Revista Brasileira de Inovação
ISSN 2178-2822
DOI: https://doi.org/10.20396/rbi.v21i00.8663725

ARTICLE

Relationships of scientific and technological production in research networks: the case of the Northeast Biotechnology Network (RENORBIO)

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RECEIVED: 22 DECEMBER 2020 REVISED VERSION: 01 SEPTEMBER 2021 ACCEPTED: 05 JANUARY 2022

ABSTRACT

This research analyzed actors' interactions in the Northeast Biotechnology Network (in Portuguese, RENORBIO), based on the study of their profile of scientific and technological production. RENORBIO is a pioneer in the Northeast region, since the creation of the Graduate Program in Biotechnology. Data collection consisted in searching information on bibliographic production (articles, books, and reports), technical production (patents), and spin-off records from research carried out in the 13 focal points. These represent the coordinations located in the main education and research institutions accredited in the Network, which comprise around 30 other institutions associated to RENORBIO, to identify the interactions between the network's agents. To analyze the results, we processed data by using the UCINET software. The software was essential for studying the interactions among network agents, assisting to characterize technical and academic interactions within RENORBIO, based on the analysis of its actions of Technology Transfer; this allowed profiling this network in the light of the Theory of Social Networks. We identified that the Network has a 'satellite' topology, where a central network attracts and influences the research relationships between the actors of the other networks, which gravitate around it, creating a force of institutional attraction between them. It is a heterogeneous network, characterized by low density and wide flow of diverse interactions of its actors. In addition, it shows a strong representation of the innovations produced in the Northeast region, capable to affect directly or indirectly the socioeconomic condition of this region, and bring solutions for national problems in the area of biotechnology.

KEYWORDS: Technology transfer; Cooperation networks; Biotechnology

1. Introduction

The development of technologies in universities usually takes place in collaborative environments such as research networks, especially when they involve academic and market relationships (HAYTER; RASMUSSEN; ROOKSBY, 2020). By combining knowledge, these research networks can build innovative technological development processes (HILÁRIO; GRACIO, 2018; CASTRO et al., 2018; CHEN et al., 2020; LEENDERS; DOLFSMA, 2016).

Several approaches can define and classify academic research networks, including Social Network Analysis (SNA), derived from the Theory of Social Networks. In Brazil, the 1990s marked the beginning of academic studies on social networks, fostered by the expansion of new information technologies that facilitated building large networks (CASTRO et al., 2018). From the perspective of the Social Network Theory, the actors, represented by the people in the network, organize themselves structurally, driven by four kinds of ties: similarities, interactions, flows, and social relationships (BRASS et al., 2004).

Confirming this statement, several studies in the field of science, technology and innovation argue that the connection of agents in a national network is determinant for its innovative capacity (MORLACCHI; MARTIN, 2009; MALERBA; VONORTAS, 2009; KOSCHATZKY, 2014; CASTRO et al., 2018; CHEN et al., 2020).

A significant part of these studies elucidates aspects related to the evaluation of research networks' performance. However, the dynamics arising from the relationships among network agents is something that needs advancing, especially in studies regarding emerging countries, such as Brazil. This shortage stands out when we focus on the analysis of relationships among the actors in networks of scientific cooperation, supported by their technical and academic production, in order to trace the organizational profiles of these networks.

Regarding RENORBIO, the Northeast Biotechnology Network, selected as the study object, its consolidation process began with the priority task that created the Networked Doctorate Course in

Biotechnology, pioneered by the State University of Ceará (UECE). From this initiative, other states in the Northeast region formalized the association of education and research institutions, which became part of the core of collaborating institutions of RENORBIO network.

Among scientific studies on this topic, we observed the absence of research on the actors and their scientific and technological production, from the perspective of SNA. The studies found address the characteristics of RENORBIO, by describing the number of articles, number of patents, and participating laboratories (SOLA; QUINTELLA, 2011; SILVA et al., 2016; MEDEIROS; RONDON, 2018). However, this study sought to understand the profile of the selected Network and, to do this, it was necessary to study it by considering the actors as co-responsible for its products, and these are the results of their relationships' flows, whether professional or personal. We identified, accounted for, and analyzed such relationships in order to show the Network's social and production profile, shedding light on RENORBIO's creation goals and their connection with the products of the relationships among its actors.

The relevance of this topic is evident through several statements, such as Newman's (2001), who considered scientific cooperation networks as authentic social networks, due to the level of autonomy of the relationships within this type of network. For Marteleto (2010), the relational bonds among agents inserted in social networks allow increasing their acting abilities, represented by the mobilization of intellectual and material resources, thus reflecting their important influence on their individual productivity.

Based on these observations and on the importance of Brazilian academic research networks, this study proposed the following question: what is RENORBIO's profile, based on the study of its scientific and technological production, in the light of Social Network Analysis? Therefore, the general objective was to identify the actors and their interactions at RENORBIO, based on their profile of scientific and technological achievement.

The article has five sections, including this Introduction. In the Literature Review, we address the concepts of technology transfer and its application in the graduate programs of Brazilian universities, highlighting the object of this article - RENORBIO, its actors and interactions. In the second part of the section, we show the importance of cooperation networks for the scientific field, with their innovative capacity, in addition to the theoretical approach of social network analysis for understanding this phenomenon. Next, we present the methodological procedures and the analysis of data collection and its results. In the last section, we show the contributions to the area and the general limitations of the study.

2. Literature review

2.1 Scientific and technological production, technology transfer, and RENORBIO

In the literature on economics of innovation, especially on National Innovation Systems, a central element is scientific and technological production, mainly through the interaction of Scientific and Technological Institutions (STI) and companies. This interaction favors the creation and transfer of technology to the production sector, contributing to the competitiveness of regions and nations (LUNDVALL, 1992; FREEMAN, 1995; SCHAEFFER; RUFFONI; PUFFAL, 2015).

In this perspective, the concept of Technology Transfer [TT] is often discussed by researchers that disagree on two prevailing paradigms. The first paradigm sees TT as a result of formal contracts, signed between universities and companies, resulting from scientific research done at the university, with a focus on developing patents, licensing, and spin-offs. Hence, the TT process can lead to economic benefits for the sender and the receiver (RASMUSSEN; MOEN; GULBRANDSEN, 2006; BRAGA JÚNIOR; PIO; ANTUNES, 2009; RASMUSSEN, 2008; BEKKERS; FREITAS, 2008; HOYE; PRIES, 2009; FERNANDES et al., 2018; DOMINGUES et al., 2018).

The second paradigm considers two main types of TT: formal contracts, mentioned above; and informal contracts, represented by knowledge achieved through university education, academic publications, reports, and technical training offered by universities to companies (LANDRY et al., 2010; CLOSS et al., 2013; BATTISTELLA; TONI; PILLON, 2016; FERREIRA; GHESTI; BRAGA, 2017; AMORIM; PIRES; SANTOS, 2019).

This paper followed the second paradigm, where TT consists of formal contracts, such as the production of patents, licensing, and creation of spin-offs; and of informal contracts, represented by academic production, teaching activities, technical reports, and other informal relationships between universities and companies. We chose this approach based on several studies that show the relevant complementarity between the production and licensing of patents and the publication of scientific articles (AZOULAY; DING; STUART, 2007; CLOSS et al., 2013; BATTISTELLA; TONI; PILLON, 2016; FERNANDES; MACHADO, 2019). These articles highlight the benefits of this complementarity in the academic environment, for the development of an entrepreneurial culture, which drives the production of new technologies transferred to the market.

As research mainly takes place at universities, largely in *stricto sensu* graduate programs, they gradually increase their capacity to generate technological innovations, by working in research networks and underpinning their TT processes largely on patent-protected knowledge (OLIVEIRA; FONSECA, 2010; ALVES, 2016; BRASIL, 2005).

In Brazil, a legislation to encourage the development of science, innovation, and technology only emerged in 2004, through Law No. 10,973, named Innovation Law (Santos, 2009). Thus, Brazil differs from developed countries, in the technological field, since it has a recent legislation; for example, the United States enacted the first law to foster scientific and technological development in 1980, called the Bayh-Dole Act (MOWERY; SAMPAT, 2005).

The delay in Brazil's technological development relates directly to the chosen model for its historical and economic progress, especially the strategies for industrialization and economic growth. The country had well-defined stages in the development of its economic model (CANO, 2015; TURCHI; MORAIS, 2017): i) the first focused on extensive growth and industrialization through intense State action, participating as financier, planner, and inducer; ii) the second sought to boost economic growth by opening the country to foreign capital, with privatization and liberalization of the economy.

However, in neither of these stages did the country gave priority to technology and innovation as driving forces for economic development (TURCHI; MORAIS, 2017; VIOTTI, 2008); hence, there was no planning of public policies for promoting Science, Technology and Innovation (S,T&I). Table 1 shows some policies that guided the Brazilian economic development model.

Therefore, the creation of cooperation networks was based on a recent strengthening of relationships between universities and companies, which contributed to the expansion of graduate programs, encouraged by the New Legal Framework for Science, Technology, and Innovation - Law 13,243 of 2016 (NAZARENO, 2016; TORKOMIAN, 2009). This law contributed to increasing local scientific production and technology creation and transfer (SIDONE; HADDAD; MENA-

TABLE 1
Drivers of development policies (1950-1980)

1950-1980	Attributes
Context	● Import substitution
	● State dirigisme
	● Protectionism
	● Limited competition
	● Restricted democracy
Vectors	● Industrialization
View on technology and innovation	● Industrialization would foster competition, technology creation, and increase competitiveness

Source: Turchi and Morais (2017).

CHALCO, 2016). However, there is a great spatial heterogeneity of these programs, and, consequently, large numerical divergences regarding the regional distribution of publications and researchers, more concentrated in the Southeast region (GUIMARÃES et al., 2009).

However, in recent years, there was a strong growth of *stricto sensu* graduate programs, particularly inter-institutional, in the North and Northeast regions (SIDONE; HADDAD; MENA-CHALCO, 2016). Public policies fostered the advancement of these programs, in these regions, through resource allocation for strengthening innovative systems, thus allowing the search for partners to optimize the impact on research visibility and on the generation and diffusion of technologies for solving regional problems (TATSCH et al., 2021).

Brazilian researchers working in different fields of Biotechnology encouraged the formation of clusters, which are agglomerations of companies that operate in the same sector (BRESCHI; MALERBA, 2005). They also fostered the creation of regional networks of research and teaching activities in Biotechnology, in order to strengthen the regional development of Research and Development (R&D) and the creation of companies in that market (AZEVEDO et al., 2002). Hence, the following regional Biotechnology networks were created: RENORBIO; Biodiversity and Biotechnology Network of the Legal Amazon (Bionorte); Biotechnology and Biodiversity Network (REDE PRÓ – Midwest); and the Biotechnology Network of the South Region (South Biotec). These networks gather around 200 researchers, located in nine states in the Northeast region and in Espírito Santo, in addition to 30 associated institutions focused on scientific and technological development.

RENORBIO's creation was an effort of several agents in different Northeast states, in addition to Espírito Santo, where their coordinated actions resulted in the establishment of the first networked Graduate Program in the Northeast region (MEDEIROS; RONDON, 2018). Therefore, RENORBIO was born with the main goal of promoting scientific and technological development able to influence positively the socioeconomic context of the region and the states where it is located (BRASIL, 2005). Through network research actions, it produces patents and technical records ready for licensing and co-ownership, for commercialization.

2.2 Social networks and scientific cooperation networks and their innovative capacity

Social Network Analysis - SNA refers "[...] to a structural approach that is based on the study of the interaction among social actors" (FREEMAN, 2004, p. 2). Hanneman and Riddle (2005) and Tomael and Marteleto (2013) emphasize that the relationships among agents is the basis of this approach, formed by connections and ties, where individual agents are not the focus of analysis in these relationships. SNA consists in applying formal methods of analysis to social relationships, through the use of diagrammed dots and lines, in order to examine, precisely, the attributes and properties of the interrelationships of network actors (CROSSLEY; PRELL; SCOTT, 2009; WANG et al., 2009).

The literature on SNA has stood out, in recent decades, in the field of social sciences (HOLGADO, 2013). For the accurate processing and analysis of social relationships, SNA uses two types of analysis: mathematical and visual. The former consists of mapping a wide universe of relationships among the network agents (Abdel-Ghany, 2008), as well as drawing the system of these relationships by means of dots and lines among the nodes, which represent the links formed by the people in the networks. Thus, social network analysis seeks to understand networks and their participants through two targets: the agents, represented by the nodes in the graphs, and the relationships among them, indicated by the lines, in a specific social context (BORGATTI; EVERETT; JOHNSON, 2018).

In a current perspective, the definition of networks reflects a modern vision, characterized by the complexity of its operation. Networks refer to structures formed by a set of nodes, represented by entities or actors that relate through threads (ties' relations), where actors, resources (tangible or intangible), and activities form the three levels of network relationships, so that the particularity of the nodes, or interactions, is paramount (FORD et al., 2011; RATAJCZAK-MROZEK, 2017).

Borgatti et al. (2018) classified the main attributes of SNA according to the following indices:

(1) density, which shows the level of interaction among network actors (ZHANG, 2010);

(2) degree of centrality, which shows the connections of an actor with other members of the network, through nodes' links (OTTE; ROUSSEAU, 2002);

(3) centralization index, where the actor has a central position, when connected to the network's other nodes (VELÁZQUEZ ÁLVAREZ; AGUILAR GALLEGOS, 2005);

(4) degree of intermediation, regarding the frequency with which actors place themselves among the links of other actors, affecting the process of communication among them (BALESTRIN; VERSCHOORE; REYES JUNIOR, 2010); and

(5) degree of proximity, represented by the level of closeness of a network actor regarding the other actors, in order to show their interdependence and efficiency (ZHANG, 2010).

Barabási (2003) classified social networks in two types: random networks, referring to the homogeneity of their connections, that is, a similarity in the number of relationships among the network nodes; and scale-free networks, represented by the heterogeneous nature of their relationships, where the majority of nodes has few connections, and a little representative part of the nodes has many connections.

Using the actors' structure and their main aspects, another type of classification of networks emerged – one-mode and two-mode social networks (WASSERMAN; FAUST, 1994). One-mode networks contain a single set of actors, for example, networks of friends from the same neighborhood. Two-mode networks, on the other hand, present two or more classes of actors, such as relationship networks between for-profit and non-profit organizations (MACHADO, 2012).

On the other hand, Gloor (2006) defines three network typologies, by considering the depth of network connections: 1) collaborative innovation networks, whose actors continuously seek to produce innovations; 2) collaborative learning networks, whose focus is to share knowledge continuously; and 3) collaborative networks of interest, whose agents mostly require knowledge and innovations.

In the academic environment, collaborative network research has expanded since the end of the 20th century, supported by advances in information and communication technologies, as well as theoretic-empirical studies that sought to explain the modes of collaboration among actors (SIDONE; HADDAD; MENA-CHALCO, 2016).

These authors state that shared production of technical and scientific knowledge, through networks, plays a key role in strengthening the regions' innovation system. It is also a challenge for Science, Technology and Innovation policies, since such networks are instruments for regional de-concentration, contributing to increase the quality of the scientific production and technology transfer, as well as the economic value of the results achieved. The creation and diffusion of knowledge and TT are processes spatially located, since they are concentrated in the territory. In these cases, the geographical proximity of network actors becomes a mechanism that facilitates learning, transmission of knowledge, and stimulates the generation of innovation among its agents.

Several studies show how cooperation networks are organized to provide knowledge and information sharing for innovation (BRESCHI; MALERBA, 2005; MALERBA; VONORTAS, 2009; KOSCHATZKY, 2014; FUNK, 2014; CASTRO et al., 2018; CHEN et al., 2020; JORDÃO; SALTORATO; FERRARINI, 2019). Castro et al. (2018) argue that the concept of innovation networks [...] is increasingly important, mainly in an "analytical context of criticism of the closed and linear view of innovation systems, as opposed to a systemic and open view".

Therefore, collaboration and sharing networks are important for innovation and TT at the university. There are several TT mechanisms from the university to the production sector, as mentioned in item 2.1 of this study. This is because, in recent decades, the university has transferred knowledge and expertise to society in different ways, overcoming the border of scientific articles' production, characterized by the consolidation of knowledge for the academic community (ETZKOWITZ, 1998).

In this environment of knowledge production, exchange, and transfer, networks are an alternative to cooperation strategies between organizations and individuals that aim to produce innovation and enable TT (POWELL; KOPUT; SMITH-DOERR, 1996; TSAI, 2001; KOSCHATZKY, 2014; LEENDERS; DOLFSMA, 2016; CASTRO et al., 2018). Therefore, network association becomes the alternative for TT to take place at the university, whether in the marketing sense of patent licensing and spin-off creation, or by transferring technical knowledge, which stems from the other TT modes already mentioned.

3. Methodology

The research was exploratory and descriptive, based on the Social Network Analysis approach. To achieve our goal, we used investigation strategies that involved collection and processing of numerical data, thus a quantitative approach (CRESWELL, 2010); and text information, through content analysis of the relationships and links among the network agents, thus a qualitative approach (GODOI; BANDEIRA-DE-MELO; SILVA, 2006).

Data collection stage comprised searching information on scientific production (articles, books, reports), technical production (patents), and records of spin-offs resulting from research developed in the 13 focal points: State University of Ceará (UECE); Federal University of Ceará (UFC); Federal University of Sergipe (UFS); Rural Federal University of Pernambuco (UFRPE); Federal University of Pernambuco

(UFPE); Federal University of Alagoas (UFAL); Federal University of Rio Grande do Norte (UFRN); Federal University of Maranhão (UFMA); Federal University of Piauí (UFPI); Federal University of Paraíba (UFPB); University of Tiradentes (UNIT); Federal University of Bahia (UFBA); and Federal University of Espírito Santo (UFES).

The focal points are the Network's local coordinations, located in 13 education and research institutions, which comprise around 33 institutions associated to RENORBIO, among them the University of Fortaleza (UNIFOR) and the Regional University of Cariri (URCA), both linked to the UECE focal point, with a large representation of actors in the Network. Their goal is to map the interactions among Network agents. Data collection consisted of three stages of surveys:

STAGE 1 – Search for data made available by the coordinators of the Program's focal points: this stage involved information search at RENORBIO official website, in addition to sending letters and *e-mails* to coordinators, in order to receive statistics regarding the internal surveys on the number of articles, patents, and spin-off creation in the Network.

STAGE 2 – Obtaining data on scientific papers published by researchers who have academic links with the Program: in this stage, we used the Sucupira Platform – CAPES database (BRASIL, 2019), to assess the impact factors of the bibliographic output linked to the Program, between 2013 and 2017.

The Sucupira Platform was essential for searching data related to publication of scientific articles, from which we created reports of intellectual production, by using the following fields as a research strategy:

- year: we defined data collection period from 2013 to 2017;
- production stratum: we selected the option "all", which covers the layers A (A1 and A2), B (B1-B5), and C.
- within the production field: "Bibliographic"

The choice of the years for bibliographic data collection was due to the availability of complete data on this production at the Sucupira Platform, during the field research period.

STAGE 3 – Obtaining data on RENORBIO protected technologies (patents): this stage refers to cataloging the number of the program's patents between 2010 and 2018, where 2010 was the first year of a patent registration by RENORBIO in the Sucupira Platform. In addition, the identification of their inventors, and the concentration areas linked to the Network, through the report available at RENORBIO official website, with basic information on patents' registration number, their titles, main authors, and the year of filing at the National Institute of Industrial Property [INPI].

Data extracted from the different databases were stored in electronic spreadsheets in the Microsoft Excel® program, to which we applied standardized filters for each search, to enable the subsequent stage of data analysis.

Tables 1 and 2 show a detailed summary of data collection sources, the category of collected data, the years considered for the analyses, and the types of analyses adopted.

Tables 2 and 3 contain a detailed summary of data collection sources, the category of collected data, the years considered for analysis, and the types of analysis used in this study.

Regarding SNA, whose source of data were the technical products (patents) resulting from scientific research of Network actors, Otte and Rousseau (2002) consider it an important strategy for research on social structures, where the relationships among the agents in these structures are based on their flows and interactions.

This type of analysis consisted of assessing different aspects, in five stages (ALCARÁ et al., 2006): 1) identification of the population, through the analysis of RENORBIO's network of researchers; 2) data collection, through search in documentary files; 3) network configuration, through the use of a software – UCINET (version 6. 2) - for recognizing the links among the network actors; 4) study of the network, through a detailed analysis of the links and connections among RENORBIO's

TABLE 2
Methodological description of the research effort in the official site of RENORBIO

Source of Data Collection	Typology of Collected data	Characteristics of collected data	Years of collection	Types of Analysis after data collection
RENORBIO Official Site	Qualitative and quantitative data	Number of focal points and associated institutions	2005 to 2018	General field of study – collection sources
RENORBIO Official Site	Qualitative and quantitative data	Number of firms from *alumni* and *Spin-offs*	2005 to 2018	
		Concentration area and research lines		
		Number of professors		Descriptive Analysis
		Number of enrolled students		
		Number of dissertations approved		
		Number of registered laboratories		Descriptive Statistical Analysis

Source: data collected at RENORBIO official site (2019).

TABLE 3
Methodological description of the research effort in Sucupira and INPI platforms

Data Collection Source	Typology of Collected Data	Characteristics of Collected Data	Years considered for collection	Type of Analysis used after collection
Sucupira Platform (Capes) and INPI Platform	Qualitative and quantitative data	Number of articles published in scientific journals and Number of registered Technical Production	2010 to 2018	Social Network Analysis (SNA)
		Number of patents with sufficient data for descriptive analysis		
		Number of patents with sufficient data for SNA		
		Number of main inventors identified		
		Total numer of inventors from the Network		

Source: Data collected from Sucupira and INPI platforms (2019).

actors, by processing data from patents, with software support; and 5) monitoring and evaluation, especially for the analysis of informal networks present in organizations' formal environments.

We excluded the last methodological step, because it was not necessary for achieving general and specific goals. We used the UCINET software (version 6.2) to analyze the relationships among the actors and the research concentration areas of RENORBIO, in order to identify and describe the characteristics of the Network regarding density, centrality, centralization, intermediation, and proximity.

We analyzed the connections and links among RENORBIO agents, through their technological production (patents). We got Network's density indices, degree of centrality, centralization index, degree of intermediation, and degree of proximity, classified by Borgatti et al. (2018) as the main characterization indices of a social network. Thus, this analysis shows particular attributes of RENORBIO, by gathering the interactions of all focal points, through the research relationships developed by its actors.

4. Result analysis and discussion

4.1 RENORBIO characterization and analysis of the relationships among the network agents

Since its inception, in 2004, until 2018, RENORBIO shows the following numbers: 226 permanent professors and collaborators, 143 registered laboratories, 635 enrolled students, 869 approved dissertations, 8,471 articles in journals, 831 filed patents, and 15 firms created by egresses from RENORBIO, or which have egresses as partners, among them nine spin-offs.

Regarding the technologies produced, of the 831 patents resulting from research developed within RENORBIO and registered at the Sucupira Platform, we only found descriptive information on 521, through their registration numbers and titles available on the Network website. Based on these 521 patents, we carried out SNA in 358 of them, since the INPI Platform had data on the inventors of these technical products. The number of published articles and of patents filed represent the consolidation path of RENORBIO, which develops each year a higher number of scientific studies that can lead to several TT methods.

The ratio between patent filing and articles published in journals by the network reached 9.8%, showing an approximate rate of conversion of scientific and technological knowledge very close to TT, mostly through informal contracts (AMORIM; PIRES; SANTOS, 2019; BATTISTELLA; TONI; PILLON, 2016; FERREIRA; GHESTI; BRAGA, 2017; LANDRY et al., 2010; CLOSS et al., 2013). Despite this positive index, we felt it was necessary to explore the production of patentable technologies for the market, thus exploring RENORBIO's entrepreneurial potential more efficiently. This action seemed relevant, given the low number of spin-offs originated from the Network - only nine -, from its creation until 2018.

The general analysis of the relationships among the agents linked to RENORBIO consisted of studying the interactions of the 359 internal agents, who were inventors of 358 patents. In this stage of the analysis, we outlined RENORBIO's general profile, based on these interaction studies, that is, in potential TT through formal contracts. The common purpose of these actors relates to the network's objective of "[...] integrating human resource training efforts with scientific and technological development..." (BRASIL, 2005, p. 16).

Hence, this analysis refers to the various attributes that characterize RENORBIO, based on Alcará et al. (2006), who emphasize that the performance of actors driven by a specific purpose in a network fosters dynamism and increases the potential of this Network's inflows. RENORBIO fits three definitions, according to Gloor (2006): 1) it is a collaborative innovation network, since we found data on its continuous search for innovations, and identified a high number of filed patents; 2) it is a collaborative learning network, when we observe its high rate of scientific publications since its creation; and 3) it is a collaborative network of interest, gathering students and professors in constant search for knowledge production and innovations.

RENORBIO is also a two-mode network, as it gathers heterogeneous agents distributed in nine states of the Northeast and Espírito Santo; it does research in four different concentration areas (health biotechnology, natural resources, agriculture and industry); and it comprises people with distinct basic knowledge formation, thus confirming that concept (WASSERMAN; FAUST, 1994).

RENORBIO showed general relationships among 359 internal agents, that is, the formation of 359 interaction nodes, resulting from the development of research in partnership that resulted in the total filing of 358 patents considered in the analysis. After examining the relationships among these agents, the Network exhibited the following general attributes, shown in Table 4.

The configuration of the relationships among the actors linked to RENORBIO shows a density level of 1.2%, which is a low figure, given the general level of connection of the agents (Table 4), as observed by Otte and Rousseau (2002). In addition, the low density identified confirms Machado (2012), that the larger the network, the lower the link density among its agents. Regarding the degree of centrality, actor A60, professor at UECE

TABLE 4
Analyses' indices of the general interactions within RENORBIO

Density	1.20%
Degree of Centrality	A60 – 7.542
	A24 – 6.983
	A46 – 6.983
Centralization index	6. 890%
Degree of Intermediation	A167 – 8.919
Degree of Proximity	0. 564
Caption	"A" corresponds to Network actors
	A24, A46, and A60 = UECE professors
	A167 = UFS student

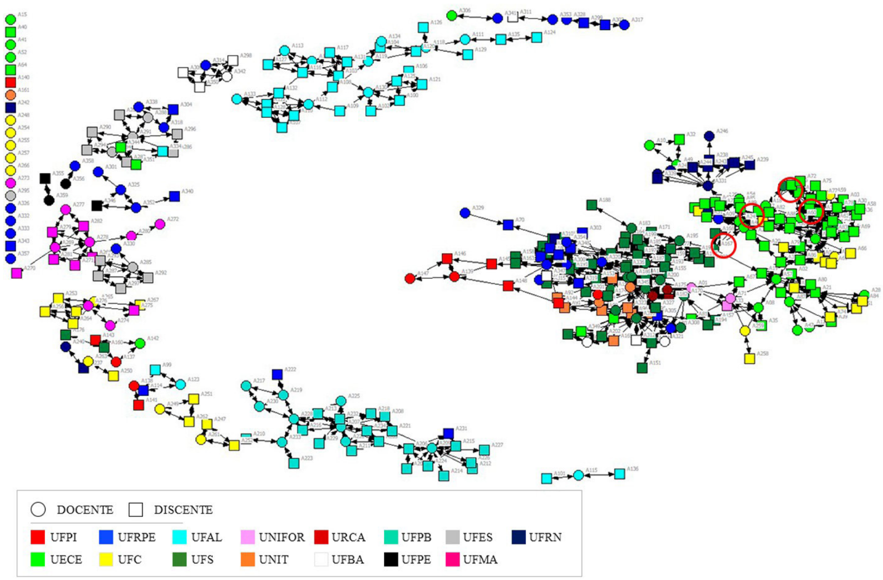
Source: Based on UCINET data (2019).

focal point, has a higher figure than actors A24 and A46, also professors at the same focal point, which shows his/her extreme importance for RENORBIO's research relationships (MACHADO, 2012).

Actor A167, from UFS, has the highest degree of intermediation, showing a high level of efficiency (ZHANG, 2010) for keeping and disseminating relationships among the actors in the Network. Regarding the centralization index, only 6.89% of the examined actors had a central role in research relationships at RENORBIO, linked to the other network nodes (BORGATTI; EVERETT; JOHNSON, 2018). This low index may be associated with the large number of actors analyzed, and the numerous flows among them, an indication that RENORBIO works as a scale-free network, with a heterogeneous character of its connections (BARABÁSI, 2003).

In addition, several actors from different focal points of the Network showed the highest degree of proximity - 0.564. The focal points represented by these actors are UECE, UFS, and UFRPE, with high efficiency and independence in their research relationships, shown in Figure 1.

FIGURE 1
Analysis of interactions among RENORBIO actors (nodes).



Regarding the analysis of relationships among the actors, RENORBIO exhibited many interactive ties of those linked to the different focal points of the Network (Figure 1). The number of nodes identified and the reciprocity of these relationships showed a frequent interaction of RENORBIO actors, generally by developing research that resulted in innovations and potential TT, thus confirming the concept of innovation networks (TSAI, 2001; CASTRO et al., 2018), and with a heterogeneous character (BARABÁSI, 2003), when studied through the perspective of social networks.

The formation of several connections by these actors showed different flows in their research relationships, especially researchers linked to UECE, UFS, and UFRPE focal points, in addition to UFC focal point and UNIFOR, associated to UECE focal point, who intermediated and centralized many connections.

The Network has a "satellite" topology, as there is a clear central and concentrated network, and many other small networks that gravitate around it, due to the institutional attractiveness of the RENORBIO program, and not due to work links or knowledge flow. We assumed that this central network attracts most of the Program's publications and technological products, and relationships expand to the satellite networks. The next analyses address the main focal points listed by the general analysis of the Network, represented by UECE, UFS, and UFRPE.

Considering the representation of these three focal points in the research relationships and interactions of Network's researchers, showed in the general SNA by the mentioned indices, we did a specific analysis for each of these three focal points.

UECE showed relationships among 96 network's internal actors, that is, the formation of 96 interaction nodes, resulting from collaborative research, led to filing 87 patents considered for this analysis. UFS, in turn, revealed relationships among 60 internal actors, through collaborative research, which resulted in 35 patents filed, considered for this analysis. In addition, UFRPE showed relationships among

77 actors within the network, which resulted in filing 56 patents considered for this analysis.

These initial data show that UECE has the highest actors' representation in RENORBIO, compared to the other focal points. After analyzing the relationships among the actors of the mentioned focal points, we found the following figures, shown in Table 5.

The analyzed data show that UECE has the lowest level of density among all focal points examined, of 5.7%, explained by its extensive pool of actors (MACHADO, 2012). Regarding the degree of centrality, actor A40, professor at UFS focal point, has the highest degree of centrality compared to the other actors of this focal point, which shows his/her high relevance in research relationships, confirming Machado (2012).

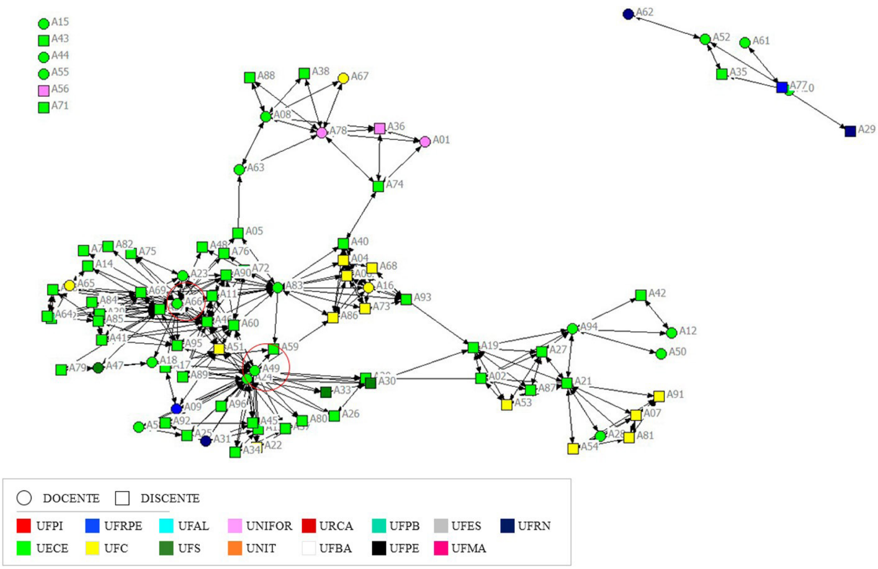
As for the degrees of intermediation and proximity, actor A49, professor at UECE focal point, stands out as the largest intermediary and the closest to the other actors in this network, showing a high level of efficiency (ZHANG, 2010) for the interactions of this focal point, as shown in Figure 2. Regarding the centralization index, 28.09% of UFS researchers played a central role among RENORBIO's research relationships, followed by 24.044% of UECE actors, and 21.797% of UFRPE's, considering their central position linked to the other nodes in the network, within each focal point mentioned (BORGATTI; EVERETT; JOHNSON, 2018).

TABLE 5
Indices of analyses of UECE/UFS/UFRPE focal point interactions in the Network

Attributes of analysis	UECE	UFS	UFRPE
Density	5.70%	11.40%	6.10%
Degree of Centrality	A66 – 28.421	A40 – 38.983	A31 – 27.632
		A14 – 00.000	
Centralization Index	24.04%	28.01%	21.80%
Degree of Intermediation	A49 – 21.702	A12 – 16.913	A31 – 10.623
		A40 – 15.903	
Degree of Proximity	A49 – 6.653	A12 – 7,.973	A31 – 2.674
		A40 – 7.877	A64 – 2.674

Note. "A" corresponds to the Network actors. Source: Based on UCINET data (2019).

FIGURE 2
Analysis of interactions among UECE actors (nodes).

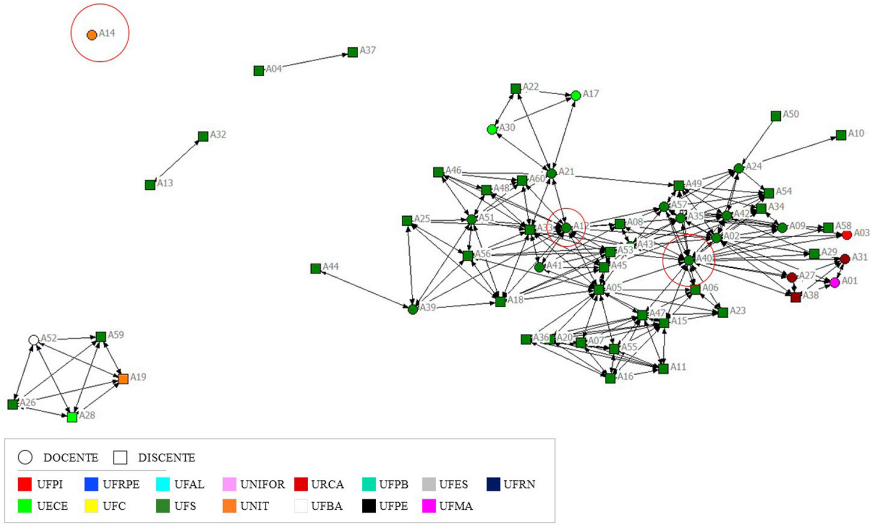


Furthermore, UECE showed a connection between its actors and almost all the Network's focal points, as we see in Figure 2. This shows the high level of interaction and the leading role of these actors with RENORBIO, through the development of research that leads to TT.

Regarding UFS, there was an increase in the integration of this focal point's actors with the other Network focal points, since we identified relationships with actors linked to UFBA, UNIT, UFC, UFPI, UECE and the associated institutions UNIFOR and URCA, collaborators of UECE focal point. Therefore, we notice an important representation of the Network as a whole in research relationships and technical production of this focal point (Figure 3). We also observed the existence of ten nodes with isolated links, thus showing isolated relationships at that focal point.

In the configuration of UFRPE focal point, regarding the integration of the actors linked to it with the other agents of RENORBIO network, we identified relationships with actors linked to the focal points UNIT, UFS, UECE, UFPI, UFBA, UFPE and UFES; that is, a wide integration

FIGURE 3
Analysis of interactions among UFS actors (nodes).

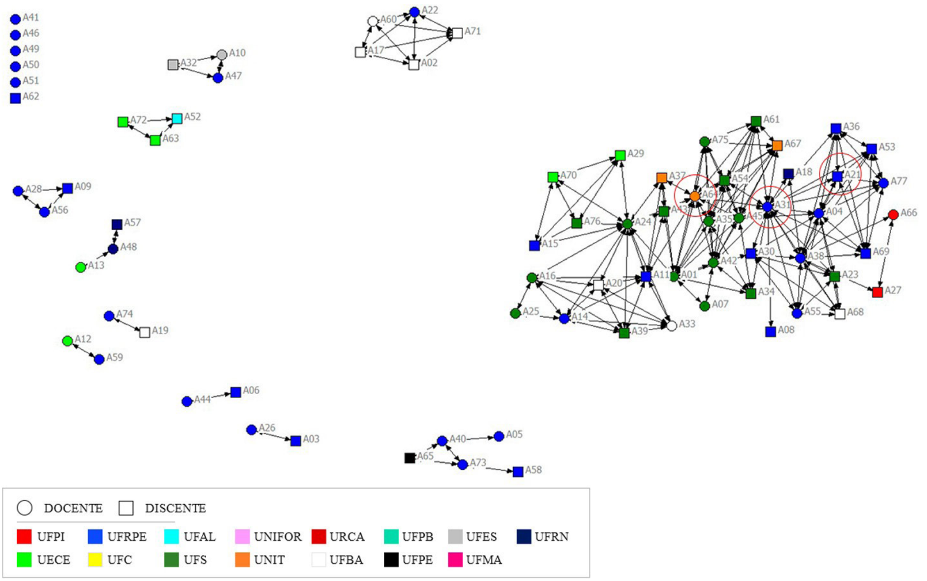


of these actors in the Network as a whole (Figure 4). However, we observed the existence of 27 nodes with isolated links, thus presenting isolated relationships or with few connections at that focal point. In addition, six actors had no links with the other members of UFRPE.

Given the general scenario and the study of actors' interaction within the Network, we observed that RENORBIO has a relevant representation in innovation production for the Northeast region, through the index related to its technical production, represented by the patents that we analyzed. Innovations resulting from research relationships among the Network actors can have a direct or indirect impact on the socioeconomic condition of that region (TATSCH et al., 2021). This is because the high number of technical products tends to generate economic activities related to the production of new technologies for the Northeast, besides contributing to expand the regional Biotechnology market.

From the numerous interactions identified in RENORBIO's research relationships, it can be a leading actor for the regional de-concentration of technical and bibliographic production (SIDONE;

FIGURE 4
Analysis of interactions among UFRPE actors (nodes).



HADDAD; MENA-CHALCO, 2016). This analysis refers not only to the high numbers of this production, but also to its high quality. In addition, the geographical proximity of these actors, organized mostly in local networks in the Northeastern territory, becomes a mechanism for facilitating the relationships for learning, knowledge transmission, and encouraging innovations among its agents. This network is also a collaborative network of interest (Gloor, 2006), where participating actors seek to achieve similar goals in building their relationships.

In addition to these aspects, we emphasize that the late implementation of Brazilian legislation for fostering innovations and TT (Santos, 2009), when compared to developed countries (SILVA et al., 2016; NAZARENO, 2016; TORKOMIAN, 2009), is responsible for the low number of scientific cooperation networks in Brazil, such as RENORBIO. This network shows high levels of complexity in its interactions, through several heterogeneous links, which generate scientific and technical products, bibliographic and TT, arising from flows of research, development, and innovation relationships among researchers.

5. Final remarks

The research aimed to identify RENORBIO's actors and their interactions, supported by the study of their profile of scientific and technological production, using the SNA approach.

Regarding the interactions of its actors working in TT, the Network has a "satellite" topology, where a central network, which is the leading actor in the flow of interactions as a whole, attracts and influences research relationships among the actors of the other networks, which gravitate around RENORBIO. We inferred that this central network is represented by the oldest focal points, born with its foundation, in 2004, contributing to an institutional pull among these agents.

As for the general density of the Network, data showed a low density of connections among the actors linked to RENORBIO, representing a wide flow of links among different points of the Network. That is, RENORBIO shows a profile of de-concentration among the groups that develop research, development, and innovation activities. On the Network's degree of centrality, the three actors with the highest figures were linked to UECE focal point, which strengthens the efficiency of this institution in interactions resulting from scientific research developed in partnership with RENORBIO researchers.

In addition to these characteristics, RENORBIO showed a free-scale network profile, through the wide and divergent flow of connections among its actors. Regarding the degree of proximity, UECE, UFS, and UFRPE focal points had the actors that were closest to the others in the Network, considering their links in scientific research with technological products. However, despite the good integration among them, with researchers linked to the focal points that represent the Network, we identified that research connections are concentrated in a few groups of researchers, who interact intensely, thus achieving many technical products ready for TT. This means that, in general, most actors have a low engagement in developing collaborative research.

Finally, the studied Network has many attributes that define it as a collaborative innovation network, a collaborative learning network, and a collaborative network of interest. These definitions are the result of its high volume of academic and technological production, in addition to its large number of actors interacting with the same scientific and technological purpose.

Furthermore, RENORBIO shows a considerable representation in innovation production for the Northeast region, which can affect its socioeconomic condition, through the generation of jobs and income, arising from additional economic activities, besides contributing to the strong expansion of the regional biotechnology market. The Network also contributes significantly for the attraction of public and private investments for research, development, and innovation, due to its high number of agents and technical and bibliographic products of great relevance, acting as an important instrument to solve national problems in several Biotechnology areas.

Research limitations regard the need to expand the analysis to the other technologies identified, since we could only analyze 521 patents descriptively. To study actors' interactions, based on the social network approach, we considered only 358 patents, which had sufficient data for this type of analysis.

On the other hand, this research reveals an important gap that further studies can explore, by focusing on a detailed analysis of technology transfer processes from patents filed by RENORBIO. This analysis can show the real innovative capacity of the Network for the production of new marketable technologies, through the study of licensing and granted patents, already identified in this paper. Our study contributes to extending academic literature on scientific cooperation networks, focusing on the analysis of interactions among RENORBIO actors, by showing how these interactions take place, and how they enhance the capacity for innovation and technology transfer from the academic environment.

Acknowledgements

The authors would like to thank IDESCO for the translation and support during the research.

References

ABDEL-GHANY, M. M. M. Social network analysis of the diffusion of innovations. Ekonomika ir Vadyba, Kaunas, v. 2, n. 11, p. 270-272, 2008.

ALCARÁ, A. R. et al. As redes sociais como instrumento estratégico para a inteligência competitiva. Transinformação, Campinas, v. 18, n. 2, p. 143-153, 2006. http://dx.doi.org/10.1590/S0103-37862006000200006.

ALVES, J. N. O processo de desenvolvimento e mudança das redes interorganizacionais. 2016. Tese (Doutorado) - Universidade Federal de Santa Maria, Santa Maria, 2016. Available from: <https://repositorio.ufsm.br/bitstream/handle/1/3148/ALVES%2C%20JULIANO%20NUNES.pdf?sequence=1&isAllowed=y>. Access in: 22 Dec 2020.

AMORIM, G. M.; PIRES, E.; SANTOS, F. Desafios na transferência de tecnologia Universidade-Empresa: um relato de experiência do Núcleo de Transferência de Tecnologia da UFRB. Cadernos de Prospecção, Salvador, v. 12, n. 1, p. 59-78, 2019. http://dx.doi.org/10.9771/cp.v12i1.27265.

AZEVEDO, N. et al. Pesquisa científica e inovação tecnológica: a via brasileira da biotecnologia. Dados, Rio de Janeiro, v. 45, n. 1, p. 139-176, 2002. http://dx.doi.org/10.1590/S0011-52582002000100005.

AZOULAY, P.; DING, W.; STUART, T. The determinants of faculty patenting behavior: demographics or opportunities? Journal of Economic Behavior & Organization, Amsterdam, v. 63, n. 4, p. 599-623, 2007. http://dx.doi.org/10.1016/j.jebo.2006.05.015.

BALESTRIN, A.; VERSCHOORE, J. R.; REYES JUNIOR, E. O campo de estudo sobre redes de cooperação interorganizacional no Brasil. Revista de Administração Contemporânea, Rio de Janeiro, v. 14, n. 3, p. 458-477, 2010. http://dx.doi.org/10.1590/S1415-65552010000300005.

BARABÁSI, A.-L. Emergence of scaling in complex networks. In: BORNHOLDT, S.; SCHUSTER, H. G. (Org.). Handbook of graphs and networks: from the genome to the internet. Weinheim: Wiley-VCH, 2003. p. 69-84. https://doi.org/10.1002/3527602755.ch3.

BATTISTELLA, C.; TONI, A. F.; PILLON, R. Inter-organisational technology/knowledge transfer: a framework from critical literature review. The Journal of Technology Transfer, Indianapolis, v. 41, n. 5, p. 1195-1234, 2016. http://dx.doi.org/10.1007/s10961-015-9418-7.

BEKKERS, R.; FREITAS, I. M. B. Analyzing knowledge transfer channels between universities and industry: To what degree do sectors also matter? Research Policy, Amsterdam, v. 37, n. 10, p. 1837-1853, 2008. http://dx.doi.org/10.1016/j.respol.2008.07.007.

BORGATTI, S. P.; EVERETT, M. G.; JOHNSON, J. C. Analyzing social networks. 2nd ed. Thousand Oaks: Sage Publications, 2018.

BRAGA JÚNIOR, E.; PIO, M.; ANTUNES, A. O processo de transferência de tecnologia na indústria têxtil. Journal of Technology Management & Innovation, Santiago, v. 4, n. 1, p. 125-133, 2009. http://dx.doi.org/10.4067/S0718-27242009000100011.

BRASIL. Ministério da Ciência, Tecnologia, Inovação e Comunicações – MCTIC. Portaria nº 3, de 14 de abril de 2005. Institui no âmbito do MCTIC o Conselho Diretor da RENORBIO. Diário Oficial da União, 14 abr. 2005, Seção 2, nº 71, p. 5.

BRASIL. Ministério da Educação. Plataforma Sucupira. Brasília, 2019. Available from: <https://sucupira.capes.gov.br/sucupira>. Access in: 22 Dec 2020.

BRASS, D. J. et al. Taking stock of networks and organizations: a multilevel perspective. Academy of Management Journal, New York, v. 47, n. 6, p. 795-817, 2004. http://dx.doi.org/10.5465/20159624.

BRESCHI, S.; MALERBA, F. Clusters, networks and innovation. Oxford: Oxford University Press, 2005.

CANO, W. Crise e industrialização no Brasil entre 1929 e 1954: a reconstrução do Estado Nacional e a política nacional de desenvolvimento. Brazilian Journal of Political Economy, São Paulo, v. 35, n. 3, p. 444-460, 2015. http://dx.doi.org/10.1590/0101-31572015v35n03a04.

CASTRO, N. et al. (2018). Redes de inovação: uma abordagem teórica. Rio de Janeiro: Grupo de Estudos do Setor Elétrico, UFRJ. (Texto de Discussão do Setor Elétrico, 84). Available from: <http://wiki.gonzaga.edu/dpls707/images/6/6e/Introduction_to_Social_Network_Methods.pdf>. Access in: 22 Dec 2020.

CHEN, K. et al. Do research institutes benefit from their network positions in research collaboration networks with industries or/and universities? Technovation, Amsterdam, v. 94-95, p. 102002, 2020. http://dx.doi.org/10.1016/j.technovation.2017.10.005.

CLOSS, L. et al. What motivates Brazilian academic researchers to transfer technology? Journal of Technology Management & Innovation, Santiago, v. 8, n. 4, p. 79-90, 2013. http://dx.doi.org/10.4067/S0718-27242013000500007.

CRESWELL, J. W. Projeto de pesquisa: métodos qualitativo, quantitativo e misto. Porto Alegre: ARTMED, 2010.

CROSSLEY, N.; PRELL, C.; SCOTT, J. (2009). Social network analysis: introduction to special edition. Methodological Innovations Online, Plymouth, v. 4, n. 1, p. 1-5. https://doi.org/10.1177/205979910900400101.

DOMINGUES, L. H. et al. Transferência de tecnologia: uma revisão sistemática sobre modelos e processos. In: CONGRESSO BRASILEIRO DE ENGENHARIA DE PRODUÇÃO, 7., Ponta Grossa, PR. Anais... Ponta Grossa: APREPRO, 2018.

ETZKOWITZ, H. The norms of entrepreneurial science: cognitive effects of the new university–industry linkages. Research Policy, Amsterdam, v. 27, n. 8, p. 823-833, 1998. http://dx.doi.org/10.1016/S0048-7333(98)00093-6.

FERNANDES, C. R.; MACHADO, A. G. C. Technology transfer capability: development dynamics in higher education institutions. Brazilian Business Review, Vitória, v. 16, n. 1, p. 1-15, 2019. http://dx.doi.org/10.15728/bbr.2019.16.1.1.

FERNANDES, R. F. et al. Práticas de transferência de tecnologia: uma análise multicasos. Cadernos de Prospecção, Salvador, v. 11, n. 5, p. 1342-1359, 2018. http://dx.doi.org/10.9771/cp.v12i5.27316.

FERREIRA, C. L. D.; GHESTI, G. F.; BRAGA, P. R. S. Desafios para o processo de transferência de tecnologia na Universidade de Brasília. Cadernos de Prospecção, Salvador, v. 10, n. 3, p. 341-355, 2017. http://dx.doi.org/10.9771/cp.v10i3.22148.

FORD, D. et al. Managing business relationships. 3rd ed. Chichester: Wiley, 2011.

FREEMAN, C. The 'National System of Innovation' in historical perspective. Cambridge Journal of Economics, Cambridge, v. 19, n. 1, p. 5-24, 1995. http://dx.doi.org/10.1093/oxfordjournals.cje.a035309.

FREEMAN, L. C. The development of social network analysis: a study in the sociology of Science. Vancouver: Empirical Press, 2004.

FUNK, R. J. Making the most of where you are: geography, networks, and innovation in organizations. Academy of Management Journal, New York, v. 57, n. 1, p. 193-222, 2014. http://dx.doi.org/10.5465/amj.2012.0585.

GLOOR, P. A. Swarm creativity: competitive advantage through collaborative innovation networks. Oxford: Oxford University Press, 2006.

GODOI, C. K.; BANDEIRA-DE-MELO, R.; SILVA, A. B. Pesquisa qualitativa em estudos organizacionais: paradigmas, estratégias e métodos. São Paulo: Saraiva, 2006.

GUIMARÃES, T. D. A. et al. A rede de programas de pós-graduação em administração no Brasil: análise de relações acadêmicas e atributos de programas. Revista de Administração Contemporânea, Rio de

Janeiro, v. 13, n. 4, p. 564-582, 2009. http://dx.doi.org/10.1590/S1415-65552009000400004.

HANNEMAN, R. A.; RIDDLE, M. Introduction to social network methods. 2005. Available from: <http://wiki.gonzaga.edu/dpls707/images/6/6e/Introduction_to_Social_Network_Methods.pdf>. Access in: 22 Dec 2020.

HAYTER, C. S.; RASMUSSEN, E.; ROOKSBY, J. H. Beyond formal university technology transfer: Innovative pathways for knowledge exchange. The Journal of Technology Transfer, Indianapolis, v. 45, n. 1, p. 1-8, 2020. http://dx.doi.org/10.1007/s10961-018-9677-1.

HILÁRIO, C. M.; GRÁCIO, M. C. C. A contribuição de Robert Merton e Thomas Kuhn para a visão auto-organizada da colaboração científica: um estudo metateórico. Informação & Informação, Londrina, v. 23, n. 3, p. 17-37, 2018. http://dx.doi.org/10.5433/1981-8920.2018v23n3p17.

HOLGADO, D. Review: analyzing social networks. Redes-Revista Hispana para el Análisis de Redes Sociales, Sevilla, v. 27, n. 2, p. 141-145, 2013. Available from: <https://www.redalyc.org/articulo.oa?id=93147629009>. Access in: 22 Dec 2020.

HOYE, K.; PRIES, F. 'Repeat commercializers', 'the habitual entrepreneurs' of university–industry technology transfer. Technovation, Amsterdam, v. 29, n. 10, p. 682-689, 2009. http://dx.doi.org/10.1016/j.technovation.2009.05.008.

JORDÃO, A. A.; SALTORATO, P.; FERRARINI, C. F. Redes de pesquisa e inovação: um estudo das relações da Petrobras com instituições de ciência e tecnologia. Brazilian Journal of Development, São José dos Pinhais, v. 5, n. 4, p. 2928-2941, 2019. Available from: <https://www.brazilianjournals.com/index.php/BRJD/article/viewFile/1401/1282>. Access in: 22 Dec 2020.

KOSCHATZKY, K. New forms of regional interaction between universities and industry: evidence from Germany. Karlsruhe: Fraunhofer-Institut für System- und Innovationsforschung ISI, 2014. (Arbeitspapiere

Unternehmen und Region, R3/2014). Available from: <http://hdl.handle.net/10419/95961>. Access in: 22 Dec 2020.

LANDRY, R. et al. Evidence on how academics manage their portfolio of knowledge transfer activities. Research Policy, Amsterdam, v. 39, n. 10, p. 1387-1403, 2010. http://dx.doi.org/10.1016/j.respol.2010.08.003.

LEENDERS, R.; DOLFSMA, W. A. Social networks for innovation and new product development. Journal of Product Innovation Management, Hoboken, v. 33, n. 2, p. 123-131, 2016. http://dx.doi.org/10.1111/jpim.12292.

LUNDVALL, B. A. Introduction. In: LUNDVALL, B. A. (Org.). National systems of innovation: towards a theory of innovation and interactive learning. London: Pinter Publishers, 1992. p. 1-20.

MACHADO, D. Q. (2012). Esforços de inovação em redes sociais: uma análise na Rede Nordeste de Biotecnologia. 2012. Dissertação (Mestrado) - Universidade Estadual do Ceará, Fortaleza. Available from: <http://siduece.uece.br/siduece/trabalhoAcademicoPublico.jsf?id=70710>. Access in: 22 Dec 2020.

MALERBA, F.; VONORTAS, N. S. (Org.). Innovation networks in industries. Cheltenham: Edward Elgar, 2009.

MARTELETO, R. M. Redes sociais, mediação e apropriação de informações: situando campos, objetos e conceitos na pesquisa em Ciência da Informação. Pesquisa Brasileira em Ciência da Informação, João Pessoa, v. 5, n. 1, p. 27-46, 2010. http://dx.doi.org/10.22478/ufpb.1981-0695.2010v5n1.11995.

MEDEIROS, M. L. S.; RONDON, J. N. Rede Nordeste de Biotecnologia (RENORBIO): Um panorama atual do programa. Interações, Campo Grande, v. 19, n. 1, p. 103-117, 2018. http://dx.doi.org/10.20435/inter.v19i1.1124.

MORLACCHI, P.; MARTIN, B. R. Emerging challenges for science, technology and innovation policy research: a reflexive overview. Research Policy, Amsterdam, v. 38, n. 4, p. 571-582, 2009. http://dx.doi.org/10.1016/j.respol.2009.01.021.

MOWERY, D.; SAMPAT, B. (2005). Universities in national innovation systems. In: FAGERBERG, J.; MOWERY, D. C.; NELSON, R. R. (Org.). The Oxford handbook of innovation. Oxford: Oxford University Press.

NAZARENO, C. As mudanças promovidas pela Lei n° 13.243, de 11 de janeiro de 2016 (novo marco legal de ciência, tecnologia e inovação) e seus impactos no setor. Brasília: Consultoria Legislativa, Câmara dos Deputados, 2016. Available from: <http://bd.camara.leg.br/bd/bitstream/handle/bdcamara/28439/mudan%C3%A7as%20_promovidas_nazareno.pdf?sequence=1>. Access in: 22 Dec 2020.

NEWMAN, M. E. J. The structure of scientific collaboration networks. Proceedings of the National Academy of Sciences of the United States of America, Washington, v. 98, n. 2, p. 404-409, 2001.

OLIVEIRA, J. F.; FONSECA, M. A pós-graduação brasileira e o seu sistema de avaliação. In: CATANI, A. M.; OLIVEIRA, J. F.; FERREIRA, N. S. C. (Org.). Pós-graduação e avaliação: impactos e perspectivas no Brasil e no cenário internacional. São Paulo: Mercado de Letras, 2010. p. 15-52.

OTTE, E.; ROUSSEAU, R. Social network analysis: a powerful strategy also for the information sciences. Journal of Information Science, Amsterdam, v. 28, n. 6, p. 441-453, 2002. http://dx.doi.org/10.1177/016555150202800601.

POWELL, W. W.; KOPUT, K. W.; SMITH-DOERR, L. Interorganizational collaboration and locus of innovation: networks of learning in biotechnology. Administrative Science Quarterly, Ithaca, v. 41, n. 1, p. 116-145, 1996. http://dx.doi.org/10.2307/2393988.

RASMUSSEN, E. Government instruments to support the commercialization of university research: lessons from Canada. Technovation, Amsterdam, v. 28, n. 8, p. 506-517, 2008. http://dx.doi.org/10.1016/j.technovation.2007.12.002.

RASMUSSEN, E.; MOEN, O.; GULBRANDSEN, M. Initiatives to promote commercialization of university knowledge. Technovation, Amsterdam, v. 26, n. 4, p. 518-533, 2006. http://dx.doi.org/10.1016/j.technovation.2004.11.005.

RATAJCZAK-MROZEK, M. Network embeddedness: examining the effect on business performance and internationalization. Basingstoke: Palgrave Macmillan, 2017.

SANTOS, M. E. R. Boas práticas de gestão em núcleos de inovação tecnológica (NIT). In: SANTOS, M. E. R.; TOLEDO, P. T. M.; LOTUFO, R. A. (Org.). Transferência de tecnologia: estratégias para a estruturação e gestão de núcleos de inovação tecnológica. Campinas: Komedi, 2009. p. 75-108.

SCHAEFFER, P. R.; RUFFONI, J.; PUFFAL, D. Razões, benefícios e dificuldades da interação universidade-empresa. Revista Brasileira de Inovação, Rio de Janeiro, v. 14, n. 1, p. 105-134, 2015. http://dx.doi.org/10.20396/rbi.v14i1.8649091.

SIDONE, O. J. G.; HADDAD, E. A.; MENA-CHALCO, J. P. A ciência nas regiões brasileiras: Evolução da produção e das redes de colaboração científica. Transinformação, Campinas, v. 28, n. 1, p. 15-32, 2016. http://dx.doi.org/10.1590/2318-08892016002800002.

SILVA, K. et al. A contribuição da RENORBIO para o progresso técnico: análise a partir do indicador de patentes no período 2011-2016. Cadernos de Prospecção, Salvador, v. 9, n. 4, p. 428-440, 2016. http://dx.doi.org/10.9771/cp.v9i4.17996.

SOLA, M. C. R.; QUINTELLA, C. M. Desenvolvimento biotecnológico no âmbito da RENORBIO–Rede Nordeste de Biotecnologia. Cadernos de Prospecção, Salvador, v. 4, n. 4, p. 50-56, 2011. http://dx.doi.org/10.9771/S.CPROSP.2011.004.006.

TATSCH, A. L. et al. Interaction networks in health human area: a longitudinal study for Rio Grande do Sul. Revista Brasileira de Inovação, Rio de Janeiro, v. 20, p. 1-31, 2021. http://dx.doi.org/10.20396/rbi.v20i0.8659069.

TOMAÉL, M. I.; MARTELETO, R. M. Redes sociais de dois modos: Aspectos conceituais. Transinformação, Campinas, v. 25, n. 3, p. 245-253, 2013. http://dx.doi.org/10.1590/S0103-37862013000300007.

TORKOMIAN, A. L. V. Panorama dos núcleos de inovação tecnológica no Brasil. In: SANTOS, M. E. R.; TOLEDO, P. T. M.; LOTUFO, R. A. (Org.). Transferência de tecnologia: estratégias para a estruturação e gestão de núcleos de inovação tecnológica. Campinas: Komedi, 2009. p. 21-37.

TSAI, W. Knowledge transfer in intra-organizational networks: effects of network position and absorptive capacity on business unit innovation and performance. Academy of Management Journal, New York, v. 44, n. 5, p. 996-1004, 2001. http://dx.doi.org/10.5465/3069443.

TURCHI, L. M.; MORAIS, J. M. (Org.) Políticas de apoio à inovação tecnológica no Brasil: avanços recentes, limitações e propostas de ações. Brasília: IPEA, 2017. Available from: <https://www.ipea.gov.br/portal/images/stories/PDFs/livros/livros/171103_politicas_de_apoio_a_inovacao.pdf>. Access in: 22 Dec 2020.

VELÁZQUEZ ÁLVAREZ, O. A.; AGUILAR GALLEGOS, N. Manual introductorio al análisis de redes sociales. 2005. Available from: <http://revista-redes.rediris.es/webredes/talleres/Manual_ARS.pdf>. Access in: 22 Dec 2020.

VIOTTI, E. B. Brasil: de política de C&T para política de inovação? Evolução e desafios das políticas brasileiras de ciência, tecnologia e inovação. In: SEMINÁRIO INTERNACIONAL AVALIAÇÃO DE POLÍTICAS DE CIÊNCIA, TECNOLOGIA E INOVAÇÃO - DIÁLOGO ENTRE EXPERIÊNCIAS INTERNACIONAIS E BRASILEIRAS, 2008, Rio de janeiro,. Anais... Brasília: CGEE, 2008. p. 137-173. Available from: <https://livroaberto.ibict.br/bitstream/1/852/1/avalia%C3%A7%C3%A3o%20de%20pol%C3%ADticas.pdf#page=138>. Access in: 22 Dec 2020.

WANG, J. J. et al. Review on multi-criteria decision analysis aid in sustainable energy decision-making. Renewable & Sustainable

Energy Reviews, Oxford, v. 13, n. 9, p. 2263-2278, 2009. http://dx.doi.org/10.1016/j.rser.2009.06.021.

WASSERMAN, S.; FAUST, K. Social network analysis: methods and applications. Cambridge: Cambridge University Press, 1994.

ZHANG, M. Social network analysis: history, concepts, and research. In: FURHT, B. (Org.). Handbook of social network technologies and applications. Boston: Springer, 2010. p. 3-22.

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Conflict of interest: the authors declare that there is no conflict of interest.

Source of funding: the authors declare that there is no funding.