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Innovation Capabilities in an Inter-Organizational Network in Brazilian Amazon

Capacidade de Inovação em Rede Interorganizacional na Amazônia Brasileira

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Resumo

O artigo analisa as capacidades de inovação em uma rede interorganizacional para o estabelecimento de negócios baseados em biotecnologia aplicada a ativos da biodiversidade na Amazônia brasileira. Trata-se de um estudo de caso de uma rede de inovação para o desenvolvimento e comercialização de uma linha de compostos antioxidantes de um fruto regional - o açaí (*Euterpe oleracea*) -, no estado do Pará. A rede é formada por uma universidade pública, uma pequena empresa de base tecnológica que desenvolve produtos de alto valor agregado baseado na biodiversidade e uma agroindústria de processamento e comercialização de produtos frutíferos da região amazônica. O artigo mostra que a articulação em uma rede interorganizacional é capaz de congregar capacidades necessárias ao processo de inovação que individualmente as organizações locais não teriam condições de desenvolver. No caso estudado, essa concatenação de capacidades possibilitou a exploração de uma oportunidade biotecnológica no âmbito da cadeia produtiva do açaí com a criação de uma linha de produtos competitivos. Entretanto, limitações quanto à apropriabilidade da inovação são entraves à efetiva exploração econômica da linha de produtos pelas organizações inovadoras no formato interorganizacional.

Palavras-chave: Inovação; Capacidade de Inovação; Biotecnologia; Rede Interorganizacional; Amazônia.

Abstract

This article analyzes innovation capabilities in an inter-organizational network for businesses based on biotechnology applied on biodiversity assets in the Brazilian Amazon. It is a case study about an innovation network for development and commercialization of an antioxidant compounds line of a local fruit called açai (Euterpe oleracea) in the state of Pará. The network is formed by a public university, a small technology-based company that develops high value-added products based on biodiversity, and an agribusiness company that processes, markets, and distributes products made from fruits of the Amazon region. The study shows that the capabilities found in an inter-organizational network produce innovation processes that the network's members would not be able to develop alone. In the case researched, the network connecting the organizations' capabilities enabled the exploration of biotechnological opportunities within the açaí production chain by creating competitive products. However, limitations linked to innovation appropriability prevent those innovative organizations, operating as an inter-organizational network, economically explore this product line.

Keywords: Innovation; Innovation Capability; Biotechnology; Inter-organizational Network; Amazon.

JEL Code: O3, L73, D85.

Introduction

This article analyzes the innovation capabilities of an inter-organizational network formed by a public university, a small technology-based company, and an agribusiness firm operating in the Amazon region (specifically in the Brazilian state of Pará), to establish a biotechnology-based enterprise applied to assets of regional biodiversity. A case study was conducted examining an inter-organizational network of innovation that aimed to develop and commercialize a product line based on antioxidant compounds produced with açaí (*Euterpe oleracea*), an asset of the Amazon biodiversity, that focuses on cosmetics and functional food industries.

Brazil is one of the 17 countries with biological megadiversity, taking into account the representativeness and endemic aspects of the number of species in the country in comparison to the biological diversity found in the rest of the world (Ministério do Meio Ambiente, 1999). The Brazilian Amazon is the largest biome in the country and covers around 40% of the remaining forests of the humid tropics, is recognized by its role of maintaining biodiversity, regional hydrology, and climate (Laurance et al., 2001). Therefore, biodiversity and environmental services represent a potential for natural capital for business, employment, opportunities of work, and income generation. Innovations based on biotechnology can provide added value and sustainable use of biodiversity to build processes that are more economically dynamic and socio-environmentally inclusive.

Biotechnology emerged in the 1970s by the convergence of the sciences of molecular biology, chemistry, and genetics, together with technological advances that may involve different levels of technological intensity and multiple application areas (Albagli, 1998; Rocha, 2016). Biotechnology has been seen as a market opportunity for the development of innovative services and products, for example with new pharmaceutical research and improved agricultural productivity, at the same time being useful for biodiversity conservation (Centro de Gestão e Estudos Estratégicos [CGEE], 2006; Corlett, 2017). In addition, there are debates on ambiguities between biotechnological development and the sustainable use of biodiversity, discussing ethical issues, socio-environmental risks, and possible conflicts between the countries and actors who have the biotechnological capabilities, and those having high biodiversity or traditional knowledge about biodiversity (Albagli, 1998; Cunha & Melo, 2005; Rocha, 2016).

This article observes the divergence existing in territories where there is prominent biodiversity, but organizations with incipient biotechnological innovation capacities, such as in the case of the Amazon. We understand that the development of sustainable innovations in the biotechnology segment in the Amazon region meets the propositions of business models based on a scientific-technological revolution, as advocated at the 4th National Conference on Science, Technology, and Innovation. These business models would enable producing in the region while emphasizing biodiversity production chains that guarantee, simultaneously, the emergence of innovation, and the local development (Becker & Egler, 2010; Centro de Gestão e Estudos Estratégicos [CGEE], 2010). However, despite the existence of the biotechnological opportunity, the effective use of this potential in the region has still not been identified (Enríquez, 2007).

Against this backdrop, it is essential to analyze the capabilities needed for biotechnological innovation in organizations in the Amazon. The focus of the research is on the technological and complementary capabilities observed in a local inter-organizational network. We aim to shed light on the capabilities (or lack of them) for innovation in local organizations and their effectiveness in generating and profiting from innovative processes. Also, the work examines the possibilities and limits of the coordination of these capabilities through the inter-organizational network as an arrangement that enables local abilities, and that is often used in the biotechnology sector (Machado & Ipiranga, 2013; Cunha & Melo, 2005; Powell, Koput, & Smith-Doerr, 1996; Najafi-Tavani S., Najafi-Tavani Z., Naudé, Oghazi, & Zeynaloo, 2018).

As for the methodology adopted, the case study followed two interrelated directions of analysis. First, examining the capabilities shared by each organization within the network for the development and commercialization of innovation. Second, by verifying the influence of these capabilities regarding the necessary conditions for these organizations to profit from the innovative process. This approach was based on a study of multilevel processes related to the innovation capabilities of each organization and the capabilities they present when operating together, through the inter-organizational network.

The data collection and analysis were conducted in two phases: an exploratory phase with open and semi-structured interviews with representatives of two organizations members of the network (a public university and a small company in the process of technology incubation in this university). The other phase consisted of field visits and in-depth interviews with four representatives of the three organizations that form the inter-organizational network, and with two actors external to the network, who are professionals specialized in the topics related to the research (açaí production chain and promotion of science, technology, and innovation in the Amazon).

Innovation Capability

Miranda and Figueiredo (2010) and Bell and Figueiredo (2012) differentiate the lines of research on innovation capabilities. Studies to understand innovation and knowledge creation at the international technology level have been conducted, usually based on agendas set in advanced economies, which emphasize R&D activities and indicators of technology expansion, such as the number of patents registered. These studies emphasize debates on how companies develop the ability to integrate technological and organizational competencies and to support innovative practices in the face of already existing knowledge bases (Miranda & Figueiredo, 2010; Bell & Figueiredo, 2012).

However, these works do not adequately focus on how the first accumulation of technological knowledge used to build innovation capabilities occurs. This aspect is at the core of the typical problems of economies of late industrialization, such as in developing countries (Miranda & Figueiredo, 2010; Bell & Figueiredo, 2012). Thus, from the 1970s onwards, lines of research emerged to understand the engagement of companies in learning processes, as well as to examine the technological accumulation in developing countries. As for the latter, it is marked by the development of the ability to absorb and adapt technologies (therefore, based on the diffusion of technologies created externally), in order to carry out production in local conditions. In this perspective, external technology would support the development of the ability to create new technologies internally (Lall, 1992; Bell & Pavitt, 1993; Miranda & Figueiredo, 2010; Bell & Figueiredo, 2012).

Bell and Pavitt (1993) establish an essential distinction between technological innovation capabilities and production capacity. Production capacity consists on coordination of resources (equipment, systems, organizational processes and workers' skills) to produce goods or services within a certain level of efficiency based on a previously existing technology, which in the context of late industrialization had generally been developed externally (Bell & Pavitt, 1993; Bell, 2009). This type of capacity tends to represent the main effort of assimilation in companies operating in developing countries going through late industrialization. On the other hand, innovation capabilities encompass the development of resources such as skills, knowledge, roles, and organizational structures required to create new products or processes, through internal technological changes, catching up to create competitive advantages (Bell & Pavitt, 1993; Bell, 2009; Bell & Figueiredo, 2012).

Although these capabilities may be developed simultaneously (since the frontiers among them are diffuse and permeable and, in contexts of late economies, some firms show innovation capabilities since the moment they start to operate), Figueiredo (2017) stresses the importance of the distinction among innovation capabilities. For the author, the distinction allows an understanding that the innovation capabilities' development process occurs gradually, increasing in different levels of complexity. However, this is not an automatic or linear process, once it requires deliberate learning efforts and capability building in specific directions (Figueiredo, 2010; 2017).

Thus, innovation capability comprises a set of elements of technological dimension (human capital, knowledge intangible and tangible assets) and organizational dimension (functional arrangements, structure and strategies articulated in processes of specialization, differentiation, integration, and reconstruction of capabilities), coordinated in different levels of complexity regarding the performance of the innovative activities and in constant change due to the interaction with external elements (Bell, 2009; Bell & Figueiredo, 2012; Miranda & Figueiredo, 2010).

Teece (1986) explored a specific problem of capability-building in innovative processes when seeking to understand the failure of innovative firms to appropriate significant returns from innovation developed ahead of other actors (such as imitators, suppliers, customers). The author alerts to the need to coordinate different capacities related to innovation as a critical factor of competitiveness (Tecce, 1986; 2006). In addition to technological capabilities directly linked to the development of new products or processes, Teece (1986) highlighted the relevance of complementary capabilities or assets associated with innovation's production, distribution, and commercialization.

The analytical framework proposed by Teece (1986) combined characteristics of the appropriability regime (how difficult would it be to imitate the innovation, and the effectiveness of mechanisms to protect intellectual property) with the type and degree of dependency on complementary assets for the successful commercialization of innovation in the market. In this perspective, the author opened discussions with implications for both competition and cooperation innovation strategies developed by enterprises, and for national public policies to encourage innovation, with a focus on complementary assets and institutional conditions to distribute benefits (such as job and income generation), especially in a context of globalized markets.

Although the original discussion by Teece (1986) was based on a context of advanced economies, and the fact that the author later directed the research towards a dynamic approach to capabilities (Teece, Pisano, & Shuen, 1997; Teece, 2006), we understand that the notion of coordination of capabilities and the concept of complementary assets favor the analysis of strategies for the development of innovation capability, especially those anchored in inter-organizational relations and involving technology-based startups and small companies (Chesbrough, Birkinshaw, & Teubal, 2006). When analyzing the institutional and technological conditions of appropriability regimes, the concept of complementary assets reveals important elements to define strategies toward the firm's appropriation of profit in the absence of this specific assets (for instance, establishing when to develop internal capability, build inter-organizational partnerships, or acquiring a firm that has these assets). Also, the nuances of the strategies need to be observed against specific contexts.

In particular cases of developing countries, such as Brazil, characterized by a passive technological learning system (Viotti, 2015), the examination of the appropriability regime is critical because of the tendency of spurious competitiveness, and because of fragilities (or absences) in mechanisms to promote innovation that would be typical of the so-called national systems of innovation observed in countries of developed economy (Viotti, 2002).

Another contribution in the field of innovation capabilities refers to the interaction of the direction of the capability based on Pavitt's seminal proposal (1984) of a taxonomy of sectoral patterns of technical change. Pavitt (1984) and Bell and Pavitt (1993) analyzed different technological trajectories in firms that tended to develop specific innovative characteristics according to the economic sectors in which they operated, considering the nature of technological needs and uses, the sources of knowledge used, the means of appropriation of innovations, and other issues related to technological and economic criteria. The taxonomy developed by the authors contemplated five categories (Table 1):

Table 1

Synthesis of the Classification of Sectoral Patterns of Technical Changes

Sectoral Patterns	Characteristics
Supplier dominated	Supplier dominated firms are typical in traditional manufacture sectors such as textile and wood, artisans, and farming that work in smaller production scales and have low technological and engineering capacity. The development of technical change comes almost exclusively from suppliers of capital goods and other production supplies manufactured by industries outside the application sector. It is characterized as a process of diffusion of innovations and best practices focusing on incremental improvements and efficiency gain.
Scale intensive	Scale-intensive firms are generally large durable consumer goods industries, such as the automotive industry, and industrial materials businesses such as metallurgy. The technology is built up by the ability to design and construct components, equipment, and subsystems, as well as to assembly large complex systems with incremental development.
Information intensive	Information intensive firms represent sectors such as banks and large financial, advertising, and data processing companies. This category of technological accumulation has emerged from the development of the capacity to store, process, and transfer information through the design, assembly, and operation of complex information systems. Technical changes tend to be incremental, and the primary sources are suppliers of systems and experiences of large user firms.
Science-based	Science-based firms are typically in the chemical, electronics, and biotechnology sectors. The technological accumulation emerges from R&D activities in large industrial or technology-based companies, related to knowledge and technologies originated in academic research. The direction of technical change tends to apply a horizontal (within the industry) search for a broad set of new or technologically improved products based on scientific discoveries. The most relevant technological capabilities are reverse engineering, R&D, and design activities.
Specialized supplier	Specialized suppliers do not tend to be very large firms. They act in sectors such as mechanical engineering, instruments, and software for capital goods production, and assembly of complex systems. These firms benefit from interaction with advanced users with operational experience and accumulate knowledge in systems' requirements and designs, characterized by the complexity of processes and interdependency.

Note. Classification of sectoral patterns of technical changes proposed by Bell and Pavitt. Source: Adapted from Pavitt, K. (1984). Sectoral patterns of technical change: Towards a taxonomy and a theory. Research Policy, 13(6), 343-373. https://doi.org/10.1016/0048-7333(84)90018-0; and Bell, M., & Pavitt, K. (1993). Technological accumulation and industrial growth: Contrasts between developed and developing countries. Industrial and Corporate Change, 2(2), 157-210. https://doi.org/10.1093/icc/2.2.157.

When comparing the trajectories of intersectoral changes in developed and developing countries, Bell and Pavitt (1993) showed that although they recognize vast differences in the intensity and structure of technological accumulation among developing countries, they tend to have a history of industrialization based on supplier dominated sectors, through technology import strategies. This characteristic emphasized the development of production capacities, but neglected the technological capabilities for innovation, as a deliberate effort of endogenous technological accumulation.

In a study on the constitution of learning systems, Viotti (2015) compared Latin American and Asian countries, offering a complementary view on the evolution of technological accumulation in countries of late industrializations. The author argues that Latin American countries tended to establish passive technological learning systems in most of the economic sectors, focusing predominantly on production capacities, based initially on import substitution, in a context of spurious competitiveness with an emphasis on price and extensive and predatory use of natural resources. Asian countries, on the other hand, have implemented active learning systems aimed at building innovative capabilities, historically based on an export economy in more technologically dynamic sectors.

However, as emphasized by Possas (2003), the contribution of the taxonomy of sectoral patterns of technical change is not to merely provide criteria a priori for the different industrial sectors. The main contribution of these patterns is to suggest a set of variables to clarify the analysis on innovation dynamics in sectors, or even to understand a company's innovative performance and history (Possas, 2003; Archibugi, 2001).

The categories proposed have been used as a basis for research to identify critical aspects of innovative efforts, for example, in different organizational configurations, such as the research done by Jong and Marsili (2006) for small companies and new and different industrial and services sectors (Bogliacino & Pianta, 2016).

Archibugi (2001) points out that the taxonomy classifies typical profiles of technological behavior of companies in sectors, arguing that the classification should ideally be applied at the level of companies and not at the level of the sector, with aggregated data. The advantage of applying at the company level is because it allows highlighting the variety of inter-sectoral technical change patterns, as well as revealing intra-sectoral heterogeneities (Archibugi, 2001). For the author, using this approach, the taxonomy offers the possibility to recognize a substantial variety of innovative behaviors and to explore the interactions among these different behaviors through connections like user-producers and other inter-organizational relationships.

This observation about heterogeneities is relevant especially in developing countries, where there is a high variety in the levels and speed in the development of innovation capabilities among companies within the same industry (inter-firms) and different activities within the same company (intra-firms) (Bell & Figueiredo, 2012; Figueiredo, 2017). Also, the importance of interactions with external sources and inter-organizational arrangements for further advancement in the development of innovative performance results in emphasizing the role of the absorptive capacity. This role enables the learning processes in companies based on identification, communication, assimilation, and integration of internal and external knowledge (Bell & Figueiredo, 2012; Cohen & Levinthal, 1990; Lall, 1992; Najafi-Tavani et al., 2018).

Innovation in Biotechnology and Inter-Organizational Networks

For Powell, Koput, and Smith-Doerr (1996), the rise of rapidly developing technologies, such as biotechnology, has led to the creation of a complex knowledge base that is sophisticated and diffuse, at the same time. The speed and complexity of the biotechnological development requires a set of scientific and technological skills that generally exceed the capabilities of a single organization, not only regarding the intensity of the investments and research, but also for the diversity of sources of innovation needed (Powell et al., 1996; Cunha & Melo, 2005).

Different profiles of organizations are required to contribute to a process of innovation in biotechnology. In addition to private companies, there is a constant presence of research institutions, universities, and public and private laboratories, as well as non-profit organizations (Powell et al., 1996; Enríquez, 2003; Cunha & Melo, 2005). Therefore, Powell et al. (1996) argue that the development of biotechnology-based innovation occurs predominantly within networks of organizations.

According to Powell et al. (1996), this phenomenon occurs because biotechnology operates a process of technological change with different effects on the organizational competencies base. Biotechnology has caused changes in the knowledge and technological development trajectories that make up the process and product innovation capabilities. However, there is a tendency that skills and assets connected to commercialization and compliance with market regulations will be preserved (Pisano, 1990; Powell et al., 1996). Based on the work by Teece (1986), these assets can typically be characterized as complementary assets.

Therefore, although the technological change has favored the creation of many new biotechnology companies, including small and startup companies, it is not rare to observe alliances of these incoming enterprises with firms already consolidated in the market, which have complementary and mature assets of production, distribution, and commercialization (Chesbrough et al., 2006; Rothaermel & Hill, 2005; Rothaermel, 2001).

For Powell et al. (1996), inter-organizational networks for innovation are characterized by relationships associated with inter-organizational learning. In these networks the collaborations cannot be narrowly conceived to compensate for the lack of internal capabilities of the network's members, nor should these collaborations be seen as stagnated transactions. Inter-organizational collaborations for innovation would be fundamentally immersed in a network of social relationships where trust, reputation, and reciprocity are essential to promote effective knowledge and risk sharing (Powell et al., 1996; Cunha & Melo, 2005).

Innovation Network in the Açaí Production Chain

Açaí production chain in the state of Pará

The quality of açaí is related to a high energetic and nutritional value (proteins and minerals) with a high content of phenolic compounds, mainly anthocyanin, which are antioxidant compounds (Cohen, Oliveira, Chisté, Pallet, & Monte, 2006). These characteristics attract the interest of industries such as functional foods and nutraceuticals, cosmetics, and pharmaceuticals for technological innovations that allow aggregating such qualities in products of superior performance to those existing in the current consumer market.

The açaí productive chain has great economic and food security importance in the state of Pará (Oliveira & Tavares, 2016). In 2014, 5,930,780 kg of açaí pulp was exported for US$ 22,523 million, corresponding to 84% of the total export agricultural products of the Brazilian state of Pará (Oliveira & Tavares, 2016). Nogueira and Santana (2009) identified in research from 2004 to 2007 that the demand for açaí grew faster than the supply, as well as having an expressive seasonal pattern of fruit prices due to the harvest and off-season periods, which presents significant amplitude in the variation of the fruit supply.

In the metropolitan region of Belém, the capital of Pará, and also in the Northeast of the state, an industrial processing structure was established, in response to an increased product demand by the national and international markets. The processing structure was formed by firms larger than the small local businesses (called "*batedores*") that commercialize the açaí pulp for domestic and immediate consumption (Costa, 2009). The main reasons for the emergence of these agribusiness firms were the need to increase the scale of production and the use of phytosanitary processes (pasteurization and freezing) for the proper conservation of the product that is extremely perishable and subject to contamination.

Homma (2014) asserts that the increasing demand for açaí and rising prices in the domestic and international markets led the product's manufacturers to find ways to improve the product's placement in the market, and led producers to seek alternatives to increase production and productivity, with better planting techniques and improving the management of native areas that has guaranteed a minimum match between supply of raw material and demand for pulp.

However, according to Costa (2009) and Homma (2014), although this minimum compatibility between supply and demand enables sufficient profitability to expand the activity in the production chain, basic technological deficiencies are verified both in the rural and logistics phases of the production chain; or in its industrial design, due to the existence of a considerable idle processing capacity, as well as a very small capacity to absorb and produce innovations.

As for the rural production, Homma et al. (2006) and Tagore, Canto, and Vasconcellos Sobrinho (2018) express their concern about the extensive management of native açaí plantations in floodplain areas (Amazon ecosystem subject to regular flooding), as this practice would promote "green clearing" in riparian areas, i.e., the substitution of multi-culture by a monoculture of açaí in these areas. For these authors, the extent to which the monoculture of açaí crop in the floodplain has occurred may conceal severe consequences for flora and fauna in the mouth of the Amazon River in medium and long term.

In this way, Homma et al. (2006) point out the tendency of expansion of the açaí plantation towards the land areas, including its possible incorporation in agroforestry systems, not only in Pará or in the Amazon, but in other Brazilian states and also in other tropical regions worldwide, due to its economic valorization.

This medium- and long-term perspective of a high volume of production in other regions out of the state of Pará may be a threat to the local production chain, eliminating the comparative advantages on which the region's agroindustry is based, whose competitive industrial development presents many challenges to be overcome.

One of the main challenges is the need to expand the technological capacity of the industrial processing of açaí. We characterize the initial implementation of agribusiness firms as in a supplier-dominated pattern, adopting the classification of sectoral change by Bell and Pavitt (1993). This pattern indicates a low internal technological capacity of the companies for the accomplishment of technical changes and the existence of a dependence of innovations from other sectors.

Another critical challenge is to be able to add value to products through innovations, either by increasing their durability, diversifying applications and also the portfolio of the companies' product lines since most local agribusiness firms exclusively produce açaí pulp (Costa, 2009).

In addition, Costa (2009) warns about the lack of mechanisms for regulation, coordination, and promotion of vertical or horizontal cooperation (vertical meaning cooperation among links in the production chain; horizontal meaning cooperation among actors operating in the same link in the production chain). For Costa (2009), the implementation of these mechanisms could reduce the risks of predatory competition between agribusiness firms around raw material sources and consumer markets. At the same time, it would establish the basis for better interaction between the various actors (governments, industries, rural producers, Science, Technology & innovation) to articulate interdependent solutions using local investment arrangements, learning efforts, and collective efficiencies.

Inter-organizational network for innovation

The inter-organizational network studied in this research emerges in this context of the *açaí* production chain in Pará. At first, there is an interaction between the public university (from now on referred to as 'university') and a small technology-based company (from now on referred to as 'small company') to carry out research and development of an innovative product line. Later, the relationship expands with the participation of a regional agribusiness firm (referred to as 'firm'), which provides a better supply structure, and industrial production and commercialization scale.

The capabilities involved in the constitution of the inter-organizational network studied may be understood when knowing the technological history and innovation capabilities of each participant organizations, observing their individual contributions and limitations in the innovation process, as well as emphasizing the coordination among all capabilities within the inter-organizational network.

Scope of capacities of the public university

The university is headquartered in the state of Pará, and offers teaching, research, and extension activities in all areas of knowledge, acting in several campuses in different regions of the state. When it comes to promoting innovation, universities are characterized as bridging institutions of science, technology, and innovation (ST&I). In the case of the university studied here, its main operation strands are: (1) training qualified professionals, having a strong training role including through graduate programs; (2) developing scientific and technological research; and, (3) acting in incentive programs for innovation, using its infrastructure (as an incubator of technology-based companies) and partnership agreements.

Regarding the identification of capacities related to the biotechnology-based innovation process under analysis, the two university's units that had a preponderant involvement in the inter-organizational relations described here were:

- The unit with the faculty in the area of food engineering, responsible for the capability building of the small company's professionals involved in the innovative process and in the scientific and technological research; and,

- The unit responsible for managing the university's innovation policy, following the guidelines of the Núcleo of Inovação Tecnológica (center of technological innovation) (NIT) established by Law 10973/2004 ("Innovation Law", our translation), which coordinates activities to foster innovation, including the incubation of technology-based companies and management of the intellectual property.

Since 2000, the faculty of food engineering area has offered a specific undergraduate course, as well as a graduate program (since 2004) on engineering and food technology. The unit's website informs its commitment to prioritize the development of research projects on new technologies that add value to regional bioassets, in order to 'verticalize' food production by supporting the establishment, modernization, and expansion of local agroindustry. As for infrastructure, the unit is associated with pilot processing plants and operations, as well as having access to analysis and research laboratories.

The NIT unit comprises three main areas of action: (1) consultancy and technological services; (2) incubation of technology-based companies; and (3) intellectual property office, the participation of the latter two areas were predominant in the case studied.

In one of the interviews, the head of NIT indicates that support for biotechnology at the university can be divided into bioprospecting, knowledge protection, and technology transfer. The interviewee declared that, regarding bioprospecting, the university had the fundamental technological capabilities needed to develop in the region: "[...] we have established really strong centers in biology and chemistry, there is a great competence in [the university], and outside [the university] you find very little [competence]." (Interviewee 2).

However, the head of NIT acknowledges that there is still a great deal of effort to be made in the Amazon since only a small part of the regional biodiversity is registered. The interviewee mentions the importance of raising awareness that the use of biodiversity is still not well explored, since there is a need for substantial bioprospection in order to find assets that meet the products' economic and market requirements: "We have already worked with more than 5,000 biodiversity assets, and we now have 7 or 8 or 10 that are ready to go to the market." (Interviewee 2).

Interviewee 2 identifies that the interaction between the university and companies is essential since the productive sector plays an essential role in guiding and moving forward the bioprospecting activities. For the interviewee, the interaction between university and companies is the main bottleneck, as it is difficult to find local firms prepared to work with bioassets. Usually, the companies with this profile are small companies incubated in the NIT program.

It is possible to observe that the difficulty the interviewee pointed out is related to problems of institutional relations resulting from the history of the implementation of S&TI structure in Brazil, both on the part of science and technology institutions, where the predominant mindset is guided by the "offering" technology; and on the part of the firms, which present incipient capabilities of internal technological development (Viotti, 2002; 2015).

In general, we understand that the university has technological capabilities connected to the activities of basic and applied scientific research in knowledge bases in biotechnology and with a focus on the region's biodiversity. However, it is essential to point out the difficulties of the university to coordinate with the productive sector, which implies in two main limitations: (1) the lack of interaction in technological development projects with the productive sector reduces the sensitivity regarding the appropriate directions and adequate intensity of the research for innovation; and (2) the lack of experiences related to the technology transfer and commercialization developed at the university for effective production.

Scope of the small technology-based company's capabilities

The small technology-based company's core business is to develop high value-added products based on Amazon biodiversity, utilizing the region's natural resources sustainably. The company develops its activities in three main areas: (1) extraction of antioxidant compounds from plants of the Amazon; (2) purification of compounds; and (3) quality control of processes and products developed.

The company was established in 2002 by researchers and graduates of the university's food engineering faculty, i.e., the company is a spin-off of the university academic activities. In 2006, the small company established a partnership with the university to develop products with greater technological complexity, the main focus of which was açaí, whose development of the first line of products was completed in 2010 when the patent was filled in the Brazilian National Institute of Industrial Property (INPI).

The small company has developed a high complexity capability linked to process technology for bioasset extraction, fragmentation, and purification. It has sought expansion in the base of bioassets for the development of new products having from 4 to 6 different bioassets in the R&D phase.

If, on the one hand, the small company developed relevant technological capabilities for innovation, on the other, we observed that it had deficiencies regarding the production capacity to operate on a large industrial scale, both in terms of processing volume limit and in management capabilities regarding the supply and logistics chain, which are characterized as complementary assets (Teece, 1986; 2006).

These capabilities can also be observed by the professional staff of the small company, where there is a concentration of professionals in the R&D area. According to data collected in the field, there are 56% of professionals in the R&D department. The rest of the personnel is in production (17%), the board of directors (16%), and back office (11%).

The limitation on production capacity is reinforced by the fact that the market segment targeted by the açaí product line is focused on supplying the cosmetics industry and the large scale food industry, which in turn requires a supply that is large enough to respond to the consumers demand of the end product. The açaí crop restrictions associated with the industrial supply-demand become an additional difficulty, because it requires a concentrated processing capacity of the raw material during the harvest, producing, in this period, enough products to cover the annual demand from industrial clients.

In addition to industrial processing capacity, there is still a need for supply chain management capabilities, which requires, in the local açaí segment, the ability to secure supply in a market with intense competition for the raw material (Costa, 2009), as well as obtaining internationally accepted certificates on the products origin.

According to the taxonomy of the sectoral pattern of technical change (Bell & Pavitt, 1993), the company can be characterized as a science-based company. Biotechnology is a typical field for this technical change category, and the company matches the pattern: (1) the main sources of innovation are based on its R&D capability, focused on complex products and production processes; (2) the presence of specialized professionals in the scientific team; (3) maintains cooperation with science and technology institutions; and (4) use of patents as the appropriation mechanism, primarily for the product line observed in this case study.

One of the aspects where the small company studied here did not match the pattern for the technical change category is the size because the category of 'science-based firm' was characterized by large companies. According to Enríquez (2003), however, the rise of the specific knowledge base of biotechnology, facilitated the emergence of small companies and startups working in specialized technological market niches, such as compound library research (bioprospecting) and technological development of applications in primary products to larger industries as a viable possibility to achieve competitiveness.

In this way, we understand that the small company has evolved to specialize in the B2B (business to business) niche of bioprospecting and technological development of high-performance antioxidant products based

on the Amazon biodiversity. This profile is characterized by the need for strong interaction with both research institutions and other companies, potential clients or partners, in the innovation process.

Scope of the agribusiness firm's capabilities

According to documentary information, the medium-sized agribusiness firm was created in 2005 with the primary objective of processing and commercializing fruit (mainly *açaí*) products in the domestic and international market. The firm has four industrial plants in Brazil, two in the state of Pará (in the municipality of Castanhal), one in the state of Amapá and another in the state of Ceará.

Initially, the firm based its production on processing fruit pulp and succeeded for the fast development of its production capacity. It was installed in 2005 and reached a level of production for export in just one year (2006) when it obtained the certificates required by international customers regarding the quality of the production process and supplies management.

The interviewee responsible for the marketing area (Interviewee 3), observes that the management of the açai's supply chain is a critical role. The firm has a mapping of the fruit type of each region (according to taste, color, and density), as well as its transport and logistics structure. The interviewee emphasized the development of a relationship of trust with the communities producing açaí, for which, in general, the agribusiness firm makes prepayments to guarantee the supply of raw material during the harvest.

As of 2011, the agribusiness firm diversified the portfolio of products with the development of ice cream, açaí fruit mix, and mixed drinks. These innovations were carried out by the internal R&D area as incremental innovations based on the diffusion of products already existing in the market.

According to the marketing manager (Interviewee 3), by diversifying production, the firm has identified an opportunity in the market for ingredient products (compounds for industrial production) in the functional foods and nutrition sector. However, entry into this sector would require innovations of greater technological density that were out of the firm's internal capabilities (Interviewee 3).

As for the patterns of technical change, we understand that the main basis of the business and the original pattern of expansion used by the agroindustry was predominantly supplier dominated. Two main aspects support this analysis: (1) technological accumulation for the manufacturing infrastructure was strongly based on the acquisition of capital goods by suppliers who were responsible for the assembly of industrial structures; (2) their innovations are characterized by diffusion processes and best practices.

Thus, although recognizing the emergence of some aspects of a more independent search for innovation, as reported by interviewee 3 when discussing the existence of partnerships with the research institution and with the technology-based company, it was possible to observe that these relationships were still incipient and based on sparse activities.

It was possible to observe that the agribusiness firm's development of production capacities is quite fast, even in comparison to competitors in the region's agro-industry. Although the firm was building technological capability for emerging innovation based on diffusion processes, its technological efforts were not very intense.

Inter-organizational network coordination and the innovation process

The innovation process observed began predominantly as an R&D cooperation between the University and the small company to create a product line based on *açaí*. The university carried out activities of sharing scientific knowledge and specialized laboratory services, as well as supporting the endeavor through an incubation process and co-ownership of intellectual property since the University was a co-owner of the patent generated by the technological development applied to the product line.

The small company has held knowledge-related roles in the development of industrial-scale processes, including access to a wide variety of açaí fruits, specific industrial investments in the R&D process, and the formal demand for knowledge protection (patent application).

Briefly, the invention developed referred to the technological solution for the extraction, fractioning, and purification processes of açaí fruit for the production in the industrial scale of three products: clarified açaí juice, pure antioxidant açaí, and refined açaí oil. The activities of the enterprise were related to the discovery and extraction of bioasset compounds for industrial application, as well as the development of advanced process engineering that would allow the extraction and high purification of the compounds on an industrial scale.

As the small company was a spin-off of the university, there was ease of communication and access to information regarding technological developments, based on the pre-established trust between the members of the small company and the university. The members of the small company also had a high level of academic training, so the results of research and knowledge generated at the university could be absorbed and recognized as technological opportunities for innovation of products with economic value-added. Thus, we observed that there were no barriers of technological appropriability in the relationship between the small company and the university because the history of the company members is connected to the university, not only in terms of scientific-technological production but also regarding social relations.

This type of interaction between a university (characterized by the academic and scientific emphasis) and a private company (focus on production and commercial application) has been observed in the area of biotechnology (Powell et al., 1996), and small companies in these contexts usually present an adequate absorptive capacity (Cohen & Levinthal, 1990; Najafi-Tavani et al., 2018).

In this case, the small company initially sought to produce and commercialize the innovative product line, setting up its structure. It identified the following problems: (a) limitation to make the investments and build infrastructure, as well as the small scale production that did not match the high demand in industrial scale; (b) obstacles to obtain the licenses and certificates required for export due to imputed restrictions on small-scale industrial facilities within the building of the university's incubation program, and the difficulty of the small business in establishing management processes for sanitary control and raw materials origin tracking in the region's supply network.

These obstacles, in our point of view, are directly related to the small company's lack of adequate production and management capabilities of the supply chain, which are characterized as complementary assets to the innovative process analyzed, and necessary to scale-up the product line and access the market. Thus, although the technological capabilities of the small company enable the design of an advanced production process and the creation of an innovative product line, the absence of mature routines and production structure prevented the insertion of the innovation in the market.

Given this situation, the small company decided to maintain its core business specialized in the bioprospecting and technological development niche (considering its restrictions regarding investment and other capabilities), and to develop a cooperation strategy with an already established agribusiness company in the region that would detain the complementary assets necessary to carry out the innovative process.

The small company and the agribusiness firm negotiated an agreement to produce the açaí product line together through a Special-Purpose Entity (SPE), characterized as a joint venture, in which:

- The agribusiness firm assumed the production-related roles, the management of the supply network, and the commercial contacts.
- The small company assumed the coordination of the technological transfer with the scale-up and validation of the production for the business' industrial plant, including the management of the patent and assistance of technical contacts on requirements and applications of the product line with the clients.

In this scenario, the inter-organizational network was established, with the participation of the university, the small technology-based company, and the agribusiness firm. Table 2 shows a synthesis of the conception of the capabilities coordination within the network to carry out the innovative process:

Table 2

Synthesis of the Conception of the Capabilities Coordination in the Innovative Process Through the Inter-Organizational Network

University	Small company	Agribusiness company
Knowledge and development of scientific-technological research applied to bioprospection and biotechnology	Technological development of product line and industrial scale up	Industrial manufacture of the product line
Incubation of technology-based enterprises	Technological support on the application of the product line to industrial clients	Management of the supplies' network
Management of intellectual property	Management of intellectual property	Portfolio of international clients

Nota.. Source: Elaborated by the authors.

However, for the small company to officially sign the agreement to form the Special-Purpose Entity (SPE) with the agribusiness, it had to organize the contracts made with the university regarding patents. The contracts referred to patent's ownership and management of the technological assets, which granted exclusive use for the small business. This was the first technology licensing agreement signed by the small company and the university, so that governance parameters and spaces had to be established. The time required to execute these contracts (30 months) became an obstacle for the implementation of the innovative process planned.

The small company and the agribusiness firm had reached an informal agreement on the terms of the SPE at the end of 2012. During 2013, while waiting for the contractual procedures between the university and the small company, the two partners carried out several activities, including financial investments, preparing the conditions to produce during the harvest in the second half of that year.

These activities were associated with the production, scale-up, and validation of the industrial plant, carried out by the small company, either due to the confidentiality agreements around the patent or by the low absorptive capacity on the part of the agroindustry firm. In addition, regarding the commercialization, the small company and the firm conducted visits with international clients to delivery samples. They managed to obtain an order from a North American client, interested in purchasing four containers of one of the products (clarified açaí juice) for the 2013 harvest.

However, the conclusion of patent management agreements between the university and the small company took place only at the end of October 2013 (near the end of the harvest), and the SPE with the agroindustry was not signed. In the opinion of the interviewee from the small company (Interviewee 1), one of the main reasons for the non-conclusion of the SPE was the cancellation of the order from the North American client, who purchased the product from another agribusiness firm in the region. The interviewee also pointed out the difficulty of obtaining new orders at the end of the harvest as a reason for the non-conclusion of the SPE, because such an agreement would generate obligations in a period when it would be hard to commercialize the innovation.

Regarding the commercialization of the clarified açaí juice by another regional agribusiness firm, the small company alleged that there was patent violation. The small company sued the competitor firm (who denied having committed the infraction), as well as requested the Brazilian National Institute of Industrial Property (INPI) (responsible for processing the patents in the country) to accelerate the analysis of the patent due to the case of a potential violation.

In general, regardless of the occurrence of violation, the time elapsed with the processes related to securing the patent and its management instruments, as well as the concomitant of early disclosure of products to customers (including sample delivery) neglected the use of other means of protecting innovation to ensure appropriability, such as mechanisms of industrial secrecy and pioneering in commercialization. The early disclosure, without a rapid movement of effective supply, put strong pressure on the confidentiality and mechanisms of knowledge isolation regarding the technological process, in a market context that Costa (2009) had already identified as offering risks of predatory competition.

Both the scenario of fierce competition and risks of predatory behavior in the açaí production chain in Pará, as well as institutional and technological fragilities to effectively protect the patents of the innovative technological process, resulted in a weak appropriability regime for innovation. The fragility of the appropriability regime, and the importance of the complementary assets, and the exclusive use of a mechanism of appropriability based on the protection of intellectual property, put the participants of the inter-organizational network, particularly the small technology-based company (responsible for the patent management), in a position of disadvantage in comparison to possible imitators that may have access to the needed complementary assets.

Thus, we found that the inter-organizational network formed by the university, the small company, and the agribusiness firm, facilitated the coordination of technological and complementary capabilities for the establishment of an innovative product line with market demand and competitive in terms of cost and benefit. However, limitations regarding the conditions and strategies adopted for the innovation appropriability regime prevented the effective economic profit from the product line, which was appropriated by another organization, external to the network.

Although the university and the small company showed strong bonds of trust and collaboration for learning, the relationship with the agribusiness firm was more recent and restricted regarding the collaboration both in social terms (trust, reputation) and in technological terms (strong asymmetries of technological capabilities, with low absorptive capacity on the part of the agroindustry firm). This context limited the potential for inter-organizational interaction and collaboration regarding the coordination of the participants' capabilities.

Final Considerations

The configuration of an inter-organizational network was an opportunity to coordinate the capabilities needed to the process of biotechnology-based innovation, capabilities that the local medium and small organizations would not be able to develop alone, in the period. This coordination of capabilities would be an alternative to effectively explore technological opportunities in the scope of biotechnology applied to an endogenous species of the Amazon biome, which is the case of the *açaí*-based product line.

Although we identified the potential of the inter-organizational network in connecting technological capabilities and production capacities that are required for innovation among different local organizations, we observed difficulties regarding the fragilities of conditions of innovation appropriability and the development of greater collaborative interaction among different organizations involved in the production chain.

As suggestions for future studies, it is important to deepen research on capabilities related to biotechnology in the açaí production chain and other bioassets of the Amazon, which can clarify aspects relevant to innovative development in chains of Amazon biodiversity. We also suggest future research to explore some of the shortcomings of this work, emphasizing three of them: (1) to analyze the influence of inter-organizational networks' dynamics, regarding structure, governance, and social relationships in the development of innovation processes; (2) to deepen research on the appropriability regime and strategic alternatives to stimulate the development of innovation capabilities in the region; and finally, (3) to study the convergence of business models based on biotechnological innovations and their effects on the generation of a sustainable development model.

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