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Analyses of innovation networks financed by biotechnology and energy sector funds

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ABSTRACT

Objective – This paper assessed the formation of innovation networks by firms and institutions of science and technology (IST) so that they can receive financial resources from science and technology sector funds (SFs). SFs are the cornerstones of the Brazilian national system of innovation (NSI). As the funds were created slightly over a decade ago, it is high time they underwent revision.

Design/methodology/approach – The research used data from projects offered by FINEP, RAIS and Economática. Beyond the pursuit of basic patents Derwent Knowledge of Reuters. Descriptive analyzes were performed, network analysis through Gephi software and applied a multiple regression to the available indicators on the impacts generated by FS. The indicators used originate from different areas of knowledge and are analyzed in light of the theory of open innovation.

Findings – In the preliminary stage of the program, funds were largely allocated to the science and technology sector, but firms had a low level of participation in the projects. In addition, patent applications are below expectations at that stage, given that one of the aims of SF is the incentive for technological development.

Practical implications – Despite the improved transparency in the Brazilian economy, restrictions on information do not permit the application of statistical tests to measure the impacts of investments in innovation

Originality/value – The innovation networks were assessed by social network analysis, which indicated that most nodes (actors) are occupied by more active ISTs, lowering any expectations for a higher level of participation by firms. Some suggestions are made for improving incentive programs for innovation and their management.

Keywords – open innovation, innovation networks, Sector Funds, biotechnology and energy.

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1 INTRODUCTION

The definition of innovation is ceasing to discriminate the technological status of economic activity. Developed countries have long devoted themselves to encouraging innovation through public policies by investing large amounts of funds (Albuquerque, Suzigan, Kruss, & Lee, 2015; Lundvall, 2004; Organisation for Economic Co-operation and Developmen [OECD], 2011). These countries see innovation as a driving force of economic competition, which allows for long-term economic growth and, consequently, for social welfare.

Brazil has put in a great deal of effort in trying to boost competition by means of innovation since the opening of its market in 1990. To do so, it has stimulated the formation and consolidation of a national system of (NSI), as well as of regional systems of innovation (RSI) (Ganem & Santos, 2006; Negri & Lemos, 2011). The creation of sector funds (SFs) for science and technology (S&T) in 1999 is one of the cornerstones of innovation incentive policies for the creation and consolidation of the NSI. This mechanism, alongside other government policies such as the Innovation Act of 2004 and the Welfare Act of 2005, allowed more public funds to be allocated to science, technology and innovation (S,T&I). With more funds at hand, there has been an increase in public bids for the financing of innovation projects at the firm level.

One of the goals of an NSI is to forge strong relationships between firms and institutes of science and technology (IST) through mutual cooperation, so that technology transfer (TT) is possible and innovation can be generated and disseminated across markets. This issue is relevant both for the establishment and improvement of public policies, targeted at improving the efficiency of the NSI, and for the firms and institutes that benefit from them (Albuquerque et al., 2015; Porto & Bazzo, 2010).

A little over a decade after the implementation of the SFs, this is the right time to assess how the process has evolved, since information about the impacts of government funds on science and technology SFs in the economic sectors that benefit from such incentives is still limited. Studies concerning this impact may provide a qualitative assessment of incentive programs and spot their strengths and weaknesses in comparison with international innovation models. Negri and Lemos (2009) advocate the need to assess funds as an improvement tool.

Therefore, the present study investigates the results of collaborative innovation networks obtained from projects financed by biotechnology and energy SFs. This involves the assessment of: a) developed projects in terms of their objectives and the amount of funds allocated to firms; b) sharing of innovation results among the firms in each of the selected innovation networks starting from their year of entry into the program; c) evolution of the level of technological effort of publicly listed companies contemplated by SFs starting from their year of entry into the program; d) analysis of the cohesion of collaborative networks through patent co-ownership applications.

2 THEORETICAL BACKGROUND

Since the analysis in this study focuses on the partnerships that led to the formation of innovation networks, it was made in light of the open innovation (OI) management model, which gives priority to the creation and application of the best business model to the firm as far as innovation is concerned. According to Chesbrough, Vanhaverbeke and West (2006, p. 2), "OI is the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively."

Some of the advantages of OI can be explained by the concepts of the real options theory. OI is construed as risky activities, just as corporate businesses also are. From this perspective, it has the following advantages: a) it allows for quicker contact with new technologies and business opportunities; b) it delays financial commitment; c) it allows exiting business more quickly and reducing losses; and d) exit is delayed if there is a spin-off. These benefits are not obtained automatically, only through new skills and routines for developing the potential for practice of OI real options (Vanhaverbeke, Van De Vrande & Chesbrough, 2008).

In Brazil, after analyzing firms that invest in R&D, such as Aché, Bematech, Braskem, Cemig, Chemtech, Cristália, Embraco, Embraer, Embrapa, EMS Fíbria, Herbarium, Lupatech, Natura, Petrobrás, Sabó, Tigre, Usiminas Vale, and Weg, Pitassi and Bouzada (2011) found that 80% agreed that their involvement in innovation networks was crucial to the technological strategy. In 90% of the cases, they observed that Brazilian universities were the major participants in innovation networks, indicating a possible improvement in firm-university relationships.

Breschi, Lissoni & Malerba (2003) and Azzola, Landoni & Van Looy (2010) make it clear that patents are a powerful indicator of OI analysis, used as one of the indicators in the present study. Lecocq and Van Looy (2009) looked into patent citations in the European biotechnology sector and concluded that collaboration between regional firms and universities plays a major role in the stages of emergence and development of the technological life cycle, whereas collaboration between regional firms has a stronger impact only during the emergence of the technological life cycle.

In Brazil, few studies utilize patents as an indicator of an OI modeling strategy. Cordeiro (2010) assesses patents to analyze technological complementarity and collaborative strategy in OI. Although the use of OI in Brazil has increased in recent years, evidence still runs counter to the expected tendency towards the abandonment of the closed model (Francini, 2012; Dihel and Ruffoni, 2012; Coutinho and Bomtempo, 2010).

Given the importance of coordinating public policies for the OI model, which has been adopted at a higher frequency by international technology-intensive firms and less frequently by Brazilian innovation-intensive firms, the following section holds a discussion on national and regional innovation systems, whose results are more favorable when the firms adopt the OI model in order to bring firms and ISTs, two major actors of the NSI, closer together.

2.1 National innovation systems

An NSI includes firms, ISTs, technology intermediaries, and financial agents that interact with each other in a dynamic and systematic fashion (Malerba, 2004; Albuquerque et al., 2015), in addition to public policies for the incentive and promotion of innovation and economic development, so as to strengthen the systemic and socially determined aspects of innovation processes (Valle, Bonacelli & Salles Filho, 2002). Balzat and Hanusch (2004) defined an NSI as a historically increasing subsystem of the domestic economy, in which several organizations interact with each other, influencing one another in the production of innovative activities.

Freeman (2002) related the formation of innovation networks and of an NSI to economic growth. For the World Bank (Goel et al., 2004), the NSI is one of the four basic elements for the development of a knowledge economy. The other three elements are: a) S,T&I public policies and institutional infrastructure that foster the dissemination of knowledge and entrepreneurship, producing social changes; b) education and training, leading to the development of a capable, flexible, and creative society, producing long-term knowledge; c) information infrastructure, allowing easy access of firms to good-quality information obtained from ISTs, thus making the innovation process more dynamic.

So, the improvement of the NSI is the goal of the major economies in order to face the period of crises that began in 2008 (Fealing et al., 2011; OECD, 2011).

2.2 Innovation networks

The literature describes networks in many different ways (Ryan and Gross, 1943; Friedkin, 1982; Jackson and Watts, 2002), but there exists a consensus that they consist of the relationships of firms with other organizations, both horizontally and vertically, including those that extrapolate the limits of the industry to which they belong and with no restrictions on physical distances. By way of a network of relationships, entrepreneurs improve communication, sending and receiving information in a more accurate manner, which leads to business growth (Donckels and Lambrecht, 1995).

Gulati (1998) introduces a social network perspective to the study of strategic alliances. He extends his previous research, in which he considered alliances to be just a trade-off between transaction costs and agreements, adding essential aspects such as precursors, processes, and outcomes associated with alliances. These aspects are defined and applied to the networks to which most firms belong. The author identifies five fundamental aspects for the study of alliances: a) their formation; b) the choice of their governance structure; c) their dynamic evolution; d) their performance; and e) performance consequences for firms taking part in alliances.

Schilling and Phelps (2007) assert that the structure of collaborative relationship networks, i.e., their density, influences their potential for creating knowledge and provides higher capacity of information dissemination through the network, stimulating both communication and cooperation between agents. Non-redundant connections shorten the distance between firms and expand their range of operation by increasing potential access to funds and knowledge. The author believes that firms taking part in collaborative relationship networks with high clustering and range will be more innovative than those with many redundant connections.

According to Amato (2000), the aims of innovation network formation include sharing competences, acquiring know-how from third parties, splitting technological research costs, and sharing risks. The author concludes that the determining factors for the formation of these networks are: differentiation, which fosters innovation within the network without significantly increasing costs; interdependence, which stimulates network formation and provides organizational unit; and flexibility, which supplies the whole network with competitive advantage by giving it great ability to adapt to a changing business environment.

The history of a given business network is the process whereby time and money were invested in the construction, adaptation, development, understanding, relationship, and combination of different physical and human resources. So, there is a specific structure and intensity with economic, technical, and social implications. Firms' opportunities and limitations are related to the resources invested in relationships and in their internal capacity. Each relationship and the resources can be developed and combined with those of other firms in a number of ways. These combinations create great opportunities for innovation, benefiting those firms that take part in the relationship (Håkansson and Ford, 2002).

Innovation network formation has three implications: a) they offer a coordination mechanism that allows for and supports interorganizational learning; b) they allow exploring complementarities, which is crucial for the mastery of innovative technological solutions, characterized by their complexity and multidisciplinary nature; and c) they create the possibility for the exploration of a synergistic interaction through the combination of different technological competencies (Küpers and Pyka, 2002).

2.3 Innovative behavior

The innovative performance of firms has been extensively investigated over the years. However, there is no consensus about the indicators that should be assessed. Hagerdoorn and Coodt (2003) consider the following as performance indicators: a) R&D investments; b) patent applications; c) patent citations; and d) ads for the release of new products. These indicators are closely related and overlap, showing that the use of any indicators separately is representative as a measure of firms' innovative performance.

Ritter (1999, p. 1) postulates that "a particular skill can be identified and described that allows companies to handle, use, and exploit single relationships and whole networks. The new construct "network competence" is measured by assessing a company's degree of network management qualifications and execution of network management tasks." Zukin and DiMaggio (1990) concluded that embeddedness is a transaction system with unique market-oriented opportunities and that firms within a relationship network have better opportunities and perceive risks well in advance, gaining competitive advantage. Thus, firms have better chances of survival within their networks than firms that maintain market transactions.

Uzzi (1996) concluded that a networked firm, when it practices OI, attracts better opportunities, and perceives and neutralizes threats, which contributes to creating an image of a more effective competitor, translating into market value for the firm in the medium and long run. Hall and Mairesse (2009) advocate the use of the firm's market value because it corresponds to an outlook on the future, taking into consideration both tangible and intangible R&D investment expectations. Hence, market value represents an aggregate value that contemplates other values related to network performance.

Borgatti and Halgin (2011) focused their analyses on structural measures such as centrality, cohesive subsets, structural equivalence, and regular equivalence. They suggest adding statistical models such as the exponential random graph model (a new trend) and the time dimension, which is poorly investigated by studies on affiliation networks, proposing two important approaches for their development: graphic changes in affiliation and graphic changes over time between approaches to the analysis of networks modo-2 and modo-3 (Borgatti, 2009). Carpenter, Li & Jiang (2012) highlight that highly cohesive connections make the sharing of funds among partners easier, demonstrating strong similarity and complementarity in terms of competencies, and also stimulate partners to act according to the expectations of others. Therefore, network density indicates the presence of strong connections with third parties in a relationship.

3 METHOD

This is a quantitative and descriptive longitudinal study. It is an *ex post facto* study, since the data refers to projects that have already been concluded. Secondary data (Malhotra et al., 2005) was used, from FINEP databases for energy and biotechnology SFs, accessed from the e-SIC web portal. Data from the Annual Social Information Report (RAIS) published by the Brazilian Ministry of Labor and Employment (MTE)[1] and from Economática, which shows publicly listed firms' revenue and market value. Reuters' Derwent database was also used; it allows simultaneous access to over 90 patent authorities around the world, including all the major offices such as USPTO (USA), Espacenet (Europe), JPO (Japan), in addition to INPI (Brazil), among others.

The range of firms and ISTs available from the SF database published by FINEP was used for the descriptive analysis and also for the construction and characterization of formed innovation networks. Cooper and Schindler (2004) define the population as the full set about which we would like to make some inferences, as occurs in the present study.

An intentional and non-probabilistic sampling method (Cooper & Schindler, 2004) was used to evaluate the impacts of innovation networks, with the selection of publicly listed companies that published their results, thus allowing us to assess SFs (Martins & Theófilo, 2007). Therefore, the study period was shortened to 2002-2009, especially due to the data available from Economática and from the FINEP database.

By referring to the theoretical works that served as basis for the study, we defined the variables used:

a) Innovation networks (IN): they are a graphic representation made up of a set of nodes or actors (organizations) and edges (relationships) (Borgatti, 2009). Hence, firms and ISTs are the nodes, and collaborative relationships for innovation between firms and ISTs stem from biotechnology and energy projects allowed to use SF funds from 2002 to 2009.
b) Structural variables refer to available resources; process variables refer to activities; and performance variables refer to the outcomes.
c) Impacts of SFs: mean rate of revenue and mean rate of market value of the selected publicly listed companies.
d) Cohesion of innovation networks – CN: contents associated with the flow of funds and the isomorphic pressure in each link of the pair.
e) The firm's technological effort (FTE) proxy refers to the number of employees that work in and/or are assigned to R&D.
f) Sharing of network results – number of patents with co-ownership between firm and IST, which protect innovations derived from the central topic of the agreement.
g) Number of network projects – number of SF-funded S&T projects for the period 1999-2009.
h) Funds allocated to ISTs – sum of total funds approved for the project, including research grants.
i) Growth of firms' revenue is a performance variable.
j) The firm's market value is also a performance variable and refers to the annual growth rate of the firm's market value.

4 RESULTS

The biotechnology and energy SFs account for respectively 1.2% and 4.3% of the approximate amount of funds (R$ 4.5 billions) allocated to the program over the analyzed period (IPEA, 2009). There were 440 energy projects and 126 biotechnology projects, totaling investments of R$ 522,986,472.56 and R$ 180,082,297.17, respectively.

4.1 Analysis of projects funded by energy and biotechnology SFs.

Table 1 shows the description of SF-funded projects with at least one firm. This is so because firms are the focus of this study. Therefore, projects in which only universities, associations, government organizations, and departments participated were excluded. The number of firms contemplated by both funds are also included, as well as the number of publicly listed companies for which revenue growth, market value, number of R&D employees, and number of patent applications were obtained, regarding the projects contemplated by the energy and biotechnology SF. Hence, these firms constitute the study sample.

TABLE 1 – Description of projects with participation of companies involved in energy and biotechnology SF

Projects with companies					
	Number of projects	**Contracted amount (R$)**	**Companies ***	**Publicly listed**	**ISTs**
Energy	125	R$ 81,720,074.75	127	36	54
Biotechnology	44	R$ 59,883,615.37	34	18	26
Total	**169**	R$ 141,603,690.12			

* Excluding projects with participation of only universities, departments and government agencies and associations.

Figure 1 shows that publicly listed firms, compared with the total number of SF-funded firms, account for 35% of the biotechnology sector and 28% of the energy sector. We highlight that 33% of the projects refer to the biotechnology SF, while 16% to the energy SF.

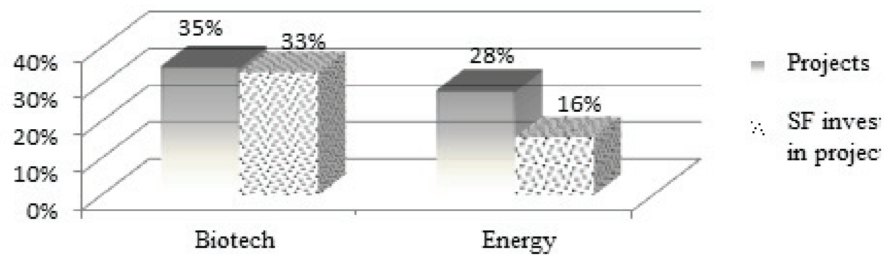

FIGURE 1 – Representativeness of projects and volume of resources with the participation of companies compared to the total presented in the FINEP database.

Table 2 shows the total number of projects funded by the biotechnology and energy SFs, without the participation of private companies, including only universities and research institutes, which represent the S&T infrastructure. The projects were proposed by NGOs and associations, in addition to State Departments, which may indicate the social or regional nature of the projects. It is important to underscore the large representation of these projects in the total amount of funds allocated to the biotechnology and energy SFs.

TABLE 2 – Representativeness of projects without the participation of companies in the SF, sorted by S & T interest projects, class interest, and regional interest

	Biotechnology	Energy
Universities and Research Institutes	63	251
Associations and NGOs	18	45
State Offices	3	20
Total value of the project without the participation of companies	R$ 120,198,681.80	R$ 441,266,397.81
Representation in SF	67%	84%

By analyzing the evolution of projects over time (Figure 2), there is a slight tendency towards an increase in the participation of firms in the biotechnology SF. On the other hand, in the energy SF, after constant growth from 2002 to 2006, the financing of projects by this fund virtually disappeared.

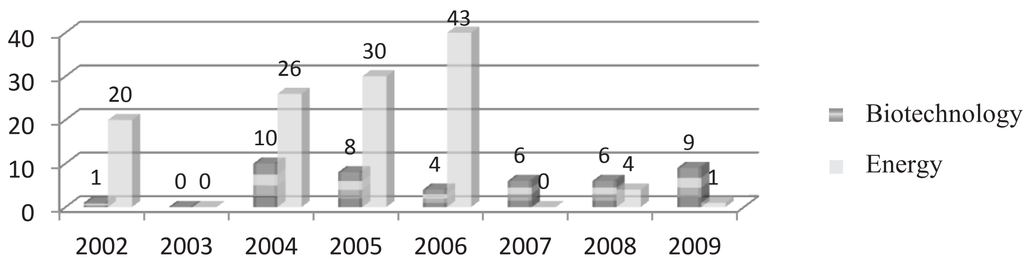

FIGURE 2 – Annual distribution of projects with participation of companies in the biotechnology and energy SF.

As to the objectives of the analyzed projects (Table 3), note that, in the case of the biotechnology SF, 50% of the projects have to do with agriculture, which predominated in the first years of the program, followed by projects in the health sector, which became more frequent in the last years of the program. Other fields of interest included cosmetics, biochemistry, and biomaterials. The small participation in biofuels and bioenergy in both funds is noteworthy. In the case of energy SF in projects with participation of firms, 35% are concerned with the improvement of energy system and efficiency. Programs for the development of thermal and wind energy and biodiesel accounted for 8% each. Photovoltaic energy represented 7%, ethanol 4%, and nuclear power 3%. The low participation in projects aimed at ethanol development is of great relevance due to the importance of biofuels and of the bioelectricity potential, especially because of the strategic relevance of second-generation ethanol for procurement of a green energy matrix. The fact that 26% of the total number of projects in this fund is not related to energy is also a key aspect; they focus on the development of institutional management and S&T, export programs in the ceramics sector, and non-energy agribusiness.

Analysis of the project goals confirms that the allocation of funds in this initial stage of the program focused more on science than on innovation. In this analysis, innovation ranged from the consolidation of habitats and innovation infrastructure, such as the organization of Technological Innovation Centers (TICs) at ISTs, and personnel training in industrial property (IP) management and TT, incentive for the establishment of incubator networks, to specific projects for new products or services, following the broader concept of innovation from the Oslo Manual (OCDE, 2005).

In the case of energy SF, 60% of the projects were related to science or infrastructure, such as the implementation of new courses or laboratories at ISTs, organization of seminars and scientific events, modernization of electrical systems, including museums, universities, and even improvement in the efficiency of national energy systems. In other words, only 40% of the projects focused on innovation, which financed the organization of TICs and the modernization and training of technological incubators. But that does not represent a typical innovation according to the Oslo Manual (OCDE, 2005).

In the case of biotechnology SF, the figures were quite similar, i.e., 41% of the projects focused on innovation, including improvement and expansion of infrastructure for preclinical and clinical analyses. The remaining 59% financed projects were concerned with science, scientific events, and scientific infrastructure (organization of biological banks and the like).

TABLE 3 – Analysis of project objectives in energy and biotechnology SF

Main objectives of the Energy SF	Amount	% of Total	Main Biotechnology SF development goals	Amount	% of Total
Thermal Generation	10	8	Agribusiness	16	36
System efficiency improvement	44	25	Biochemistry	4	9
Biodiesel	10	8	Biomaterials	6	14
Photovoltaic	9	7	Health	14	32
Wind	10	8	Other	4	9
Nuclear	4	3			
Ethanol	5	4			
Other	32	37			
TOTAL	124			44	

4.2 Innovation networks

Based on the social network analysis method, innovation networks (Figures 3 and 4) were established, consisting of firms and ISTs financed by SF from 1999 to 2011, dealing with projects which have companies as actors. Even with the low participation of firms in the total number of projects, some firms stood out. Most networks were formed by state-owned and mixed-capital companies, some of which acted as catalysts or 'sponsors', lending importance and reputation to projects taken on by small companies. In other cases, these companies clearly sought to develop research infrastructure with the implementation of laboratories and regional projects, but with no genuine interest in, or means for, the release of a new product in the market. Anyway, there were very few companies whose capital was totally private and which stood out as important nodes in innovation networks, helping to maintain a research program, which originates from the creation of a roadmap to be given an opportunity in the market and, therefore, develop multiple projects through different technological paths.

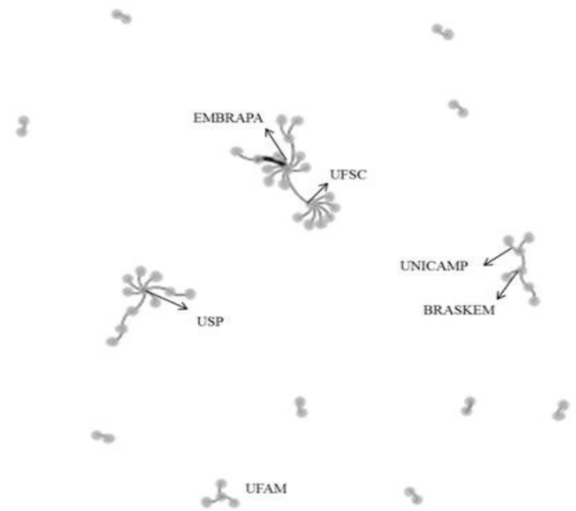

Figure 3 – Networks formed by companies and ISTs with projects financed by biotechnology SF in the period 2002-2011.

In the biotechnology network (Figure 3), Alpha Produtos Químicos EPP, Braskem/IDEOM, and Votorantim Metais S/A, companies with two or more projects, were a standout. All other companies developed only one project. As for ISTs, the participation of Universidade de São Paulo (USP), Universidade Federal de Santa Catarina (USFC), Universidade de Campinas

(UNICAMP), and Universidade Federal de Goiás (UFG), all of them with three or more projects, was noteworthy. In the biotechnology network, central nodes are basically formed by ISTs. The network itself is too fragmented, looking more like a multiple cluster than an effective innovation network.

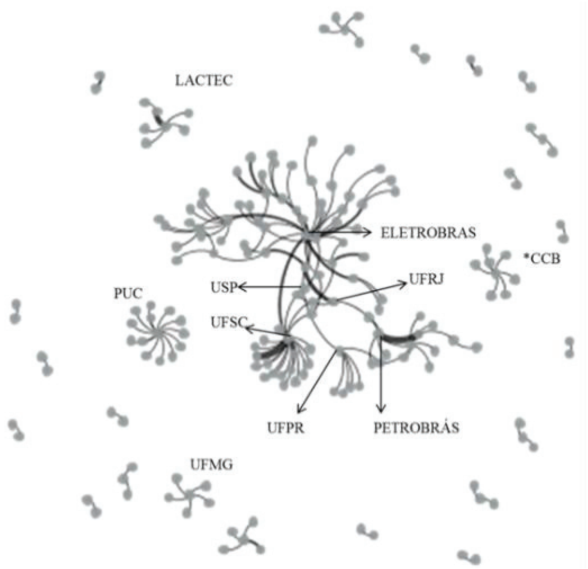

Figure 4 – Networks of companies and ISTs with projects funded by the energy SF in the period 2002-2011.
* CCB - Ceramic Center of Brazil.

The standouts in the energy network (Figure 4) were Eletrobrás, Copel, Whirpool do Brasil, Enersul Indústria e Soluções Energéticas, Indústrias Nucleares SA, and Petrobrás. Among ISTs, USFC, USP, UFPR, LACTEC, UFRJ and UFRGS, all with five or more projects, achieved a position of prominence. Hence, the energy SF proved to be a broader and closely interlinked network, with a more consistent principal component and several smaller clusters. This is desirable from the innovation network standpoint, as it may allow for the exchange of information and for the development of the whole NSI in Brazil.

The analysis of the networks identified is complemented by the analysis of centrality graphs for each of the networks. The biotechnology network shows very low levels for this indicator (Figure 5), whereas the energy network yielded higher centrality values (Figure 6). Higher centrality values indicate the presence of more important nodes in terms of connectivity, which is equivalent to easy access to information and its dissemination over the network, complementarity, and sharing of funds, which are essential attributes for collaborative innovation networks. Thus, nodes with higher centrality values have a shorter distance from more distant edges and, therefore, are better positioned in the network.

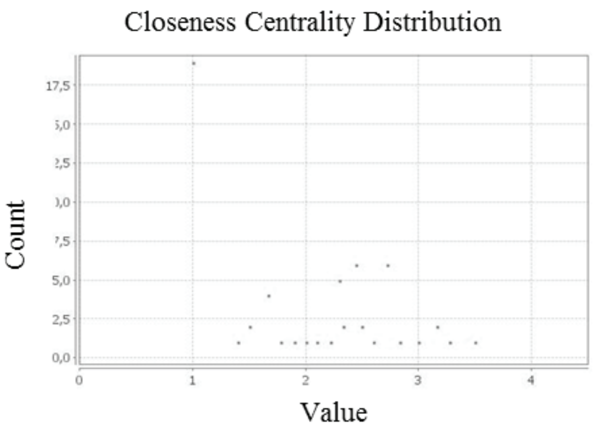

Figure 5 – Centrality of Biotechnology IR

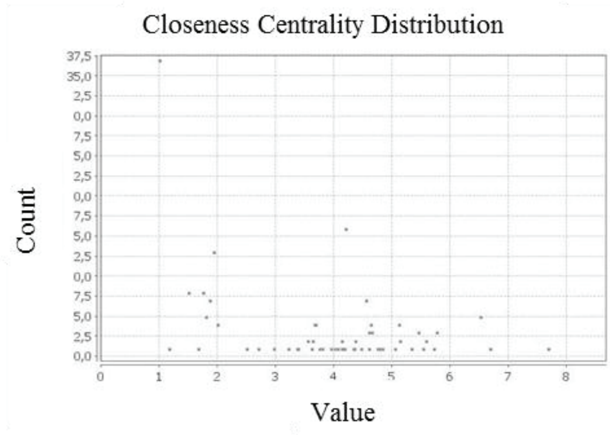

Figure 6 – Centrality of Energy IR

4.3 Company revenue and market value growth

The analysis of financial data was based on the information provided by Economática, but due to the limited number of firms that could be assessed, it was not possible to use a statistical model.

For the energy SF, there was information from 16 firms about revenue growth and from 13 firms about market value growth. For the biotechnology SF, data on revenue growth and on market value growth were obtained from three firms only. The other firms financed by SF were not publicly listed and so they did not appear in the Economática database. Market value ranged from 50 million to R$ 200 billion. Again, it should be highlighted that the information on publicly listed companies was used because it turned out to be the only available source of data. Certainly, the other firms were in the last quartile of the distribution regarding both revenue and market value.

Figure 7 shows the number of patent applications for the SF projects. Both fall short of what would be expected when one takes into consideration the main goal of SF, which is to promote technological development and innovation. This analysis was conducted for all firms participating in the SF during the study period and not only for publicly listed companies.

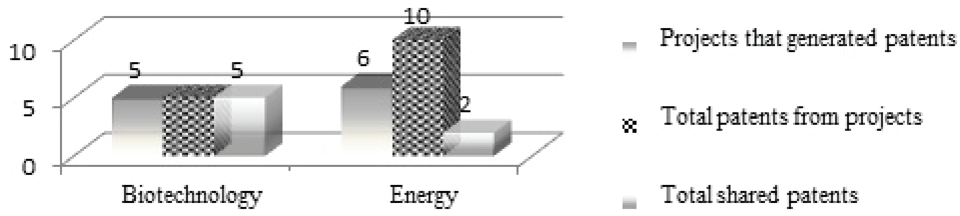

FIGURE 7 – Patent applications filed after biotechnology and energy SF

The situation is much more critical in the case of the energy SF, both because of the number of projects and volume of allocated funds. An important aspect in this case is the failure to meet the requirement of co-ownership of ISTs in the energy fund for more innovative projects compared with the biotechnology sector. The energy program is characterized by the participation of large firms, with at least 10 firms with dozens or hundreds of patent applications. Public company E8 participated in 20 projects, acted only as a 'sponsor' of projects for small companies, since it did not file for patents; consequently, patents were exclusively owned by small private companies. There is also the case of a mixed-capital company (E3), which did not share ownership with the ISTs included in the project.

Table 4 presents the data on patent applications with shared ownership, as established by the SF program.

TABLE 4 – Partial patent research – patents filed in the post affiliation period, patents referring to the project and patents shared with ICT – for companies whose variables evolution of sales and evolution in market value were drawn the Economática database

Energy Companies	Year of membership	Number of Projects	Contracted value of projects (R$)	Total patents period	Patents resulting from projects	Patent shared with ISTs
E11	2002	1	1,700,03.00	65	0	0
E1	2002	1	1,700,030.00	0	0	0
E12	2002	2	4,331,630.00	0	0	0
E13	2002	1	1,700,030.00	0	0	0
E14	2002	1	1,700,030.00	1	0	0
E15	2002	2	5,597,730.00	44	0	0
E2	2002	1	274,950.00	17	0	0
E16	2002	5	3,819,356.00	100	0	0
E3	2002	7	3,647,293.24	692	2	0
E4	2002	2	438,110.00	21	0	0
E5	2002	1	315,030.00	2	2	0
E6	2005	1	334,964.00	0	0	0
E7	2004	5	3,610,647.00	2	0	0
E8	2005	23	21.828.464.01	0	0	0
E9	2005	1	158.000.00	3	2	2
E10	2005	1	204.000.00	60	0	0
Biotechnology						
B1	2005	1	251.050.00	58	0	0
B2	2008	1	9.143.850.80	0	0	0
B3	2009	3	3.201.357.00	55	1	1

Table 5 shows the results for the firms' average technological effort – publicly listed companies participating in the biotechnology and energy SFs, based on RAIS data and using the 2002 Brazilian Classification of Occupations – CBO. For many firms, the CNPJ (National Registry of Legal Entities) consolidated data, the same used for the collection of information about revenue and market value growth, did not include data on employees who work exclusively in R&D, at least not for the surveyed activities.

TABLE 5 – Results of consolidated data listing in company research model

Energy Companies	Year of membership	Number of Projects	Resources granted by SF (R$)	Cohesion	Net results sharing	Technological effort	Evolution Company revenues	Evolution Market Value
E11	2002	1	1,700,030.00 1.700.030,00	3.938	0	0.00	0.06	0.00
E1	2002	1	1,700,030.00	3.938	0	-1.00	0.07	0.13
E12	2002	2	4,331,630.00	3.875	0	0.00	0.04	0.00
E13	2002	1	1,700,030.00	3.938	0	1.00	0.09	0.00
E14	2002	1	1,700,030.00	3.938	0	-1.00	0.10	0.00
E15	2002	2	5,597,730.00	3.875	0	0.00	0.06	0.00
E2	2002	1	274,950.00	1.800	0	-1.46	0.00	0.15
E16	2002	5	3,819,356.00	3.938	0	-1.75	0.10	0.21
E3	2002	7	3,647,293.24	3.396	2	1.39	0.12	0.21
E4	2002	2	438,110.00	1.000	0	0.00	0.13	0.23
E5	2002	1	315,030.00	3.938	2	0.00	0.04	0.14
E6	2005	1	334,964.00	3.604	0	0.00	0.14	0.14
E7	2004	5	3,610,647.00	1.667	0	0.00	0.12	0.12
E8	2005	23	21,828,464.01	2.417	0	0.00	0.11	0.11
E9	2005	1	158,000.00	4.375	2	1.26	0.17	0.17
E10	2005	1	204,000.00	4.271	0	0.00	0.07	0.07
Biotechnology Companies								
B1	2005	1	251,050.00	1.000	0	1.41	0.22	0.22
B2	2008	1	9,143,850.80	2.833	0	0.00	0.03	0.21
B3	2009	3	3,201,357.00	1.500	1	3.00	0.20	0.42

Some firms in the energy sector reduced their workforce in R&D&I activities. Two contradictory factors should be stressed for the understanding of this sector. The first one concerns the fact that the early 2000s were characterized by strong privatization efforts and consolidation in this sector. Moving companies from the public to the private sphere, especially through mergers, often means a cutback on staff for reorganization and later growth resumption. On the other hand, the concessions and privatizations model adopted led to a mandatory R&D fund that had to be used by participants. From this perspective, the model adopted aims to strengthen firms' innovative activity in the energy sector and, consequently, the R&D workforce. Owing to this combination of factors, it is very hard to draw a conclusion about these data. It is important to highlight the weaknesses of RAIS, mainly with respect to the commitment of firms to the completion of its questionnaire. However, RAIS is the available source of information for most studies on R&D employees, since PINTEC imposes strict restrictions on the access to its data (IBGE, 2015)

Table 6 shows the correlation matrix for the publicly listed companies participating in the energy SF. Due to the small number of firms with available data, it was not possible to use a statistical model to qualify the impact of sector funds on revenue and market value growth, as initially expected. Thus, this model is suggested for future studies in which information is readily available for a robust analysis (Ribeiro, 2013).

TABLE 6 – Correlation matrix of variables of the statistical model of publicly listed companies in the Energy SF. * 0,05 significance and ** 0,01 significance

	NPR	VTCR	CR	CCR	ETE
NPR	1				
	-				
VTCR	0.955**	1			
	0.000				
CR	-0.309	-0.203	1		
	0.244	0.451			
CCR	-0.039	-0.173	0.255	1	
	0.885	0.521	0.341		
ETE	0.071	0.022	0.149	0.554*	1
	0.795	0.937	0.583	0.26	

5 FINAL CONSIDERATIONS AND RESEARCH LIMITATIONS

The innovation networks formed by firms and ISTs in the energy and biotechnology SFs showed, in general, a higher level of participation of some ISTs, with firms playing a secondary role. Hence, one may say that ISTs were more active, yielded more central nodes, and allowed interconnecting different links in innovation network formation. ISTs also stood out in terms of centrality, which indicates the cohesion of publicly listed company networks in the energy and biotechnology SFs. As few firms had more central nodes in the networks, the structural properties demonstrated, in general, low variability, even with regard to centrality, the property with higher dispersion of results. By comparing the energy and biotechnology SFs, the latter was more fragmented, with lower participation of these same firms in other projects. Fragmentation also indicated some regional characteristics, which are perfectly understandable for a continental country. By and large, it is important that firms select their partners based on their competencies and have access to other ISTs, thereby expanding their access to information, technologies, and funds. The firms that stood out as to the number of projects and total volume of funds allocated to them were mostly public and mixed-capital ones, regarding both the level of participation in the projects and the diversification of partners and ISTs.

The technological effort made by publicly listed companies, measured by the number of employees in the R&D sector over the years, and taking into account their participation in SF, was undermined by the lack of information on the firms, based on their CNPJ consolidated data. This was the criterion used to collect revenue and market value growth data. The considerable changes the energy sector was subject to must be underscored: privatizations and consolidations of assets along with the creation of the mandatory innovation fund, previously discussed in the Results section. Nevertheless, these changes produced contradictory effects on the results of this variable. Some firms increased their workforce in the R&D sector. One should also recall the problem with using RAIS as source of data, as many authors criticized the lack of commitment of firms towards the completion of the questionnaire and the inaccuracy of their answers.

The sharing of intellectual property results with ISTs is mandatory pursuant to the SF regulations and also expected from firms that use the OI model. A small volume of patent applications was generated from the projects supported by SF. The patents were concerned with more innovative products and processes, but it was not possible to determine the reasons for this variation in the filing of new patents. In the case of biotechnology, which is an industry based on knowledge and innovation, all cases followed the regulations and shared results. In the case of energy SF, failure to comply with the rules was observed. Smaller companies were 'sponsored' by a public company in the projects, with joint participation in a large number of projects, and in case of a new patent granted in a common project, this company did not share ownership results. Another large mixed-capital company did not share the ownership of patents obtained from the ISTs involved in the projects.

The analysis of the impacts of the number of projects and amount of funds allocated to the energy and biotechnology SFs could not be conducted with all data, as these data were available for only 16 of the sampled firms.

A total 440 projects with the allocation of approximately R$ 523 million to the energy SF and 126 projects with R$ 180 million allocated to the biotechnology SF were developed. Of these projects, firms participated in around 35%. It was observed that several projects and funds have not been used for innovation yet. Conversely, most of the financial resources in the biotechnology and energy SFs were applied to the development of scientific infrastructure in Brazil. This scenario is expected to improve in forthcoming years with the increase in the participation of firms in programs that incentivize innovation. On the other hand, of the total number of projects in which firms participated, only 53% in the biotechnology SF and 28% in the energy SF were taken on by publicly listed companies. Therefore, the amount of data for the statistical model was substantially reduced, which prevented the achievement of results for the biotechnology SF and certainly produced a bias, probably minimizing the significance of the analysis for the energy SF as well.

For a country that wishes to participate actively in the attraction of foreign investments, the lack of data on innovation is still a major limitation and runs counter to the principle of transparency advocated by current management theories. Thus, some choices made in the selection of data further compromise the analysis of results and of the process and performance.

Despite the need to generate more quantitative analyses to improve the system, contributing to the coordination and expansion of public policies for S, T & I, it is argued that intangible impacts have gained more importance. These, in turn, are very difficult to measure and quantify.

One should also note the amount of restriction on information from the SF database for S, T & I, particularly for undisclosed amounts, especially in the price charged from businesses, which eventually limits the analysis. The difficulty in accessing data for the study of public policy programs in Brazil is also emphasized. Despite improvements required by BOVESPA's New Market; by new management practices, which adopted sustainability reporting by companies; the access to information act; and the requirements of the international capital market for approval of public program funding, access to information is still far from that observed in most developed and developing countries.

To conclude, recall that, in spite of all limitations, the goal of this study is to produce indicators and analyses of the NSI; in other words, to produce relative rather absolute arguments. This way, the aim is to produce knowledge and stimulate learning instead of absolute truths about facts.

For improvement of innovation incentive programs, a suggestion would be the mandatory completion of questionnaires at the end and submission of the projects, thus generating data for the assessment of programs and also producing knowledge for firms themselves, ISTs, and other agents in the innovation networks. The European Innovation Scoreboard is suggested as a model. The intensification of integration in the planning of programs by the funding agencies is critical. Improvements have been made, but in separate cases that cannot still be characterized as NSI and RSI integrated management. This coordination and integration of program management will also allow the improvement of government plans, actually stimulating debate and the organization of priority development fields and focus on action strategies that are too broad and diffuse for the resources at hand.

NOTA

[1] In the case of RAIS data, as data on specific firms are needed but not disclosed by PINTEC, whose confidentiality is protected by Act no. 12.527/2011, which overrides the Access to Information Act, it was necessary to sign a specific agreement to guarantee the confidentiality of participants and to comply with the law.

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