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Originally published by Ipea in November 2013 as number 1901 of the series Texto para Discussão.

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Brasília, May 2015

UNIVERSITY-ENTERPRISE INTERACTION IN BRAZIL: THE ROLE OF THE PUBLIC RESEARCH INFRASTRUCTURE

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DISCUSSION PAPER

A publication to disseminate the findings of research directly or indirectly conducted by the Institute for Applied Economic Research (Ipea). Due to their relevance, they provide information to specialists and encourage contributions.

Discussion paper / Institute for Applied Economic

Research.- Brasília : Rio de Janeiro : Ipea, 1990-

ISSN 1415-4765

1. Brazil. 2. Economic Aspects. 3. Social Aspects. I. Institute for Applied Economic Research.

CDD 330.908

JEL: O30; O31.

CONTENTS

ABSTRACT

This paper discusses the university-enterprise interactions in the Brazilian innovation system by focusing on the characteristics of the public research infrastructure which affects its propensity to interact with the industrial sector. Logistic regressions have been used to identify, in a wide set of explanatory variables, the characteristics of the research infrastructure which increase its probability of supplying technological services to firms. Besides the primary data collected from a survey carried out in a sample of institutions related to the Brazilian Ministry of Science, Technology and Innovation (MCTI), data concerning the scientific and technological production of the researchers affiliated to each laboratory have also been used in the regressions. The choice of the explanatory variables was based in a brief literature review on the role of the research infrastructure in the national innovation systems. Aiming at supporting the discussion of the results of the regressions, this review also included a brief report of the recent interactions between the research infrastructure and the industrial sector in Brazil. The main findings of the logistic regressions are: *i*) the size of the laboratory (as measured by the number of affiliated researchers) and of the qualification of its research team positively and significantly affects its propensity to interact with the industrial sector; *ii*) multidisciplinary laboratories tend to interact more with the industrial sector than laboratories focused on a single field of expertise; *iii*) there seems to be a tradeoff between scientific publications and market oriented research, since the number of papers published by the affiliated researchers is negatively correlated to the probability of supplying technological services to firms.

Keywords: technological infrastructure; technological capabilities; university-enterprise interactions.

1 INTRODUCTION

An extensive and modern scientific and technological research infrastructure is one of the basic requirements to knowledge production in a given country and might be considered one of the pillars of the national innovation system. Besides, a significant share of the R&D expenditures in most countries is directed to universities and public research institutions. In Brazil, around half of the R&D expenditures is performed by the government and it is manly directed to this kind of target.

Along the 2000s, the number of investments made in Brazil's research infrastructure has increased significantly, especially with the resources of the Ministry of Science, Technology and Innovation (MCTI), through the Sectoral Funds, but also with resources of the Brazilian Federal Agency for Support and Evaluation of Graduate Education (Capes) of the Ministry of Education (MEC), of the State Foundations of Support to Research and companies like Petrobras, for example. According to data of the Ministry of Science, Technology and Innovation (MCTI),[1] in the period between 2001 and 2010, just the Infrastructure Fund (CT-Infra) invested over R$ 1.7 billion in the implementation and recovery of the research infrastructure of public institutions in the country.

Besides an extensive and modern scientific and technological research infrastructure, the performance of the innovation system requires a high level of interaction between this research infrastructure and the local industrial sector. In the Brazilian case, despite the advances observed in the last decade and a few representative successful cases, the diagnosis proposed by Sutz (2000), that registers a reduced level of university-enterprise interaction in Brazil has been recurrently reaffirmed as in, for example, Suzigan, Albuquerque and Cario (2011).

The reasons for this low level of interaction can be found, on one hand, in analyses that emphasize the features of the Brazilian industrial sector, which is concentrated in low and medium-low technology sectors and, as a result, does not strongly demand the knowledge produced in universities and research centers.[2] Some authors, on the other hand, focus on the policy instruments that have been used to promote that kind of interaction (Viotti, 2008; De Negri *et al.*, 2009; Cavalcante, 2011). The existing research infrastructure of the country – that corresponds, in this paper, to the set of public

1. Available at: <http://sigcti.mct.gov.br/fundos/rel/ctl/ctl.php?act=projeto.fundo>.

2. See, for example, De Negri (2012).

assets destined to research and development activities (R&D) that exists in universities and research centers[3] – has not been, however, a recurring object of the analyses that intend to contribute for a better performance of the Brazilian innovation system. The lack of analyses of that nature can be blamed, at least in part, on the lack of systematic information about the physical research infrastructure available in the country.

This paper discusses the university-enterprise interactions in the Brazilian innovation system by focusing on the way the characteristics of the research infrastructure affect its propensity to interact with the industrial sector. The focus of this paper is set on the institutions related to the MCTI about which there are available data. The paper is structured in four additional sections, besides this introduction. In section 2, a brief review of the role of the research infrastructure – especially the one maintained by the government – in the national innovation systems is discussed. Besides, section 2 analyses the variables used to characterize the research infrastructure, the way these variables affect the propensity of the research infrastructure to interact with the industrial sector and some features of university-enterprise interactions in Brazil. The third section focuses on the procedures adopted to obtain the data used in the paper (which were collected through a survey carried out in a sample of institutions related to the Brazilian MCTI). Besides, the econometric procedures used to analyze the way the characteristics of the research infrastructure affect its propensity to interact with the industrial sector are discussed in section 3. The main results are discussed in section 4. The final remarks and some future research agenda are presented in the fifth section.

2 THE ARTICULATION BETWEEN SCIENTIFIC RESEARCH AND INNOVATION[4]

This section presents the theoretical background which supports the definition of the methodology and the analysis of the results of the paper. It is shown, in subsection 2.1, the importance of the research infrastructure – and specially its capacity to interact with the industrial sector – in the performance of innovation systems. It is also argued that, in the current context, the research infrastructure would have an even more relevant role

3. The definition used here converges with the concept of "public R&D", that Cohen, Nelson and Walsh (2002) associate to "universities and government research labs".

4. This section strongly relies on De Negri and Cavalcante (2013).

than the one it played along the second half of the 20th century. These arguments support the discussion, in subsection 2.2, of the interaction between the research infrastructure and industrial sector in Brazil.

2.1 The articulation between scientific research and innovation: intervenient factors

In historical perspective, scientific knowledge, innovation and income growth have shown strong correlation with one another. The positive correlation among these variables have been reinforced, in the recent period, by authors like Cohen, Nelson and Walsh (2002) and Meyer (2000), who emphasized the increasing relevance of the scientific production to the development of new technologies. Narin, Hamilton and Olivastro (1997) observed a rapidly growing citation linkage between American patents and scientific research papers. Besides, they conclude that each country's inventors preferentially cite papers authored in their own country.

After analyzing the results obtained by Narin, Hamilton and Olivastro (1997), Meyer (2000) argued that citation linkages hardly represent a direct link between cited paper and citing patent, but illustrate the multifaceted interplay between science and technology. In fact, despite the consensus about the relationship between scientific knowledge and the development of new Technologies, the way this relationship takes place is still controversial.

Thus, along the last decades, the understanding of nature of the innovation process has evolved from a typically linear conception to a more integrated approach. Schematically, it is possible to recognize two basic interpretative models of the innovation process:

- the linear model, according to which the innovation process would happen through successive steps from basic and applied research activities to experimental development and afterwards to the production and commercialization.[5] In this model, the maintenance of the infrastructure destined to basic research activities is considered a task of the public sector, that should also strongly support applied research, made in national institutes, with the companies being in charge of technological research; and

5. The reference document for the characterization of the linear model is the report titled "Science: the endless frontier" elaborated by Bush (1945).

- the systemic model, that is based in a broader and more complex conception of the innovation phenomenon, emphasizing the simultaneous influence of organizational, institutional and economic factors in the process of generation, promotion and use of science, technology and innovation (ST&I).[6]

In each one of these models, the proposed ST&I policies have different formats. Whereas in the linear model the emphasis is on the supply side (that is, the research activities that would spontaneously overflow to the industrial sector), in the systemic model what prevails are the prescriptions towards the articulation between the many agents involved in the process.[7] Freeman and Soete (1997), for example, argue that, while in the 1940s and 1950s, the emphasis of ST&I policies was on basic research, in the two following decades, the focus in incremental innovations predominated and, in the 1980s and 1990s, the technological promotion became a fundamental object of the proposed actions (Freeman and Soete 1997). Ruivo (1994 *apud* Guimarães, 2006) also shows how the ST&I policies were also influenced by these different paradigms. Thus, from the 1940s to the 1960s, the ST&I policies were strongly influenced by the linear model and based on the paradigm that science would be the engine of technical progress. Still according to Ruivo (1994 apud Guimarães, 2006), in the twenty years that followed, even though the linear model still predominated, the governance of the process was given by the market, and science was seen as a tool for solving competition problems. Finally, in the third period, that starts in the 1980s, the model became more complex and systemic, associating supply (science) and demand (market) and, in this context, science plays the role of a source of strategic opportunities for development.

Contemporaneously, the systemic model has been the basis for the formulation of ST&I policies in most countries based in the concept of a national innovation system that, essentially, means a network of public and private institutions whose activities and interactions initiate, import, modify and promote technologies. Hence, it is a broad concept that includes the research infrastructure as well as companies, public policies and regulatory apparatus related to innovation and intellectual property.

6. Viotti (2003) also mentions the "chain link" model, that considers innovation a result of the interaction between the market opportunities and the knowledge and capacitation base of the industrial sector; and the technological learning model, that is an extension of the systemic models that the authors consider more appropriate to the understanding of the technical change in the countries with late industrialization.

7. That, however, has taken some authors to contest what they call a "caricature" of the linear model (Balconi, Brusoni and Orsenigo, 2010).

Thus, a systemic view of the innovation process should not be mistaken with the prioritization of technological development activities at the expense of scientific research. Actually, the fundamental question would be the articulation of the scientific production with the technological production and the country's industrial sector. In the words of Suzigan, Albuquerque and Cario (2011), "universities and research institutes produce scientific knowledge that is absorbed by the companies, and they accumulate technological knowledge, raising questions for scientific elaboration". This articulation and interaction between scientific production and technologic development, between knowledge supply and demand, between basic and applied research and the development of new products and process would be, then, the key to an innovation system capable of leveraging the economic development of countries. Indeed, Freeman (1995) argues that a weak scientific and technologic infrastructure and its reduced relationship with the industrial sector would be, among other elements, the reason that allows the differentiation between the Latin-American and Asian innovation systems and why the latter has a better performance.[8]

Mazzoleni and Nelson (2005) also claim that the importance of the knowledge produced in universities and research institutes in the economic development process of a country has become increasingly higher. For them, the successful processes of catching up are based in a set of factors like: i) the mobility of qualified labor between countries; ii) protection and subsidies to the new industry; and iii) a weak intellectual property regime, that allowed domestic companies to appropriate technologies developed externally. However, in these authors' point of view, regulatory and institutional changes – especially in the scope of the World Trade Organization (WTO) and the Trade-Related Aspects of Intellectual Property Rights (TRIPS) – and the higher level of integration of the global economies make it impossible to use strategies based in these components. Particularly, protection measures and subsidies to this new industry and a weak intellectual property regime would be non-feasible strategies in the current context. In this context, local scientific and technological capacities are even more important to bring developing countries closer to central countries, no matter their development

8. Freeman also mentions other factors that are disadvantages of the Latin American innovation systems: *i*) the educational system (specially the low number of graduating engineers); *ii*) the reduced participation of corporate spendings in P&D in total spendings; *iii*) the slow development of the modern communication systems.

strategies. Thus, according to Mazzoleni and Nelson (2005), "indigenous universities and public laboratories will play an increasingly important role as vehicles through which the technologies and organizational forms of the advanced countries come to be mastered in the developing ones".

However, the potential interactions between scientific production and the industrial sector are affected by a variety of factors that include the specificities of the national innovation systems and the research infrastructure itself. Mazzoleni and Nelson (2005), for example, claim that government programmes for supporting research have been more effective in successful cases of catching up when: i) they are oriented to a user community; and ii) they are designed to solve relevant problems for certain activity sectors. The authors also argue that, in several successful cases, public research is part of a broader structure that aims to increase productivity in a sector, also involving education and training (Mazzoleni and Nelson, 2005).

Furthermore, the relevance of the scientific and technologic research infrastructure for innovation is not uniform between sectors. Cohen, Nelson and Walsh (2002) use data of the Research on Industrial R&D of Carnegie Mellon on the contribution of universities and government labs to industrial innovation and conclude that:

- public research is important, generically speaking, in a wide segment of the manufacturing industry, even though it impacts more significantly a limited number of segments, where the pharmaceutical sector is the most important;
- the most important access channels to public research are more personal (publications, conferences and informal interactions) than formal, such as licenses or agreements; and
- big companies tend to use more public research than the small ones.

These results point to one of the most important factors that explain the levels of more interaction between scientific research and innovation, as they show that scientific research is unevenly used among the different industries. The sectoral distribution of economic activity limits how much the industrial sector could appropriate the knowledge produced by a certain kind of research infrastructure. It is evident, for example, that basic research in the pharmaceutical area has few possibilities of being used in a country where this sector is not relevant.

Besides the limits imposed by the demand for knowledge, the characteristics of the research infrastructure may also influence the levels of interaction it can establish with the industrial sector. Institutions and research centers are not homogeneous and the way they are structured and their characteristics may affect their capacity of producing knowledge suitable for innovations and of interacting with the industrial sector. According to Stahler and Tash (1994),

> they vary enormously across a number of dimensions, some of which include: size of external support and research staff; the proportion of faculty versus professional staff researchers; level of separation from academic departments; level of integration with the university; level of interdisciplinary and multidisciplinary focus; relative emphasis on applied research.

In that sense, Tornquist and Kallsen (1994) analyzed the characteristics of the institutions that present higher levels of interaction with the industrial sector in the United States and showed that “particular characteristics of universities that may influence relationships between the two sectors include size, available resources, quality, prestige, institutional type, location, and organization”.

The first characteristic that may strongly affect the potential interaction with the industrial sector are the knowledge areas in which the research institutions and their laboratories have accumulated competences. Thus, a research infrastructure with accumulated competences in health sciences would establish, with the industrial sector, a different relationship than an infrastructure whose competences are centered in engineering. Recently, Lemos *et al*. (2009; 2010), when analyzing the interaction between scientific production and the patents registered in United States Patent and Trademark Office (USPTO), verified that the scientific production of some knowledge areas, such as physics, math and engineering, for example, are more frequently cited sourced than other areas. Thus, some knowledge areas seem to have a higher potential for generating technologies and innovations than others and a specialized research infrastructure can have different impact on the capacity of generating technology and innovation for the industrial sector.

Gains in scale and scope in research activities are also a relevant aspect related to the potential contribution of the research infrastructure to the performance of the national innovation system. Indeed, it can be argued that these economies can broaden the efficiency of the scientific research and, therefore, of the public resources allocated for its funding. Several papers tried to discuss the relevance of the so-called “big science” both on the scientific production and on the technology and innovation production for the industrial sector (Galison and Hevly, 1992; Autio, Hameri and Vuola, 2004; Vuola and Hameri, 2006). According to Autio, Hameri and Vuola (2004):

> big-science centers may possess some characteristics that facilitate the build-up of relation-specific social capital with their industrial supplier companies (…) big-science centers build large research facilities and work to an overarching project plan that should (…) serve to increase internal goal congruence. The internal goal congruence should facilitate the availability of internal resources (such as engineering expertise and laboratory facilities) to industrial supplier companies.

Dundar and Lewis (1995), on one side, find evidence both of scale and scope economies in education and research activities of American universities. Bonaccorsi and Daraio (2005), on the other hand, quote several studies on the existence of scale economies on the production of research and education, but warn about the lack of a consensus about it, since some studies show scale economies, while others show constant returns.

Another aspect related to the previous one is about the level of focus of the research infrastructure. A research infrastructure more focused in a smaller number of universities and large research centers, for example, can have a different performance from one that is more scattered in a higher number of institutions. In the first case, one can assume that the relationship with large-sized companies would be easier, besides from the scale gains that come from this format. In the second case, the diffusion of technologies can be favored by the dispersion and the capillarity of the existing research infrastructure.

Naturally, the characteristics of the research institution and laboratories are not the only factors capable of explaining their interaction with the industrial sector. D'Este and Patel (2007), for example, analyzed the variety and frequency of these interactions and argued that the individual characteristics of the researchers are more important than the characteristics of their departments and universities.

The elements mentioned so far are not all the factors that can characterize research infrastructures and determine its higher or lower impact in the performance of the innovation system and in economic development. Additional elements involve the funding sources used (if they are strictly public or if the result from service providing to private agents, for example), the management model (more vertical or marked by decisions taken by a committee, for example) and the technologic updating of the equipment available, among others. The empirical analysis carried out in this paper tries to explain the interactions between laboratories (research infrastructure) and the industrial sector based upon some of the elements discussed up to this point. Before that, however, a brief discussion of the Brazilian case is presented in subsection 2.2.

2.2 The interaction between the research infrastructure and the industrial sector in Brazil

There is a reasonable consensus that the Brazilian scientific production has had, during the last decades, a better performance than the national indicators of business enterprise R&D investments, patents and innovation, in spite of some recent improvements. It is also widely known that the level of interaction between universities and research centers and the industrial sector are still low in Brazil. Some authors (Suzigan and Albuquerque, 2011) argue that the late character of the constitution of the Brazilian innovation system helps explaining some of its limitations nowadays.

Even though the "first wave" for creating education and research institutions in the country happened because of the Portuguese court moving to Brazil in 1808 (Suzigan and Albuquerque, 2011), the first relevant attempts of creating universities in the country came in the 1920s (Cunha, 1980; Suzigan and Albuquerque, 2011, Schwartzman, 1979) during what Suzigan and Albuquerque (2011) defined as "third wave" of education and research institutes in Brazil. During this period, the University of Rio de Janeiro was created (from the gathering of colleges, such as the Polytechnic, the Medical and Law Schools), in 1920, and the University of São Paulo (USP), in 1934.

In the late 1940s and early 1950s some important institutions like the Centro Brasileiro de Pesquisas Físicas (CBPF), the Instituto Tecnológico da Aeronáutica (ITA) and the Centro Tecnológico da Aeronáutica (CTA) were created. However, it is the creation of the Brazilian Federal Agency for Support and Evaluation of Graduate Education (Capes)[9] and of the National Council for Scientific and Technological Development (CNPq), at the beginning of the 1950s, that marked the beginning of government actions explicitly directed towards the support to ST&I activities in Brazil. According to Guimarães (2002), the constitution of the Brazilian industrial estate for ST&I in this period was largely inspired by the linear innovation model and development actions

9. Later named Coordenação de Aperfeiçoamento de Pessoal de Nível Superior, keeping the acronym.

from Capes and CNPq were based on the supply of the demand of researchers, taking into consideration essentially the academic merit and discarding additional consideration on the relevance of priorization of research areas. Still according to Guimarães (2002), Capes and CNPq still "keep, very clearly, its original conceptions, whether with the hegemony on the support of basic research, on the development based on an established demand in a "free market" of talents, or on the direct relationship with the researchers".

The evolution of the understanding of the innovation process caused changes in the institutional structure of the federal government and lead to the creating of the Financiadora de Estudos e Projetos (Finep), at the end of the 1960s, to institutionalize the Fundo de Financiamento de Estudos de Projetos e Programas, that had been established in 1965. However, even if, from the institutional point of view, Finep was different from the research development and human resources education agencies, like Capes and CNPq, its initial performance favored scientific research and was essentially directed towards the funding of the implementation of post-graduation programs in Brazilian universities.

From the 1970s, the Planos Básicos de Desenvolvimento Científico e Tecnológico (PBDCT) started to be produced, seeking the articulation of goals and actions in the ST&I area to the Planos Nacionais de Desenvolvimento (PND). In the second PBDCT, for example, its goal was clearly stated: "to make science and technology the moving force of the development and modernization process of the country, industrial, economic and socially" (Salles Filho, 2003, p. 183). Even though that was their speech, there are no doubts that the ST&I policies developed based in "interests and perception that were certainly out of the core of the model of development though replacing imports" (Viotti, 2008, p. 141). Thus, even though some integration initiatives between the production sector and the universities' research centers, in reality, what predominated were policies that relied on the linear innovation model.

From the 1990s onwards, the idea that it would be necessary to stimulate the innovation in the industrial sector of the country gained strength in Brazil. Policy makers become more concerned with projects capable of involving both research institutions and the industrial sector and the conditions for the concession of fiscal incentives for the technologic capacitation of the industry and agriculture (PDTI and PDTA) are established. The grounds for the creation of the sectoral funds were to "stimulate more intensive technologic modernization processes in companies and to create an institutional environment that is more favorable to the deepening of the cooperation between public agents of the science and technology area and the industrial sector" (Morais, 2008, p. 67).

In spite of the efforts to increase the links between research institutions and the industrial sector, the last decades are marked by a faster growth of the scientific production indicators as compared to the technologic ones. In fact, the publishing of Brazilian articles in international scientific journals indexed in the Institute for Scientific Information (ISI) reached about 250 articles per million of inhabitants, achieving the world average and taking the participation of the country in the world's scientific production to over 2.5% at the end of the 2000's. On the other hand, the participation of the country in the patent concessions deposited in USPTO, that, despite its traditional limitations, represents a proxy of the technologic production, is about 0.1% of the global total. Along the series of data available, Brazil did not cross the mark of two hundred patents a year, against a few thousands in South Korea in the most recent period. Thus, even though the instruments used intended to overcome the linear innovation model and adopt a more systemic perspective, there are indications that the model, in several cases, became "bipolar", that is, a site in universities and research centers and another one in the industrial sector.

These data reinforce the need for a higher integration between the research infrastructure and the industrial sector of the country. This is a recurring matter that would characterize, according to Albuquerque (2003), the so-called immature innovation systems, typical of countries in intermediary position, like Brazil. In the author's point of view, the low connection between science (universities) and technology (firms) is an attribute typical of the Brazilian innovation system. According to Suzigan and Albuquerque (2011), "one of the features of innovation systems in that intermediary position is the existence of research and education institutions that are built, but still cannot move a certain number of researchers, scientists and engineers, if compared to more developed countries". In the case of Brazil, the authors claim that there is a relatively limited standard of interaction between the universities and enterprises, where there are only certain points of interaction between the scientific and the technologic dimensions. This interaction pattern has historical roots, according to the authors, "in the late characters of the creation of research institutions and universities in the country" on one side, and "in the late character of Brazilian industrialization", on the other.

Indeed, there are few successful examples of university-enterprise interaction in Brazil. The most mentioned examples are: i) the Brazilian Agricultural Research Corporation (Embrapa); ii) the research complex linked to the Aeronautics (the Technological Institute of Aeronautics – ITA and the Aerospace Technical Center – CTA, and also the

National Institute For Space Research – Inpe); iii) the Oswaldo Cruz Foundation (Fiocruz); iv) the research complex associated to the oil sector in Rio de Janeiro, which the Petrobras Research Center (Cenpes) and the Institute for Graduate Studies and Research in Engineering (Coppe) are a part of. In all those cases, in its constitution, these public research institutions were directed to a community of users and designed to solve relevant problems of certain activity sector, in the terms of Mazzoleni and Nelson (2005). The existence of clearly defined demands in the industrial sector has contributed for those initiatives overcame the "low degree of induction" of the ST&I policies, identified by Guimarães (2002) and Guimarães (2006).

The next sections of this paper discuss the university-enterprise interactions in the Brazilian innovation system by focusing on the characteristics of the public research infrastructure that affects its propensity to interact with the industrial sector. This task will be performed using data collected from a survey carried out in a sample of institutions related to the Brazilian Ministry of Science, Technology and Innovation (MCTI). The main argument is that the characteristics of the public research infrastructure may help understanding the reasons behind the low levels of interactions between the scientific and the technological dimensions in Brazil.

3 METHODOLOGY

The aim of this section is to present the methodological procedures used to identify the characteristics of the research infrastructure which affects its propensity to interact with the industrial sector. Subsection 3.1 focuses on the procedures adopted to obtain the data and subsection 3.2 on the model used to analyze these data.

3.1 Data base description

Data on the characteristics of the public research infrastructure related to the MCTI were obtained from a survey applied to these research institutions. The research infrastructure of the ministry is distributed among fourteen public research institutions, three para-public research institutions subordinated to the Ministry itself and five research institutions subordinated to the National Nuclear Energy Commission (CNEN). In 2011, the budget of these research institutions reached, according to data of MCTI, around US$ 180 million. These institutions are located in several Brazilian states, but they are mostly concentrated in Rio de Janeiro and Sao Paulo.

The survey was based upon 21 mostly closed-ended questions sent to institutions heads, who informed to total number of laboratories (or, more broadly speaking, research infrastructures) in each institution. The institutions heads then forward the questions to each laboratory coordinator, who is ultimately the responsible for filling the survey. At the same time, MCTI team responsible for the survey visited the institutions to clarify any doubts that may occur. All this process took around six months.[10]

The questionnaire used in the survey was designed to capture relevant information on each research infrastructure, including laboratories and other similar infrastructures (such as pilot plants, animal research facilities and observatories).[11] The questionnaire was structured into four parts that should be answered by their respective coordinators. The first part focuses on general information (e.g., description, research areas and whether the laboratory provided technological services to firms and, if affirmative, the taxpayer identification of these firms).[12] The second part focuses on the operation of the infrastructure and gathers information on the scientific and technical staff of the infrastructure, on the use of facilities and equipment by external users and on the major activities and types of cooperation in the previous year. Information on the estimated value of infrastructure, as well as data on their sources of revenue and operating costs, were raised in the third part. The last part of the questionnaire contains a subjective evaluation of the coordinator about the current conditions of the infrastructure. It was also asked when the last major investment in infrastructure took place (investment of at least 10% to the total value of the laboratory/infrastructure). Besides the information collected in the survey, secondary data on the scientific and technological production of the researches related to each laboratory were collected as well. These data involve the CV of the researchers working in the laboratories as well as the number of patents granted to them available at the Brazilian National Institute of Industrial Property (Inpi).[13]

As shown in table 1, 196 questionnaires have been answered representing different types of research infrastructure, including laboratories, animal research facilities, pilot plants, monitoring stations or networks (meteorological, seismic etc.), as well as

10. Details on the methodological procedures can be found in a report available at MCTI website (De Negri *et al*., 2013).

11. Therefore, the term infrastructure (of research) is used as a synonym for laboratory throughout the text and vice versa.

12. In Brazil, every firm has a taxpayer identification (CNPJ, the Portuguese acronym).

13. The National Council for Scientific and Technological Development (CNPq) developed a system that brings curricular information of all Brazilian researchers, including their publications and institutional affiliation. This system is called Lattes Platform.

observatories, centers, research divisions and so on. All institutions except four filled the questionnaires so that the survey in fact covers most institutions related to the MCTI. However, the response rate inside each institution is unknown as most of them simply do not have a comprehensive inventory of their laboratories. As a result, the sampling universe was unknown a priori and one of the main goals of the survey was precisely to overcome this limitation.

TABLE 1
Number of respondent research infrastructures for each institution in the survey

Public research institutions		Answered questionnaires
Brazilian Physics Research Center	CBPF	7
Renato Archer Information Technology Center	CTI	7
Mineral Technology Center	Cetem	6
Strategic Technology Center of Northeast	Cetene	5
Brazilian Institute of Information in Science and Technology	IBICT1	-
National Institute for Amazonian Research	INPA	19
National Institute for Space Research	INPE	27
National Institute of Technology	INT	7
National Institute for the Semi-Arid Climate	INSA	0
National Astrophysics Laboratory	LNA	1
National Laboratory for Scientific Computing	LNCC	6
Museum of Astronomy and Related Sciences	Mast	3
Emílio Goeldi Museum of Pará	MPEG	5
National Observatory	ON	10
Para-public research institutions		Answered questionnaires
National Center for Research in Energy and Material	CNPEM	10
Mamirauá Institute for Sustainable Development	IDSM	7
Pure and Applied Math Institute	Impa	3
Strategic Studies and Management Center	CGEE [(1)]	-
Research institutions associated with National Nuclear Energy Commission (CNEN)		Answered questionnaires
Nuclear Technology Development Center	CDTN	32
Regional Center of Nuclear Sciences	CRCN	1
Nuclear Engineering Institute	IEN	11
Institute of Radiation Protection and Dosimetry	IRD	0
Institute of Energy and Nuclear Research	Ipen	29
Total number of laboratories and infrastructures		196

Source: Brazilian Ministry of Science, Technology and Innovation (MCTI) from questionnaires applied to the laboratories of the research institutions related to the MCTI.
Note: [1] IBICT and CGEE did not respond to the questionnaire since they are not part of the scope originally defined for the project.

According to the data obtained, in 2011, the technical staff of the 196 surveyed laboratories was composed of nearly 3,000 professionals (1,363 researchers, 762 graduate students and 871 technicians with and without higher education). Each infrastructure had, on average, about seven researchers, four students and 4.5 technicians. Around 55% of the researchers hold a PhD degree, 21% hold a MsC degree, 6% were specialists and 18% hold an undergraduate degree. However, the data reveal significant variations in levels of qualification of the research team among the different institutions.

Table 2 shows the distribution of infrastructures and researchers according to the field of the surveyed infrastructure.

TABLE 2
Distribution of infrastructures and researchers according to the field of the surveyed infrastructure

Major area	Number of infrastructure	%	Number of researches[3]	%
Agricultural sciences	13	5	119	6
Biological sciences	37	14	233	11
Health sciences	14	5	74	4
Exact and earth sciences	102	39	793	38
Humanities[1]	4	2	15	1
Applied social sciences[1]	4	2	32	2
Engineering	88	34	812	39
Total[2]	**262**	**100**	**2078**	**100**

Source: ASCAV/SEXEC/MCTI from questionnaires given to the coordinators of the laboratories of research institutions under the MCTI.
Notes: [1] Although these areas have not been the focus of the research, as previously stated, there are a few laboratories, as for instance some of the MAST ones, which also operate in these areas.
[2] The sum of both the researchers and infrastructure presented in the present table is higher than the actual number of researchers and laboratories, due to the fact that many of them are multidisciplinary and operate in more than one field of knowledge.
[3] The area of expertise here regarded is the area in which the laboratory/infrastructure claimed to act and not the training area of each researcher.

As shown in the table, exact and earth sciences and engineering are the most important fields as they represent respectively 39% and 34% areas of expertise of the total infrastructure surveyed. Biological sciences is the area of expertise of 14% of the surveyed infrastructure, while agricultural and health sciences account for only 5% each. The low level of participation in these last areas at research institutions related to the MCTI is explained, among other factors, by the fact that historically, research institutions with most relevant performance in those areas are related to the Ministries of Agriculture and Health, respectively.

3.2 Econometric models

The econometric models used in this paper are intended to support the analysis of the characteristics of the public research infrastructure (and of their fellow researchers), which affects its propensity to interact with the industrial sector. Several of these characteristics have been discussed in section 2 and, provided the data are available, the theoretical issues discussed previously in this paper are used in the models. Two dependent binary variables were used in the models. The first one – considered the most important in this paper – is the answer to the question on the provision of some kind of scientific or technological services to firms in 2011. Laboratories' coordinators were asked whether any kind of technological service was provided in 2011 (the reference year of the research) to firms, to governments and to other researchers not related to the laboratory.

Besides this variable, the answer to the question on the provision of some kind of scientific or technological services to firms in 2011 along with the identification of the firms to which they provided services has been used as well. This variable was converted into a dummy which is 1 if any kind of service was provided and 0 otherwise. This second variable was used to double check the results obtained using the first one for two main reasons. Firstly, the laboratory's coordinator may not want to inform the identification of the firms to which the service was provided. As a result, variable 2 might be underestimated. On the other hand, the laboratory's coordinator might have wrongly informed that provided services to firms but in fact the services had been provided, for example, to universities. In order to avoid this kind of error, the firm identification was checked in the Annual List of Social Information (Rais). Among the taxpayers mentioned by the coordinators, only private and public firms have been considered. Besides, taxpayers identifications belonging to the industries "public administration and defence; compulsory social security" (Brazilian Standard Industrial Classification CNAE 84), "education" (CNAE 85) and "activities of membership organizations" (CNAE 94) were not considered. As a result, services provided to other research institutions or to universities, for example, were not misinterpreted as services provided to firms.

In short, two variables may be used as dependent variables in the model in order to capture the interactions of the research infrastructure with the industrial sector:

- a dummy which is 1 if the laboratory's coordinator declared the provision of services to firms in 2011 and 0 otherwise;
- a dummy which is 1 if the taxpayer identification of the firms to which the services have been provided is informed and 0 otherwise.

As both variables are binary, a logistic model has been used to identify, in a wide set of explanatory variables, the characteristics of the research infrastructure which increase its probability of supplying technological services to firms.

The explanatory variables (chosen according to the background provided in section 2, particularly subsection 2.1) and their descriptions and sources are showed in box 1.

BOX 1
Name and description of explanatory variables used in the specifications of the models

Name	Description	Source
N_RESEARCHERS	Number of researchers working at the laboratory	Survey
%_PHD_MSC	Percentage of researchers with PhD or master degree working at the lab	Survey
N_PATENTS	Number of patents of the laboratory researchers, obtained from the National Institute for Intellectual Property Rights (INPI)	INPI
LN_ARTICLES	Logarithm of the number of scientific articles published by the laboratory research team informed in their curriculum (in Lattes Platform)	CV available at the National Counsel of Technological and Scientific Development (CNPq)
LN_BOOKS	Logarithm of the number of books published by the laboratory research team informed in their curriculum (in Lattes Platform)	Survey
LN_EQUIPMENTS	Logarithm of the total value (in R$) of the research equipment available at the laboratory	Survey
ACCREDITATION	Dummy variable for laboratories that are accredited to realize specific testing and trial activities	Survey
MULTIUSER	Dummy variable for laboratories that are open to users from other institutes and research centers	Survey
LAB_AGE	Number of years since the laboratory has initiated its activities.	Survey
RECENT_ INVESTMENT	Dummy variable that indicates if the laboratory has received significant investments in modernization or extension in the last five years (significant investment was defined, in the questionnaire, as an investment superior to 10% of the estimated value of the laboratory).	Survey
ENGINEERING	Dummy for laboratories in the field of engineering	Survey
EXACT	Dummy for laboratories in the field of exact and earth sciences	Survey
MULTIDISCIPLINARY	Dummy for multidisciplinary laboratories	Survey
PARA-PUBLIC	Dummy variable for the three para-public research institutions of the survey	Survey
SÃOPAULO	Dummy variable for institutions located in São Paulo	Survey

Source: The authors.

The variables "number of researchers working at the laboratory" and "logarithm of the total value (in R$) of the research equipment available at the laboratory" aim at measuring to which extent large research centers have higher probabilities of interacting with firms as discussed in the literature about Big Science" (Galison and Hevly, 1992; Autio, Hameri and Vuola, 2004; Vuola and Hameri, 2006). Of course these variables are limited to capture scale economies in technological production as proposed by Dundar and Lewis (1995) or by Cohn, Rhine and Santos (1989). Regardless scale economies, it is expected that a larger number of researchers increases the probability of interaction of a given laboratory with firms as a natural consequence of each researcher's social networks. Even though, it is interesting to check to which extent a larger research team increases the probabilities of interaction. Besides, this variable must be used as a control variable to avoid the effects of this dimension over the remaining estimated parameters.

The variable "percentage of researchers with PhD or master degree working at the lab" aims at capturing the effects of higher levels of qualification of the research team on the probability of interaction with firms as some previous studies argue that the characteristics of the researchers are even more relevant than of the institutions (D'Este and Patel, 2007). Accordingly, the impacts of the scientific and technological (patents) stock of the laboratory researchers is used in order to analyze to which extent these variables affect the probability of interaction with firms. Data on scientific papers refer to 2008, which is the most recent year available. However, provided the data refer to the stock accumulated over a long period (1994 to 2008), the use of more recent information would not significantly affect the results.

Laboratories that are accredited to realize specific testing and trial activities are expected to present higher levels of interaction with firms. Thus, a dummy variable for this information is used in the model. Another relevant variable is a dummy for laboratories that are open to users from other institutes and research centers.

A dummy variable that indicates if the laboratory has received significant investments in modernization or extension in the recent period was used as well in the model. Dummy variables to capture the field of expertise of the laboratories are also used. Provided the field of expertise of most laboratories is "exact and earth sciences", "engineering" or "multidisciplinary", these were the variables chosen. The results for these variables must be interpreted taking into account the remaining fields of expertise as a whole. Finally, a variable to capture the possible effect of the laboratory belong to a para-public research institution is used because of the less bureaucratic procedures these institutions have to face when providing services to firms.

Once detailed the dependent and explanatory variables, two probabilistic models have been used to analyze the characteristics of the public research infrastructure (and of their fellow researchers) which affects its propensity to interact with the industrial sector.

The first logistic regression model was used according to the specification below.

$$IP_i^* = \mathbf{w}_i'\boldsymbol{\gamma} + u_i \quad (1)$$

$$IP_i = \begin{cases} 1 & if \quad IP_i^* > 0 \\ 0 & otherwise \end{cases} \quad (2)$$

$$\begin{cases} IP(IP_i = 1) = \exp(\mathbf{w}_i'\boldsymbol{\gamma}) / 1 + \exp(\mathbf{w}_i'\boldsymbol{\gamma}) \\ IP(IP_i = 0) = 1 - [\exp(\mathbf{w}_i'\boldsymbol{\gamma}) / 1 + \exp(\mathbf{w}_i'\boldsymbol{\gamma})] \end{cases} \quad (3)$$

Where:

- IP_i^* denotes the provision of services by the laboratory *i*, that is equal to one when the laboratory answered yes to the question about provision of scientific or technological services to firms (first dependent binary variable) or when the laboratory informed names of the target firms (second dependent binary variable); and
- $\mathbf{w}_i'\boldsymbol{\gamma}$ is the vector of explanatory variables included in table 4. After a set of estimations, the following vector of variables was chosen: N_RESEARCHERS; %_PHD_MSC; N_PATENTS; LN_ARTICLES; LN_EQUIPMENTS; ACCREDITATION; MULTIUSER; RECENT_INVESTMENT; ENGINEERING; EXACT; MULTIDISCIPLINARY; PARA-PUBLIC.

It is reasonable to assume that laboratories affiliated to the same institution may have some correlation as a result of specific policies adopted by the institutions. As this possibility is not capture in the prevous model, a hierarchical logistic procedure (Dai, Li and Rocke, 2006) aiming at capturing possible correlations among laboratories affiliated to the same institution was used as well. The structure of the hierarchical logistic model is the following:

$$IP_{ij}^* = \mathbf{w}_{ij}'\boldsymbol{\gamma} + \alpha_j + u_{ij} \quad (4)$$

$$IP_{ij} = \begin{cases} 1 & if \quad IP_{ij}^* > 0 \\ 0 & otherwise \end{cases} \quad (5)$$

$$\begin{cases} IP(IP_i = 1) = \exp(\mathbf{w}_{ij}'\boldsymbol{\gamma} + \alpha_j) / 1 + \exp(\mathbf{w}_{ij}'\boldsymbol{\gamma} + \alpha_j) \\ IP(IP_i = 0) = 1 - [\exp(\mathbf{w}_{ij}'\boldsymbol{\gamma} + \alpha_j) / 1 + \exp(\mathbf{w}_{ij}'\boldsymbol{\gamma} + \alpha_j)] \end{cases} \quad (6)$$

Where,

- P_i^* denotes the provision of services by the laboratory *I*;
- $\mathbf{w}_i'\tilde{\mathbf{a}}$ is the same vector of explanatory variables used in the previous models; and
- α_j is the random effect associated to different hierarchical levels of institutions and laboratories.

4 RESULTS

The first relevant information regards the number of laboratories that provided services to firms according to their coordinators and the most usual services provided.

TABLE 3
Number of laboratories that provided scientific/technological services, according to the type of service provided and the target public (2011)

Type of service provided	Public Served				
	Total[3]	Companies	Researchers	Government	Other
Access to cell banks, microorganisms etc.	1	0	1	1	0
Analysis of material	38	28	34	14	11
Analysis of physicochemical properties	33	26	28	14	0
Calibration	15	7	10	7	1
Certification	7	5	3	2	0
Consulting and Si-Tech advising[1]	64	44	44	30	15
Development and improvement of process (process innovation)	50	30	38	17	6
Development and improvement of product (product innovation)	44	28	23	16	7
Development and testing of prototypes	30	15	18	13	1
Testing and trials	64	40	52	26	12
Laboratory tests	8	1	6	3	0
Technological information	19	9	17	9	8
Inspection	7	2	6	2	1
Maintenance of scientific equipment	7	2	4	5	0
Metrology	10	6	5	8	1
Scale-up	3	3	0	1	1
Environmental services[2]	18	10	14	12	4
Other	22	10	14	9	9
Total[3]	120	82	95	65	42

Source: ASCAV/SEXEC/MCTI from questionnaires given to coordinators of the laboratories of research institutions under the MCTI.
Notes: [1] It includes, among others, the following services: Si-Tech opinions; assistance for the acquisition and transfer of technology; product or process diagnosis; evaluation and application for registration of intellectual property; development of innovation projects; high-complexity technical response to etc.
[2] It includes, among others, the following services: environmental surveys; environmental inventory; environmental audits; environmental monitoring activities; georeferencing etc.
[3] The total number of laboratories/infrastructures providing services does not match the sum of values of the ones that provide each type of service separately, since the same laboratory/infrastructure can provide more than one type of service. The same applies for the public served.

The results (table 3) show that 120 (or 61% of the sample) laboratories provided some kind of technological or scientific service and, among them, 82 (42%) laboratories provided services to firms. The most common services are "testing and trials" and "consulting and advising".

Some laboratories informed the name and the taxpayer identification of the firms to which they provided services. Some taxpayer identifications referred to universities and research institutions and, as a result, were removed from the sample which eventually was formed by 61 laboratories that declared to have provided services to the industrial sector.

Table 4 shows some indicators based on these variables to the set of laboratories surveyed, according to the provision of services to firms. In either case, the share of accredited and multidisciplinary laboratories is larger in the group of laboratories that provided services to firms. The same happens to the number of patents registered by the researchers of the laboratories that provide services to firms. Concerning the scientific production, the results show a relatively smaller number of papers published by researchers in the laboratories more oriented to technological services, what could suggest a tradeoff between scientific and technological production. Regarding the remaining variables, the results seem to be quite blurry: there is no clear difference between market oriented laboratories and those that do not provide technological services to firms.

TABLE 4
Selected characteristics of the laboratories, according their interaction with firms – provision of scientific or technological services (2011)

	Answer to the "provision of scientific and technological services" question		The laboratory informed the names of client companies	
	No	Yes	No	Yes
Number of laboratories/infrastructures	114	82	135	61
Age (mean)	14	20	15	19
Number of accredited laboratories	11	12	13	10
(%)	10	15	10	16
Number of multidisciplinary laboratories	24	30	29	25
(%)	21.1	36.6	21.5	41.0
Number of multiuser laboratories	89	67	108	48
(%)	78.1	81.7	80.0	78.7
Number of laboratories that received significant investments in the last five years	78	52	89	41
(%)	68	63	66	67

(Continua)

(Continuação)

	Answer to the "provision of scientific and technological services" question		The laboratory informed the names of client companies	
Estimated value of the set of research equipment in the laboratory (US$ thousand)[1] – mean by laboratory	2,366	1,844	2,029	2,411
Total number of researchers	1,553	1,503	1,734	1,322
Total number of PhD and Master Degree researchers	527	513	606	434
(%)	34	34	35	33
Number of national papers published by laboratory´s research team between 1994 and 2008	4,722	2,485	5,362	1,845
Number of international papers published by laboratory´s research team between 1994 and 2008	862	790	1,033	619
Papers (national + international) by researcher (mean)	3.60	2.18	3.69	1.86
Number of patents registered at Brazilian Patent Office (INPI)[1]	19	33	21	31

Source: Elaborated by the authors using data from the questionnaire applied to research institutions related to the MCTI and secondary data from CNPq and INPI.
Note: [1] Based on the mean annual exchange rate in 2011.

Although interesting, the descriptive statistics presented in table 4 are not capable of precisely explaining the correlations among the variables. For this reason, table 5 shows the results of the logistic regressions regarding the two dependent binary variables.

TABLE 5
Characteristics that affect the probability of interaction with firms (logistic model)

Variable	Answer to the "provision of scientific and technological services" question				The laboratory informed the names of client companies			
	Estimate	Marginal effects	Std error	*P*-value	Estimate	Marginal effects	Std error	*P*-value
Intercept	-2.58	-1.06	0.97	0.01	-4.87	-1.46	1.30	0.00
N_RESEARCHERS	0.42**	0.17	0.22	0.05	0.76***	0.23	0.25	0.00
%_PHD_MSC	1.65*	0.68	0.87	0.06	1.35	0.40	0.99	0.17
N_PATENTS	0.08	0.03	0.13	0.53	0.09	0.03	0.14	0.53
LN_ARTICLES	-0.18*	-0.07	0.1	0.09	-0.25**	-0.07	0.12	0.03
LN_EQUIPMENTS	0.03	0.01	0.06	0.61	0.08	0.02	0.07	0.23
ACCREDITATION	0.41	0.17	0.53	0.44	0.41	0.12	0.56	0.46
MULTIUSER	0.02	0.01	0.42	0.96	-0.52	-0.16	0.46	0.26
RECENT_INVESTMENT	-0.29	-0.12	0.36	0.42	0.24	0.07	0.40	0.55
ENGINEERING	0.79	0.32	0.64	0.22	1.30	0.39	0.88	0.14
MULTIDISCIPLINARY	1.20*	0.49	0.63	0.06	1.90**	0.57	0.86	0.03
EXACT	0.51	0.21	0.63	0.41	1.22	0.36	0.87	0.16
PARA-PUBLIC	0.6	0.25	0.7	0.39	1.17	0.35	0.76	0.12
R-squared	14.90%	-	-	-	24.9%	-	-	-
-2 ln(Like)	251.2	-	-	-	228.5	-	-	-
AIC	253.2	-	-	-	230.5	-	-	-
H-L	6.9	-	0.55	-	7.44	-	0.49	-

Source: Elaborated by the authors using data from the questionnaire applied to research institutions related to the MCTI and secondary data from CNPq and INPI.

In both cases the model showed good fit statistics. The AIC value for the first dependent variable was 253.2 and for the second dependent variable was 230.5. Hosmer and Lemesow statistics was 6.90 and 7.44, respectively. After testing several combinations, several variables were not statistically significant; however, some of them were consistently significant across these combinations. In fact, the results showed that some variables affect positively the probability of interaction with firms:

- the size of the laboratory (measured by the number of affiliated researchers) was positive and significant in both models. Although this approach does not rely on a knowledge production function, the results are compatible with the hypothesis of economies of scale in research activities as discussed in subsection 2.3;
- the qualification of the research team of the laboratory is positively associated with the probability of interacting with firms. In fact, the share of MScs and PhDs in the research team increases the probability of interaction with firms, although this result was significant only in one of the two models estimated; and
- multidisciplinary laboratories are much more likely to provide technological and scientific services to firms than laboratories focused on just one field of expertise.

The negative impact is related with the number of articles published by the laboratory's research team. This result suggests a tradeoff between scientific and technological production for the laboratories included in the survey. This result may be a consequence of the somehow "idiosyncratic" nature of the laboratories included in the survey and cannot be extrapolated to the remaining of the Brazilian science, technology and innovation system. On the other hand, patenting activity by the researchers of the lab was not statistically significant in any of the models estimated.

The results of the hierarchical logistic model presented in table 6 below are very similar to the ones observed in the previous models. The only variable that became non-significant was the dummy for multidisciplinary laboratories. The negative correlation between articles published and provision of services disappeared in one of the criteria for the dependent variable.

TABLE 6
Determinants of the probability of interaction with firms: hierarchical logistic model

Variable	Answer to the "provision of scientific and technological services" question				The laboratory informed the names of client companies			
	Estimate	Marginal effects	Std error	P-value	Estimate	Marginal effects	Std error	P-value
Intercept	-2.16	-0.91	1.01	0.05	-3.58	-1.14	1.17	0.01
N_RESEARCHERS	0.38*	0.16	0.22	0.09	0.64***	0.20	0.24	0.01
%_PHD_MSC	1.76**	0.74	0.84	0.04	1.50*	0.48	0.91	0.09
N_PATENTS	0.07	0.03	0.13	0.56	0.09	0.03	0.14	0.52
LN_ARTICLES	-0.12	-0.05	0.11	0.25	-0.19*	-0.06	0.11	0.09
LN_EQUIPMENTS	0.02	0.01	0.06	0.73	0.08	0.03	0.07	0.22
ACCREDITATION	0.55	0.23	0.52	0.3	0.50	0.16	0.53	0.35
MULTIUSER	0.14	0.06	0.42	0.74	-0.40	-0.13	0.45	0.37
RECENT_INVESTMENT	-0.42	-0.18	0.35	0.23	-0.12	-0.04	0.37	0.74
ENGINEERING	0.35	0.15	0.56	0.53	0.22	0.07	0.62	0.73
MULTIDISCIPLINARY	0.79	0.33	0.53	0.14	0.85	0.27	0.59	0.15
EXACT	0.19	0.08	0.57	0.73	0.40	0.13	0.64	0.53
PARA-PUBLIC	0.28	0.12	0.9	0.76	0.52	0.17	0.97	0.60
R-squared	15.50%	-	-	-	23.7%	-	-	-
-2 ln(Like)	861.1	-	-	-	860.5	-	-	-
Covariance institutions	877.1	-	-	-	0.776	-	0.51	-

Source: Author's elaboration using data from the questionnaire applied to research institutions under the Ministry of Science and Technology, and secondary data from CNPq and INPI.

5 CONCLUDING REMARKS

This paper discussed the university-enterprise interactions in the Brazilian innovation system by focusing on the characteristics of the research infrastructure which affects its propensity to interact with the industrial sector. Logistic regressions have been used to identify, in a wide set of explanatory variables, the characteristics of the research infrastructure which increase its probability of supplying technological services to firms. Besides the primary data collected from a survey carried out in a sample of institutions related to the Brazilian Ministry of Science, Technology and Innovation (MCTI), data concerning the scientific and technological production of the researchers affiliated to each laboratory have also been used in the regressions. The choice of the explanatory variables was based in a brief literature review on the role of the research infrastructure in the national innovation systems and on the factors that affect the interactions between science, on one hand, and technology, on the other. Aiming at supporting the discussion of the results of the regressions, the review also included a brief report of the recent interactions between the scientific production and the industrial sector in Brazil.

The main findings of the logistic regressions are: i) the size of the laboratory (as measured by the number of affiliated researchers) and of the qualification of its research team positively and significantly affects its propensity to interact with the industrial sector; ii) multidisciplinary laboratories tend to interact more with the industrial sector than laboratories focused on a single field of expertise; and iii) there seems to be a tradeoff between scientific publications and market oriented research, since the number of papers published by the affiliated researchers is negatively correlated to the probability of supplying technological services to firms.

Given the "idiosyncratic" nature of the laboratories included in the survey, these results cannot be extrapolated to the remaining of the research institutions in Brazil. However, they reinforce the perception that the interactions between research infrastructure and the industrial sector could also be explained by the organization and characterization of the research infrastructure. The deepening of this research agenda requires additional information on the research institutions in the country as well as on their research infrastructure in order to analyze the factors which explain their interactions with the industrial sector. Besides, the identification of those bottlenecks is essential for the formulation of innovation policies able to leverage the production of technologies and the country's economic development in the long term.

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Composed in Adobe Garamond 11/13.2 (text)
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