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Technological cooperation network in biotechnology

Analysis of patents with Brazil as the priority country

Cristiano Goncalves Pereira and Rodrigo Ribeiro Da Silva
Departamento de Administração, Universidade de Sao Paulo Faculdade de Economia Administracao e Contabilidade de Ribeirao Preto, Ribeirao Preto, Brazil

João Ricardo Lavoie
Engineering and Technology Management, Portland State University, Portland, Oregon, USA, and

Geciane Silveira Porto
Departamento de Administração, Universidade de Sao Paulo Faculdade de Economia Administracao e Contabilidade de Ribeirao Preto, Ribeirao Preto, Brazil

Abstract

Purpose – The establishment of partnerships between companies, government and universities aims to enhance innovation and the technological development of institutions. The biotechnology sector has grown in recent years mainly driven by its cooperative business model. Compared to other countries, this sector is slowly advancing in Brazil, with delays in science, technology and innovation, especially in the private sector. This paper aims to examine, through social network analysis, the collaborative networks between institutions that filed patents in biotechnology – medicinal preparations from plants – whose inventions had Brazil as the priority country.

Design/methodology/approach – The study of technological cooperation using patent documents is a reliable approach as they serve as good indicators of the interactions between organizations that focus on innovation and development of new product. Social network analysis of cooperation networks helps to understand the connections between patent assignees, and how they establish relationships.

Findings – Results show that public universities are the institutions that most deposit patents, as well as those that co-operate the most, especially Universidade of Campinas. The study also reveals the critical role of Research Support Agencies in stimulating research and technological development, which result in new technologies.

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Originality/value – The study applied the social network analysis to provide an overview of the interactions among Brazilian institutions with the purpose of helping in decision-making and inciting public policies to leverage the biotechnology sector.

Keyword Social network analysis

Paper type Research paper

1. Introduction

According to the Organization for Economic Cooperation and Development (OECD, 2008), innovative potential depends on how knowledge progresses and on the structure of connections of each country's National Innovation System (NIS). In this regard, the importance of establishing partnerships between companies, government and universities, aiming to enhance technological innovation, has been discussed and emphasized over the years in studies that address NIS (Freeman, 1995; Nelson and Rosenberg, 1993; Lundvall, 1992), open innovation (OI; Chesbrough, 2003) and, more recently, the joint-product orientation (Foray and Lissoni, 2010).

In an NIS, the innovative process occurs through the flow of technology and information between the actors of this system, who can be individuals, companies, universities, governments and research institutes, among others. Regarding the same issue, the triple helix innovation model is based on the relationship between government, industry and university. The latter is the driver of connections with the production sector of goods and services, represented by industry and with the government, which regulates economic activity (Leydesdorff and Etzkowitz, 1996). On the other hand, OI stresses the ability of organizations to effectively articulate the use of their internal and external resources, such as ideas, skills, projects, infrastructure, technologies and capital (Rogbeer *et al.*, 2014). Therefore, this model requires organizations to open their borders to enable innovations from internal and external combinations of resources, in view of two main objectives: to absorb external assets and to allow the licensing of the internal means that the firm will not use, avoiding the loss of investments already made (Chesbrough, 2003).

Yet, Foray and Lissoni (2010) present a proposal for the management of research, development and innovation (R&D&I), where they replace the vertical structure (by-product orientation), by a shared vocation, the joint-product. This view considers that products with shared technology achieve better results in terms of sales, in addition to lower R&D costs and risks. The development process must be shared with the most competent actors since the beginning, by involving companies and universities to shape strategic relationship networks.

The determinants of a stronger cooperation between institutions, as well as their beneficial effects for innovation, are well established in the literature. However, more studies are necessary to improve the visualization and interpretation of these relationships, allowing the identification of the main actors and those more prone to establish partnerships, as well as the dynamics of collaboration between institutions over time. The innovation process is complex, and the way actors interact with each other can define the result of the cooperative effort. As interactions between institutions to achieve innovative results shape a network structure, a valuable tool for understanding and better viewing cooperation between firms, government and universities is to use the metrics and concepts of social network analysis (SNA).

This study, in addition to presenting SNA's methodological features to measure cooperation between institutions, examines a sample of cooperative projects on medical preparations that contain products of plant origin, which resulted in joint technological development with patent applications, where Brazil is the first country of deposit. The basis of the study is the success of the new business model, flexible and open to partnerships, which the biotechnology sector has taken advantage of in the recent years. It focuses on a specific segment related to herbal products with medical and cosmetic application that were first protected in Brazil. This is a relevant topic as the variety of Brazilian biomes reflects the enormous richness of the country's flora and fauna, which houses the largest biodiversity in the planet. The country owns about 20 per cent of the world's biodiversity, and the largest regarding plants, with more than 50,000 listed species of trees and bushes. Higher plants, although better indexed, are still far from a reliable total count, and there are estimates that 10 per cent of the Brazilian species have not yet been cataloged (Lewinsohn *et al.*, 2001).

This paper presents an analysis of the global scenario of these patents with the evolution of filings over the last 20 years, the main inventors and the kinds of actors – companies, universities and research institutes. It also shows the profile of the partnerships between institutions and highlights the main patent holders with technological capability to generate inventions that adopt the collaborative R&D business model.

Following the introduction, the structure of the article consists of a theoretical background on the positive aspects of establishing cooperation, and the importance of adopting SNA for its study. In sequence, we present the methodological approach used in the study, the results and discussion and at the end, the conclusions and future perspectives.

2. Literature review

2.1 Technological cooperation networks to foster innovation

Collaborative R&D efforts for new technologies are common in several companies and sectors, and their relevance to the innovation and technological development has been highlighted under different views. Crespo *et al.* (2015) argue that the knowledge built over the years through R&D management studies proves the importance of collaborations, which lead to higher capacity for innovation and growth. Geum *et al.* (2013) observe that the benefits of collaborative efforts are evident and stem from the use of external knowledge, which results in diversification of technological skills and increases the pace of production of new technologies. In a recent study, Su (2017) drew on the phenomenon of economic globalization to investigate the interdependency between R&D global partners, pointing to the relevance of international partnerships, which would increase the creation and flow of knowledge, along with the expansion of potential applications of the developed technologies.

Mitze *et al.* (2015) conducted a survey in Germany to measure R&D performance in small and medium companies; they concluded that the most important R&D performance indicators are higher in organizations that make collaborative efforts, in comparison to those that do not conduct them. Spanos *et al.* (2015) also used surveys to investigate the impact of R&D partnerships funded by governments on the innovation of products and processes, as well as on the inimitability of technologies; they concluded that companies that cooperate show a better performance. Masum *et al.* (2013) suggest ten rules that should be applied for the effective execution of collaborative R&D and open innovation, suggesting that such efforts can help minimize the two main problems of technological development: the complexity and high costs of applying scientific developments to produce changes and social advances. According to the literature review, globalization is one of the big reasons collaborations have become more important and attractive, especially since the culture of foreign direct investment intensified, as of the 1990s (Su, 2017).

Regardless of the advantages that literature associates with collaborations, one of the major challenges is the correct identification and selection of partners (Geum *et al.*, 2013), and there is evidence that partnerships between private companies and universities have the highest potential to achieve good results (Mitze *et al.*, 2015). As for the information used in studies of collaborative networks, bibliographic data (Geum *et al.*, 2013) and patent data (Crespo *et al.*, 2015; Mitze *et al.*, 2015; Su, 2017) prevail.

Although still not as plentiful as abroad, Brazilian studies on collaborative networks and on cooperation in R&D activities are growing in national literature. Alonso-Arroyo *et al.* (2016) conducted a survey to analyze research collaborations between Brazilian and Spanish institutions in the medical sector, through bibliometric analysis. They concluded that the amount spent on collaborative research as well as the number of collaborations have increased significantly in Brazil, either through partnerships with European and Latin American countries or with the USA. Another study used SNA to investigate scientific cooperation in nanotechnology in the agricultural sector, and observed a strong integration between Brazilian researchers in this area (Campos *et al.*, 2017).

A study leaded by de Sousa *et al.* (2015) observed that R&D collaborations improve the flow of knowledge which positively influence the performance of Brazilian industrial firms as well as the rate of success in product innovation. They further expanded the analysis and concluded that collaborative efforts between private companies and public sector organizations bring economic benefits by stimulating the country's growth and improving the performance of the national innovation system. Gomes Costa *et al.* (2018) examined the curricula of researchers, between 1980 and 2010, to investigate scientific collaborations in biotechnology in Northeastern Brazil. They observed the formation of some collaboration clusters (based on geographic proximity and laboratory infrastructure), although with a stronger emphasis on intra-institutional partnerships.

The literature on R&D collaborative networks in biotechnology shows that all the advantages of cooperation mentioned before apply to this sector. In addition, owing to their own features, collaborations for scientific and technological development in this field have an even more relevant role as they focus on knowledge and innovation; therefore, companies that make alliances for technological development are more likely to get patents (Al-Laham *et al.*, 2011).

Regarding intellectual property policies, Stevens *et al.* (2016) noticed that there is a strong trend in the biotechnology sector to use public–private partnerships (PPPs) to develop better therapies. Chen and Lin (2016) concluded that biotechnology companies should maintain partnerships with universities to increase their innovation capabilities and improve the marketing of new products. After examining potential trading strategies for biotechnology products, Fernald *et al.* (2015) mention three types of collaborations used in this sector:

(1) informal interactions and knowledge transfer within clusters;
(2) intellectual property licensing and collaboration agreements; and
(3) acquisition of small companies that hold intellectual property.

Other studies restate the advantages of collaborative efforts for this sector. Such collaborations would be advantageous for companies by bringing faster advances to technological development (Eslami *et al.*, 2013), by providing start-up companies with the necessary expertise to market their products (Fernald *et al.*, 2015) and by facilitating the transfer and absorption of skills that result in innovations and new products (Al-Laham *et al.*, 2011).

Collaborations are important for biotechnology owing to the multidisciplinary profile of this sector: they involve multiple institutions of different kinds (Powell *et al.*, 1999); they facilitate the flow of information between the participating organizations (Hazir and Autant-Bernard, 2014); and they allow access to external knowledge, which is an efficient way to achieve strategic competitiveness (Al-Laham *et al.*, 2011). In addition, collaborations in biotechnology result in better products, more innovation and lower risk of development (Kamuriwo and Baden-Fuller, 2016) and the increase in knowledge flow from cooperation efforts may be an advantage for companies of this and other high-tech sectors (D'Amore *et al.*, 2013).

2.2 Social networks analysis related to cooperation studies

SNA is considered an appropriate method to view the relationships between network participants, and has gained relevance in scientific articles (Su, 2017), with applications in several cases (Chen and Lin, 2016; D'Amore *et al.*, 2013; Schiffauerova and Beaudry, 2012). In SNA, the network is a non-linear, decentralized, flexible, dynamic structure, with undefined boundaries, self-organizing, established through horizontal relations of cooperation (Borgatti and Halgin, 2011; Tomaél *et al.*, 2006). Nodes, also called actors, spots or vertices, are the discrete units that connect to each other through their intrinsic attributes, previously defined by the researcher. Their study stems from the analysis of the relationship between these nodes, also called a link or arch. Such relationships can be divided into directed, where actors either transmit or receive connections, and nondirected, where they carry out the two functions simultaneously.

Among the studies that investigated the results of R&D&I through network analysis, two main areas of application stand out. One aimed at understanding how networks can affect economic activity, such as R&D and patenting in an industry; and the other focused on the ability to reveal the process of networks formation and their influence on a particular topic. Cantner and Graf (2006) applied SNA to describe the evolution of the innovation network in Germany between 1995 and 2001; Owen *et al.* (2012) focused on R&D cooperation by comparing the organization of scientific research in the USA and Europe through network analysis.

A second set of papers shows the use of SNA to study the relationship between common academic inventors in patenting processes, with a focus on different technological categories (Balconi, *et al.*, 2004). Paci and Batteta (2003) investigated localized transfer of knowledge and examined technological networks represented by patent citation flows in different sectors. Studies on collaboration networks seek to explain the performance of individual actors by using the attributes of the network where they take part, by describing the structures of the collaboration network or even justifying the network's development and dynamics (Van Der Valk and Gijsbers, 2010).

Bazzo (2010) analyzed technological cooperation that resulted in patents in Brazil and found that subsidiaries of foreign firms, universities and research institutes exhibit a low sharing of patent ownership; that is, they do little cooperation, which is an indication of the institutional fragility of local innovation. The number of publications and patents in common is a very important indicator for measuring innovation activities and knowledge interaction between actors (Inzelt, 2004). A recent study, also using patent data, carried out a dynamic comparative analysis of interorganizational innovation networks of Brazilian and Spanish biotechnology companies, and used SNA to design and measure network attributes (Gomes *et al.*, 2017) . Results showed an impressive growth of innovation networks in the two countries, but Brazil had a lower rank in terms of frequency, volume of partnerships, diversity of partners and the main types of actors.

Patent data are one of the key indicators used by researchers to evaluate R&D&I results (Jaffe and Trajtenberg, 2002; Trajtenberg, 1990). Although they are not perfect indicators (Dosi, 1982), they are a significant factor of income generation from technologies, especially in industries that require large R&D investments, such as the chemical–pharmaceutical, responsible for launching active agents and formulations, and the biotechnology. Patent analysis provides key information to executives in charge of research and development, technological policies or technological strategy in a company (von Wartburg, Teichert and Rost, 2005; Yoon and Park, 2004), especially in the biotechnology sector.

Along with information technology, this is the fastest growing industry in the twenty-first century (Gartland *et al.*, 2013). Global market was estimated at US$369.62 billion in 2016 and is expected to reach US$727.1 billion in 2025, mainly owing to the establishment of partnerships (Grand View Research, 2017). The largest segment of the biotechnology market is healthcare and medical applications, accounting for 66.2 per cent of the total market value (Soh and Subramanian, 2014). With the increasing importance of this sector and large R&D investments and efforts worldwide, it becomes critical to ensure appropriate protection for the new and revolutionary technologies (Gupta and Subbaram, 1992; Karki and Garg, 1993).

3. Methodology

The study is an exploratory–descriptive research of qualitative and quantitative nature, regarded the analysis of patent databases in biotechnology, especially the use of plants (and their derivatives) for the formulation of drugs and cosmetics. As an indicator of technological production, we used the patentometrics technique, associated with the analysis of co-ownership of patents filed primarily in Brazil. With this study, we expect to present an overview of the patent scenario in a segment of biotechnology, as well as to understand how institutions established partnerships that resulted in patent filings. Next, we present the topic of the research; how we accessed, collected and analyzed the patent database; and finally, how we used the SNA approach to study cooperation between institutions.

In the last decades, great expectations emerged regarding potential developments in biotechnology. Brazil has been following this process and has systematically implemented policies for its evolution. Among the most relevant aspects of these policies are the support of new companies and the growth of the business sector devoted to biotechnology (Bianchi, 2013). The mastery and use of modern biotechnology require access to advanced technologies that are already available in developed countries; in Brazil, these are located in regions where academic, technological and business development are strongly concentrated, such as Southeast and South regions (Gomes Costa *et al.*, 2018). Thus, this shows the critical importance of establishing partnerships.

The rich Brazilian biodiversity is one of the most important global sources for the development of phytocosmetics and drugs that contain active principles of plant origin. The cosmetics sector benefits from it and has gained prominence in recent years. Cosmetic preparations with natural raw materials grow at considerable annual rates in the international market, between 8 and 25 per cent above the observed growth rates among products formulated with synthetic ingredients. Owing to the wide diversity of chemical derivatives from plant extracts, which have different actions, a major effort is taking place to generate investments in research and development for the discovery of new drugs containing natural ingredients. About 30 per cent of the available drugs derive directly or indirectly from natural products, mostly from plants. In diseases like cancer, the use of drugs derived from plants is even higher, reaching 60 per cent (Boldi, 2004; Newman *et al.*, 2002).

Although Brazil has a huge biodiversity, it has not been able to develop a significant amount of innovative products. The local industry of herbal drugs holds a technical capacity and is willing to invest in new products; however, it has faced practical difficulties that obstruct and sometimes render impossible the realization of its projects (ABIFINA, 2011). Hence, it is extremely important that the country keeps investing in the sector, and to do this, it is necessary to join experiences and share knowledge through institutional partnerships.

3.1 Patent database

We selected the technological area by using the International Patent Classification (IPC) code A61K 36/00, which addresses "Medical preparations of indeterminate constitution containing material from algae, lichens, fungi or plants, or their derivatives". These include all subgroups, except codes A61K 36/02 to A61K 36/09, which deal with drugs that contain materials derived from algae, fungi and lichens (WIPO, 2017). We extracted the patent database from Derwent Innovation database, of Clarivate Analytics, by searching patents using the field "IPC Current", for all IPCs previously described, along with the field "Publication year", between 1995 and 2014.

Next, we used the subfilter for adding the country "Brazil" to the field "Priority Country". Altogether, we examined 191 IPCs' classes and subclasses, totaling 225,327 International Patent Documentation (INPADOCs), of which 466 were object of the research. We selected all INPADOCs' families resulting from the search and exported them in a Microsoft Excel file, to create the patent database. Due to the 18-month confidentiality period, we decided not to include the years 2015 and 2016 as most of the patents of this period have incomplete information.

3.2 Document analysis and data preparation

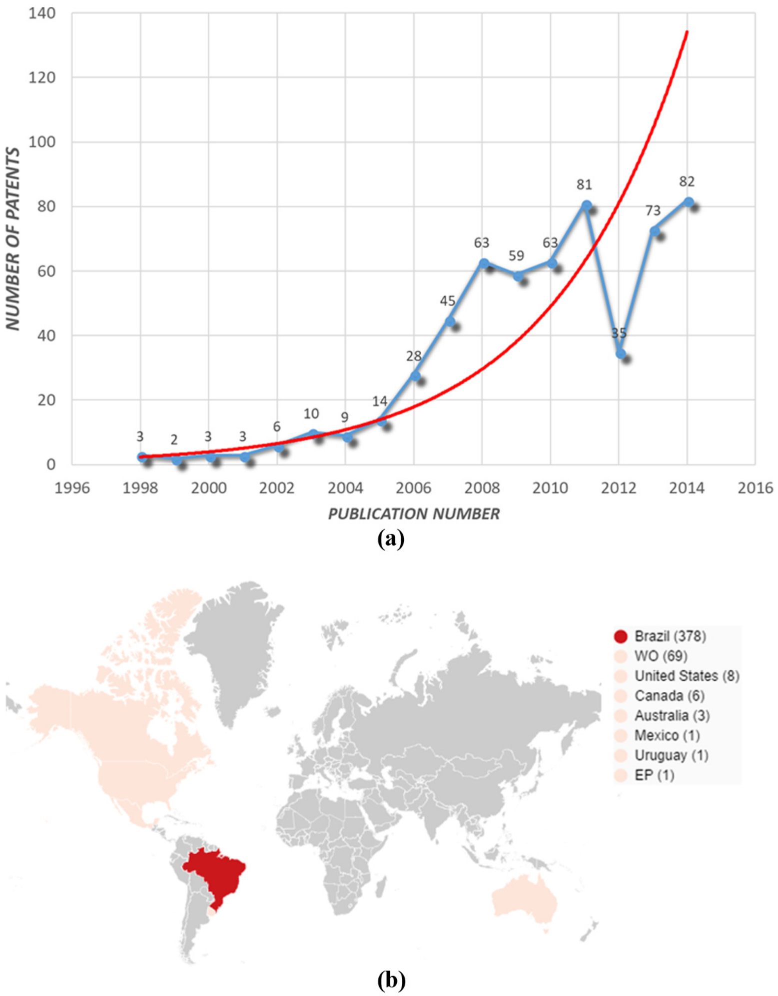
Information on patent number, country code for technology protection, inventors, holders (assignees), date of publication and filing of patents and technology areas (IPCs) were collected for further comprehensive analysis of the documents and graphic design. We standardized the names of all patent holders using the *OpenRefine* freeware tool (openrefine.org), to generate the collaboration networks.

3.3 Social network analysis

We carried out the building and analysis of cooperation networks according to the method and protocol described by Pereira and Porto (2018) and Pereira *et al.* (2018) and their adaptations. Briefly, information of assignees and code of all patents, represented by INPADOCs, were grouped in an Excel spreadsheet. The presence of co-owners in the "Assignee" field indicates partnership relationships, and as peers share more patents between them, higher is the weight given to the link between holders. We uploaded data on patent code and owners to freeware *Gephi* (www.gephi.org). To analyze data, we created a bipartite network, containing a spreadsheet of nodes (patents and holders) and a spreadsheet of edges (patents related to their owners). In the global network, nodes' sizes were adjusted according to their degree, and the color according to their category (patents in blue and owners in red). The holders' network was created by using the plug-in *Multimode Networks Transformation* (https://github.com/jaroslav-kuchar/Multimode-Networks), which eliminated patent nodes and turned them into a criterion of link between holders. Standard statistical measures available in Gephi were used, such as modularity (Blondel *et al.*, 2008), average degree, weighted average degree and centrality. The network of the largest holders was extracted from the global network through the "ego network" filter, following the node's ID command.

4. Results and discussion

The study addressed the analysis of technological collaboration networks that resulted in patents in biotechnology related to drugs and cosmetics containing products of plant origin and their derivatives (IPC classes A61K 36/10 to IPC A61K 36/9068), whose invention has Brazil as the priority country, that is, the first country where patents were filed. Altogether, we found 742 documents, of which 466 INPADOCs (patent families), that is, distinct inventions that were first filed in Brazil. The trend line shows that since 2006, there has been an exponential growth in the number of patent publications in this topic in Brazil [Figure 1(a)] .



Notes: (a) Rising trend curve of the number of patent publications over 20 years; (b) global coverage of patent documents deposited primarily in Brazil. A total of 466 patent documents (INPADOCs) were analyzed according to the country code of where the patent was deposited or granted

Figure 1. Evolution of the publication and geographic coverage of patents priority filed in Brazil in the period 1995 to 2014 in the sector of medicinal preparations containing products of plant origin and their derivatives

This considerable increase in the number of patents may reflect the National Policy for Medicinal Plants and Phytotherapics, approved by Decree No. 5,813, of June 22, 2006. This policy favors the safe access to these plants and their rational use in Brazil, with the development of technologies and innovations, as well as the strengthening of chains and productive arrangements, for the sustainable use of Brazilian biodiversity and the growth of the Healthcare Productive Complex (Ministério da Saúde, 2006).

We also examined the inventions with regard to the coverage of countries where patents were filed or granted, after the first request in Brazil. Results showed that of the 466 INPADOCs, 378 applied for protection only in Brazil, 69 were filed internationally through Patent Cooperation Treaty (PCT) and 8 were filed in the USA. Requests for protection at the Canadian and Australian offices followed, with six and three inventions, respectively [Figure 1(b)]. It is worth noting that although Brazil has several native plants with technological potential, shown by patent requests, most of them are still filed only by foreign companies (Moreira *et al.*, 2006).

Among the technological areas represented by IPCs, which classify inventions, we highlight the top 10 IPC codes [Figure 2(a)]. The two most frequent, with 68 documents each, were A61K 8/97 (cosmetics or similar preparations for personal hygiene characterized by a composition containing materials or their derivatives of unknown plant origin constitution, such as plant extracts) and A61K 36/185 (medicinal preparations containing materials of undetermined constituents derived from dicotyledonous plants). In sequence, with 66 documents, comes IPC A61K 36/28 (medicinal preparations containing materials of undetermined constituents derived from *Asteraceae* or *compositae* plants – family of the aster or sunflower – like chamomile, tansy, Aquileia or Echinacea) and IPC A61K 36/48 (medicinal preparations containing materials of undetermined constituents derived from *Fabaceae* or *leguminosae* plants – pea and legumes) [Figure 2(a)]. Plants of the family *Asteraceae* and *Fabaceae* are the most diverse in number of species found in the country (Giulietti *et al.*, 2005), which justifies the higher number of patents in these specific classes.

Among patent holders, we found 51 universities, with 200 documents (with proprietary technology or in collaboration). On the other hand, we identified 56 companies as assignees of 100 patents. These results show that although the number of universities is smaller than the number of companies, they have twice the potential to generate technologies (represented by patents) in this sector. Another fact that confirms this finding is the

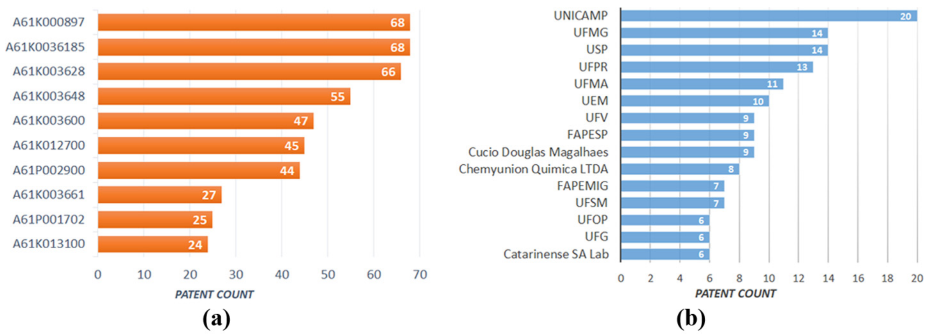


Figure 2.
The top ten most frequent technological areas and the top 15 largest assignees in relation to the number of INPADOCs

Notes: (a) The top 10 Classes of IPCs (subgroups of IPCS) most frequently found in patents analyzed; (b) top 15 largest patent holders in quantity of INPADOCs for the sector of medicines and cosmetics containing products of vegetal origin and their derivatives presence of public universities among the seven largest patent holders [Figure 2(b)]. On this issue, Soh and Subramanian (2014) argue that collaborative R&D efforts in biotechnology are extremely important because universities and research centers are those that develop more technologies in this area. In Brazil, companies are much dependent on knowledge generated by universities, which are their main partners (Gomes *et al.*, 2017). The use of knowledge produced at Science and Technology Institutions (ICTs) represents a rich source of information and qualification for the development of new technologies; once transferred to the manufacturing sector, they promote an alternative and complementary path for companies to reach a higher technological level (Garnica and Torkomian, 2009).

In a list of the top 15 patent holder institutions, the first is University of Campinas (UNICAMP) with 20 filings. Next come the Federal University of Minas (UFMG, Gerais) and University of São Paulo USP) with 14 patents each, UFPR (Federal University of Paraná) in the third place with 13 documents, fourth is the Federal University of Maranhão (UFMA) with 10 and in the fifth place is UEM (State University of Maringá), with nine documents. Among the 15 largest holders, 10 are universities, two are Research Support Agencies (FAPs), two are private companies and one is an individual. It is important to highlight the presence of individuals or inventors as patent holders. Altogether, we found 353 different individuals, either with proprietary technology or as co-owners. Buttow and Steindel (2012) analyzed patent filing in subclass C12N (also related to biotechnology) in Brazil and found that the four largest holders present in our research were the main requesters in the period 2001-2005, showing that these institutions are still operationally relevant.

The network, which shows the connections between patent holders and the patents they share, is called a bipartite network, where two different categories of nodes are displayed (Figure 3). Blue nodes represent the patents and red nodes the holders. The relationship between them is established according to the information of co-ownership in the patent document. The bipartite network has 225 connected components, with a value diameter equal to 13, and average degree equal to the weighted average degree of 1,627; that is, in this network, the holder relates to the same patent only once (that is why the edges have a weight equal to 1). In addition, we identified the node of higher centrality of the eigenvector type – UNICAMP –, as the node of greatest influence in the network, owing to its connections.

The technology collaboration network between the holders emerged from the general network, through the application of the multimode networks transformations plugin, available in Gephi (Figure 4). In this case, the network only shows the connections between the holders (nodes), represented by the patents in partnership and the number of patents they share, which is an element that affects the weight of the edge (edge thickness) that connects the nodes. In this case, the collaboration network has 477 nodes (or holders), among which are companies (56), governmental institutions (17), universities (51) and inventors registered as holders (353). The technological cooperation network has 222 components, with a value diameter equal to 6, average degree of 3.11 and a weighted average degree of 3.417, showing that partnership relationships are still scarce. UNICAMP stands out as the institution with the highest number of connections (45), greater centrality of intermediation and greater centrality of the eigenvector type, assuming the role of the holder that most builds partnerships among Brazilian institutions. UNICAMP was previously cited as the second largest requester of medicinal plants, specifically the use of andiroba, only behind Fiocruz (Amaral and Fierro, 2013).

Although UNICAMP is the institution with the largest number of cooperation agreements, these have resulted, at most, in two patents with the same partner; this means that cooperation relationships are not persistent and lasting, and the institution is not

Nodes	943
Edges	767
Average Degree	1.627
Weighted Average Degree	1.627
Network Diameter	13
Graph's density	0.002
Connected Components	225
Node with higher centrality	UNICAMP

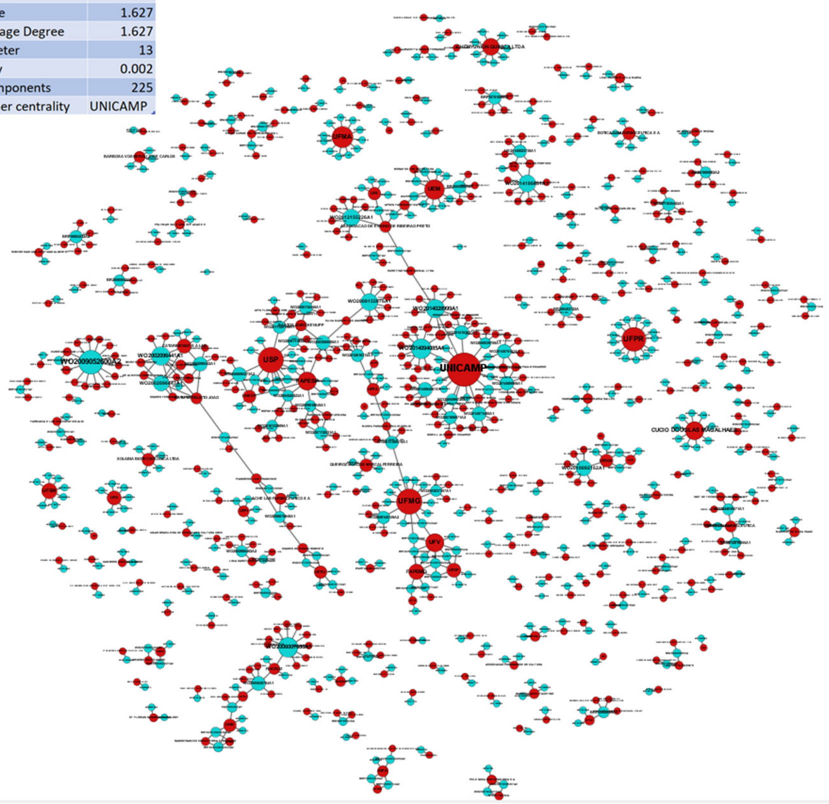


Figure 3.
Global bipartite network of interactions among patents and its assignees. The knots in blue are patents and their holders are in red

present on the list of cooperative relationships that most resulted in patent filings (Table I). In this respect, it is worth emphasizing that there is indeed a gain in strategic competitiveness by using collaboration, but there is a limit to that gain, and companies must be careful when establishing partnerships to avoid an excessive number of alliances that could undermine their innovative capacities, rather than help them (Fernald *et al.*, 2015).

Among the collaborations with greater sharing of patent ownership, we highlight the Federal University of Viçosa (UFV) with FAPEMIG (Research Support Agency of the State of Minas Gerais), and USP with FAPESP (Research Support Agency of the State of São Paulo), and these collaborations yielded five patents to each institution. This shows the important role of these state agencies for the incentive and strengthening of research and technological development in Brazil. There are also significant partnerships between universities of the same state, such as UFV with Federal University of Ouro Preto (UFOP), in Minas Gerais, and USP with UNESP (São Paulo State University), which resulted in four and three patents, respectively (Table I).

For a better view of the collaboration networks between the institutions, we selected, from the general network of holders, the ego network with depth 2 (except UNICAMP) for the owners with the highest number of patents (Figure 5). UNICAMP's ego network had

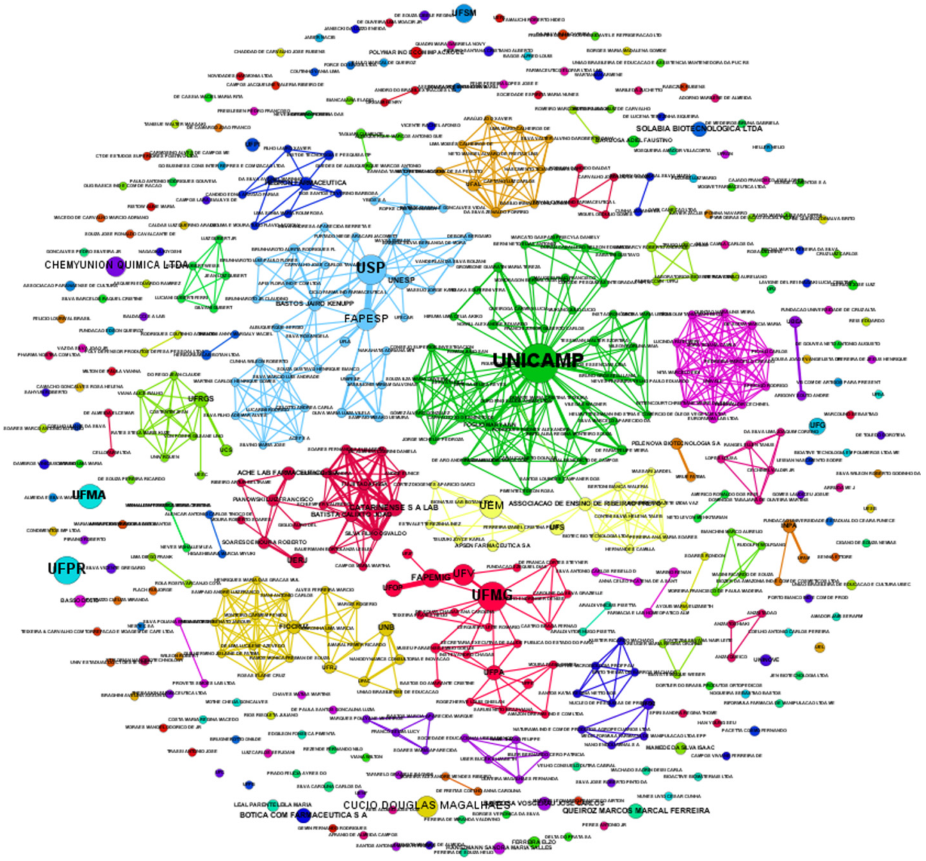


Figure 4.
Collaboration network among patent assignees for the sector of medicinal preparations containing products of plant origin and their derivatives, and that had inventions deposited first in Brazil

Table I.
Cooperation among assignees that produced the most patents for the sector of medicines and cosmetics containing material of plant origin and its derivatives

Assignee 1	Assignee 2	Patents in cooperation
UFV	FAPEMIG	5
USP	FAPESP	5
UFV	UFOP	4
UNICAMP	Foglio, Mary Ann	3
USP	UNESP	3
Catarinense S.A. Lab	Batista Calixto, João; Silva Filho, Osvaldo; Fujii, Tadafissa	3

depth 1 as the institution has partnerships with a series of other owners and many of them are individuals who, in turn, also have subsequent partnerships; in this case the ego network with depth 2, would be very large, which would hamper the analyses. We highlight that UNICAMP mainly cooperates with individuals, and these collaborations did not result in other patents (few edges with weight above 1).

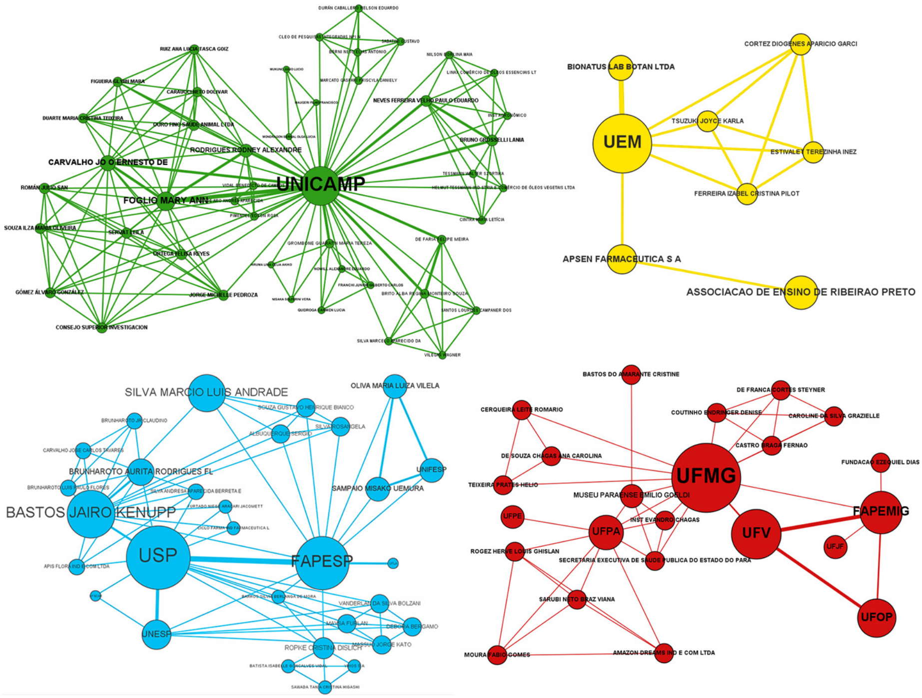


Figure 5.
Ego network of the collaboration among the largest assignees in quantity of patents for the sector of medicinal preparations containing products of plant origin and that had Brazil as a priority country

Yet, in the case of UEM, we observed that it has collaborations that resulted in more than one patent, with private institutions such as Bionatus and Apsen Pharmaceutical, indicating that these partnerships are lasting. In relation to USP's ego network, we observe a collaboration hub of this university with FAPESP (five patents) and UNESP (three patents), showing a strong connection between them. A recent study that examined patents from the twelve largest Brazilian universities showed the central role of FAPESP in promoting innovation, by interacting not only with universities located in the state of São Paulo, but also with UFMG (Fischer *et al.*, 2018). In our study, FAPESP showed a similar performance, with cooperative ties with the Federal University of Lavras, located in Minas Gerais.

UFMG's ego network shows the importance of partnerships between geographically close universities located in Minas Gerais, and the relevance of FAPEMIG actions to encourage research that results in innovation. There is also a strong cooperation between distant institutions, such as those in the State of Pará, with collaborations with Federal University of Pará (UFPA), Evandro Chagas Institute, State Secretariat of Public Health and Emilio Goeldi Museum, which shows a common interest of these ICTs toward medicinal preparations containing plant extracts. In a recent study, Gomes Costa *et al.* (2018) highlight the positive side of partnerships between Northeastern and Southeastern institutions to foster the development of biotechnology in that region, as they observed, through SNA, a strong interaction between UNICAMP and UFRGS with organizations in the Northeast.

Other holders stand out in patent number, but do not invest in technological development in cooperation with other institutions (Figure 6). These are UFPR (13 patents), UFMA (11), Federal University of Santa Maria (UFSM; seven), Chemyunion Química Ltda. (eight), Federal University of Goiás (UFG, six), Solábia Biotecnologia (five), Douglas Guimarães

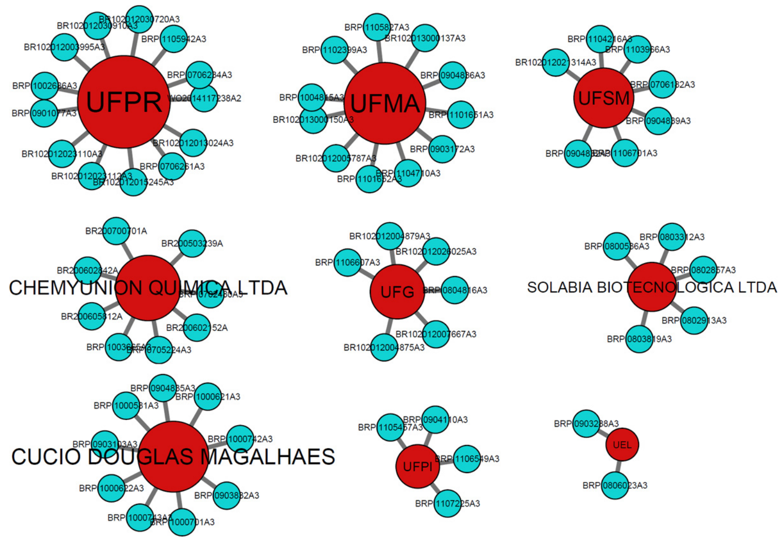


Figure 6. Components of the general (bipartite) network showing assignees with a reasonable number of patents, but who do not establish partnerships with other institutions in this sector

Cucio (inventor with nine patents), UFPI (Federal University of Piauí; four patents) and UEL (Londrina State University; two). These demonstrate that non-participation in collaborative projects that result in technological development is widespread in the country, and not concentrated in regions where research incentives are scarce; and it is an attitude found in both public and private sectors.

5. Conclusion and future perspectives

This study analyzed collaboration networks between institutions that produced patents in a specific sector of biotechnology, and had Brazil as the priority country. Technologies protected by patents regarding medicinal preparations containing plant materials have a high worldwide interest. With more than 200,000 inventions around the world, Brazil has only 466 patent families as the priority country, that is, inventions that were first filed in Brazil, at INPI (National Institute of Industrial Property). The study highlights the importance of cooperative relationships and the advantage of using SNA to better view these ties between actors.

Universities and FAPs are the key drivers of innovation in Brazil, whose actions are seen through the higher number of patent filings and the interactions they establish. However, national participation in innovation in biotechnology is still low, although investments have been a priority of the national policy for science, technology and innovation for more than a decade and the country's basic science is significant in this area. We conclude that basic science and technology development in biotechnology still lack knowledge transfer that corresponds to the efforts made.

The study has important empirical implications, mainly regarding the urgent need to establish partnerships to create technological solutions that are relevant not only locally, but also for the international market, through decisions that foster the participation of foreign companies in projects developed in Brazil. In addition, we noticed that applied knowledge for the creation of new technologies comes mainly from public universities. Hence, universities must spread this knowledge back to industry, through improved education and qualification of human capital concerned with technology transfer activities (Fischer *et al.*, 2018). In addition, there are institutions that develop technology separately, but still have a high capacity of innovation, proved by the number of patent requests. These institutions could better use their skills by establishing cooperation with other organizations to promote their innovative efforts and drive new discoveries in the area.

One limitation regards the restricted field that we chose to examine. Although biotechnology related to herbal medicine has an extensive knowledge and technical capacity, the study addressed only part of what the country produces in this sector. Therefore, it is necessary to extend the study to other sectors. In addition, future research should include the analysis of the collaborations of Brazilian institutions with the global market, and investigate if the technologies protected primarily in the country attract the interest of international institutions. Another study proposal that emerges from our results is to check which of the Brazilian institutions that we studied take part in the routes of technology trends.

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About the authors

Cristiano Gonçalves Pereira is a Bachelor of Science, Masters and PhD in Molecular and Cell Biology. He is a former postdoc in innovation management from the University of Sao Paulo/FEARP. Pereira was a visiting scholar at the University of Texas/MD Anderson Cancer Center and at Portland State University in the ETM Department. He is specialized in innovation management, patent analysis, social network analysis and technology forecasting toward health-care biotechnology. Pereira also develop studies involving the combination of patent assessment and multi-criteria decision making to identify emerging technologies in biotech. Cristiano Goncalves Pereira is the corresponding author and can be contacted at: cristianogp@usp.br

Rodrigo Ribeiro da Silva is a Bachelor in Biomedicine at the Federal University of Triangulo Mineiro, Brazil. A Masters and PhD in cell and molecular biology at Ribeirão Preto Medical School, University of Sao Paulo, Brazil, Ribeiro de Silva is a former visiting PhD Student at the University of Oxford, Ludwig Institute for Cancer Research, UK. "He has knowledge related to Intellectual Property, Technology Forecasting tools, management and product innovation, and R&D Management".

Joao R. Lavoie is a PhD candidate at the Engineering and Technology Management Department – Portland State University, Portland, Oregon. He has a graduate certificate in Energy Policy and Management, from Portland State University, and a B.S. in Industrial Engineering from UNICEP University, in Sao Carlos, Brazil. He is a Research Assistant in Dr. Tugrul Daim's group and works with the Bonneville Power Administration (BPA) Technology Innovation group. His research areas are technology transfer, roadmapping and technology readiness levels. He is a member of Phi Kappa Phi and Omega Rho Honor Societies, and is part of the PICMET Conference Organizing Committee.

Geciane Silveira Porto is Bachelor of Business, Masters and PhD in business administration, who is currently an Associated Professor at the University of São Paulo/FEARP and a Researcher at the Institute of Advances Studies/USP. She has extensive experience in innovation and entrepreneurship management, with topics related to company–university cooperation and cooperation networks; analysis of technological trends and forecasting of emerging technologies through social network analysis; Innovation Habitat's, incubators and technology parks. She is a former President at FIPASE (The Foundation Institute Advanced Pole of Health of Ribeirão Preto), former invited researcher at Institute for Applied Economic Research (IPEA), former Director of INCT-if (Pharmaceutical Innovation) and currently a Director of INGTEC. She is a fellow researcher producer at National Council for Scientific and Technological Development (CNPq), and she integrates the NAP-EBC (Low Carbon Economy).