technologies produced and disseminated in technological cooperation networks; factor 2 - the patent as a valuable resource that merges and highlights knowledge, innovations, and technological routes for the firm, its networks and the industry; and, finally, factor 3 - research conceived as a networked activity that promotes the intersection between science produced in universities, technologies conceived in firms, and the dissemination to industry and society of articles, patents, and innovations.

Research is a determining point in the biotechnology sector in the development of new products and processes within the scope of the firm (factor 1), the main driver of cooperation networks. In addition, due to the demand for innovation as a crucial factor for biotechnology companies to gain competitive advantage, the patent (factor 2) is an asset in this process, guaranteeing ownership over the biotechnological invention. In this respect, conceiving research as a network activity (factor 3) in the biotechnology sector is essential for the firm (factor 1), universities, science and technology institutes, and the government to relate as effectively as possible. These partnerships result in the search for new knowledge, new technologies, or complementary resources, aiming at efficiency in their processes and organizational excellence referring to the concept of open innovation where interorganizational collaboration contributes to the participants to reduce investment costs (Chesbrough & Appleyard, 2007; Guan & Wei, 2015), reduce risks (Liyanage, 1995), and favor the search for information and access to complementary resources (Guan et al., 2015; Marquardt, 2013), thus improving the innovative performance of the participants (Sampson, 2007).

To provide an overview of the main constructs that contributed to building the theoretical-conceptual basis of the theme "technological cooperation networks" over the past 31 years, an illustration summarizing and grouping the main concepts and theoretical currents and their relation for each factor was prepared. Table 6 briefly presents the main authors and their conceptual constructs for the development of their research.

Table 6

Summary table with the main authors and their conceptual efforts for the development of their research

Main concepts and theoretical currents	Factor 1 (Firm)	Factor 2 (Patent)	Factor 3 (Research)
Resource-Based View (RBV)	Teece (1986 and 1997); Dyer (1998)	Barney (1991)	
Transaction Cost Theory (TCT)	Pisano (1990)		
Technological Cooperation Networks (TCN)	Shan (1994); Henderson (1993); Baum (2000)		Murray (2002); Liebeskind (1996)
Social Network Analysis	Almeida (1999)	Stuart (1996)	Arora (1994); Audretsch (1996)
Dynamic Capacity (DC)	Teece (1997)	Henderson (1994); Chesbrough H (2003)	
Knowledge-Based Vision (KBV), Learning and Knowledge Spillovers	Ahuja (2000 and 2001); Mowery (1996); Levitt, (1988); Griliches (1990); Rothaermel (2004); Decarolis (1999)	Nelson (1982); Rosenkopf (2001); March (1991); Dosi (1982); Alcacer (2006); Grant (1996); Levinthal (1993); Kogut (1992)	Gittelman (2003); Hicks (1995); Zucker (1998 and 2002); Liebeskind (1996)
Strategic Alliances	Schilling (2007); Rosenkopf (2003)	Rothaermel (2008)	
Absorptive Capacity (AC)		Choen (1990); Zahra (2002)	Cockburn (1998)
Innovation	Arora (1990);	Phene (2006); Chesbrough (2003); Henderson (1994); Laursen K, (2006);	Hicks (1995); Mansfield (1995); Stern (2004)
Patents	Levin (1987); Jaffe (1993); Ahuja (2000); Decarolis (1999); Almeida (1999)	Alcacer (2006 and 2009); Fleming (2001 and 2004), Hall (2005); Harhoff (1999); Lerner (1994); Lanjouw (2004); Jaffe (2002); Albert (1991)	Mowery (2001); Thursby (2002); Zucker (2002)

Source: Authors elaboration.

From the timeline established in the descriptive summary of figure 3, it is possible to observe the construction of the theme “cooperation networks” with the seminal articles by Pisano, (1990) on transaction cost theory (TCT); Barney, (1991) on resource-based vision (RBV) and Teece, (1986, 1997 and 1990) with “Capabilities”. In the topic “knowledge-based vision” are the articles developed by Ahuja (2000 and 2001); Mowery (1996); Levitt, (1988); Griliches (1990); Rothaermel (2004); Decarolis (1999). Regarding the topic “patents” are the articles developed by Levin (1987); Jaffe (1993), Ahuja (2000); Decarolis (1999); Almeida (1999), Mowery (2001); Thursby (2002); Zucker (2002), and finally, “innovation” based on the articles by Arora, (1990); Powel, (1996); Phene (2006); Chesbrough (2003); Henderson (1994) and Laursen K, (2006).

To close a line of reasoning from the conceptual basis followed by researchers over the past 31 years, it is noteworthy to observe the similarity graph, involving the three factors together generated by the Iramuteq software. Apparent is that the three factors are interconnected, and factor 1 “Firm” continues to represent the central construct, which links factor 2 “Patent” and factor 3 “Research”.

This relationship demonstrates the role of centrality and the importance of the "firm" in the biotechnology sector, showing the importance of an actor's structural position within a network. Conversely, the "Patent" has its branch in the "citations" and "measures" constructs, reinforcing what was found throughout reading, since nearly all articles used the patent count, as well as the patent citations as indicators of productivity or knowledge generation for the competitive advantage of companies and universities. The use of patent and citation data is a window on the process of technological change and a powerful tool for research on the economy of innovation (Jaffe, 2002). Patent registries contain a wealth of information, including the inventors' identity, location, and employer, as well as the technological field of the invention. Patents also contain citation references from previous patents, which allow tracking links between inventions (Jaffe, 2002).

"Research" is directly linked to the "Knowledge" branch, specifically, research seeks knowledge, which in turn is connected to research: academic, public, universities, and industry. Zucker, Darby and Armstrong (2002) observed that scientific research contributes to the performance of companies that operate in networks and that research conducted in a collaborative way, evidenced by leading publications from universities and scientists, also has a significant effect on the performance of companies.

Finally, it enables the conclusion that biotechnology companies live in a highly dynamic environment with rapid scientific and technological transformation. Knowledge, which brings new resources, skills, and abilities, is mainly obtained from the development of research between the public and private sectors that work cooperatively. In this scenario, it is possible to observe that knowledge from universities is considered a key factor within the processes of open innovation, even resulting in the emergence of the concept of entrepreneurial university (Lawton Smith and Bagchi-Sen 2006; Rosli and Rossi 2016) to make the process of developing new products and services more effective. The patent emerges as an important asset for companies in this segment, as it offers a public title of ownership for their products that can contribute to companies obtaining a stronger competitive advantage for a period. Griliches (1990) illustrated in his research that patent data is a unique resource for the study of changes and for the strategic management of technology, and the information incorporated in patent data can also be used for strategic planning.

In this way, the research reaches its final objective of identifying the converging factors of the conceptual field of technological cooperation networks in biotechnology. However, this research was limited to the biotechnology sector for the reasons already explained. It is precisely because of this limitation and the importance that technological cooperation has for companies today and in highly competitive environments that it is suggested to address the topic of technological cooperation networks in other segments.

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