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Siqueira Rapini, Marcia; Chiarini, Tulio; Bittencourt, Pablo; Caliari, Thiago

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The intensity of private funding and the results of university? Firm interactions: the case of Brazil

Marcia Siqueira Rapini
Centro de Desenvolvimento e Planejamento Regional, Belo Horizonte, MG, Brazil

Tulio Chiarini
Instituto Nacional de Tecnologia, Rio de Janeiro, Brazil

Pablo Bittencourt
Universidade Federal de Santa Catarina, Florianopolis, Brazil, and

Thiago Caliari
Instituto Tecnológico de Aeronáutica, Sao Jose dos Campos, Brazil

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Abstract

Purpose – The purpose of this paper is to investigate the academic side of university–firm linkages, reporting the results of research (called the "BR Survey", a primary database) conducted in Brazil with leaders of research groups that interacted with firms. The authors analysed the answers from 662 research groups (from both universities and research institutes) to investigate whether the intensity of private funds affects the results of the interactions. The main intent is to answer the following question: Is there a difference between funding sources and the type of results achieved by research groups when interacting with firms?

Design/methodology/approach – To verify the impact of some variables on the perception of the main results of university–firm interactions, highlighting the impact of funding sources, the authors present a Logit Model defined with binary dependent variables. The null value is categorized as a "scientific result" (new scientific discoveries and research projects; publications, theses and dissertations; human resources' and students' education) and the value 1 is classified as an "innovative/technological result" (new products, artefacts and processes; improvement of industrial products and processes; patents, software, design and spin-off firms).

Findings – The authors found that the modes of interaction (relationship types) and some knowledge transfer channels, besides the number of interactions with firms, have statistically significant coefficients, so their values present different impacts on the results of the interaction. The results suggest that the Brazilian innovation policy towards a more active and entrepreneurial role of universities is fostering innovative/technological results from university–firm interactions.

Originality/value – The originality of the study lies on the results found that given the fact that private funding sources do not affect the conventional mission of Brazilian universities – teaching and research – university research groups should be even more incentivized to search for private funds to

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carry out their research. This may be a solution to the public fund scarcity and may help in reducing the historical distance between universities and firms in Brazil.

Keyword Brazil

Paper type Research paper

1. Introduction

Universities and research institutes are claimed to be playing a new role by pursuing knowledge and its application for the creation of wealth (Geuna, 2001). Universities are seen as important parts of the modern capitalist engine (Nelson, 1990) and key actors in national innovation systems due to their direct and indirect contributions to the innovation process, as a pool of general and specific knowledge (Klevorick, Levin, Nelson, & Winter, 1995; Nelson, 1990), for personnel training to work in firms (Rosenberg & Nelson, 1994), as they develop new instruments and techniques (Rosenberg, 1992), and for the creation of spin-off firms (Brown, 2016).

The contribution to the innovation process is attached to a new rationale for funding and resource allocation and to a push for cooperation with industrial firms fostering technological and entrepreneurial results. This new rationale is based on a contractual-oriented approach and has unintended consequences (Geuna, 2001). In developing countries, the university – firm (U-F) interaction is also seen as a way to deal with the lack of resources (Brudenius, Lundvall, & Sutz, 2009).

Within this new framework, some studies attempt to investigate the role of industrial funding in the university research and training mission (Florida & Cohen, 1999; Gulbrandsen & Smeby, 2005; Hottenrott & Thorwarth, 2011; Perkmann & Walsh, 2009; Van Looy, Ranga, Callaert, & Zimmermann, 2004). Public funding is also investigated, as it could foster interactions with firms by establishing different collaborative channels (Muscio, Quaglione, & Vallanti, 2013) or institutional mechanisms (Freitas *et al.*, 2010). Although there are few studies from developing countries (Giuliani, Morrison, Pietrobelli, & Rabellotti, 2010; Petersen, Kruss, Mcgrath, & Gastrow, 2016), there are none from Brazil that investigate the consequences of private funding for the universities' traditional mission. This is our contribution in this article.

In Brazil, the main locus of knowledge production is public universities (Chiarini & Vieira, 2012; Oliveira & Moraes, 2016). The Brazilian university system developed late (Maculan & Mello, 2009; Mello, Maculan, & Renault, 2009), and Brazilian scientific activities are concentrated mainly in the south and southeast regions of the country and only in a few institutions (Chiarini, Oliveira, & Do Couto E Silva Neto, 2013). The Brazilian innovation system is also characterized by weak links to production activities (Rapini, 2018).

The objective of this paper is to investigate the academic side of university–firm linkages, reporting the results of research (called the "BR Survey", a primary database) conducted in Brazil with leaders of research groups that interacted with firms. We analysed the answers from 662 research groups (from both universities and research institutes) to investigate whether the intensity of private funds affects the results of the interactions. We classify interaction results as:

- *scientific*: new scientific discoveries and research projects; publications, theses and dissertations; human resources' and students' education; and
- *technological/innovative*: new products, artefacts and processes; improvement of industrial products and processes; patents, software, design and spin-off firms.

To reach our goal, this article is organized as follows. Section 1, we present briefly a literature review on the private funding of U-F interactions and its impacts on universities' activities. After delving deeply into the literature, we show that studies on the impact of private funding on universities' activities are scarce in Brazil in Section 2. Therefore, in Section 3, we present some facts about U-F interactions in Brazil and its funding scheme. In Section 4, we present the database and the models used in the analyses. We use an econometric logit model in which we test the influence of different sources of funding on the type of result (scientific versus technological), controlling for other variables. In Section 5, we present the results and discussions, and finally, we conclude the paper in the light of the literature in Section 6, the Brazilian specificities and the implications for further research.

2. Private funding of U-F interactions and academic results

Innovation is shaped by a variety of institutional routines, social conventions and interactions. The systems of innovation (SI) approach interpret innovation as an interactive process and considers that countries differ in terms of institutions and patterns of specialization (Lundvall, 1992). That said, all parts and aspects of the economic structure and the institutional set-up that affect learning as well as searching and exploring innovative activities are studied by SI scholars. Within this framework, U-F interactions are especially relevant, as universities are important institutions in the knowledge society (Vedovelho, 1998).

The fact that universities are no longer "ivory towers" aimed at producing knowledge for their own use is also important to demonstrate that universities are now seen as instruments of a knowledge-based economy to promote development and change (Mowery & Sampat, 2005). Universities have to satisfy the knowledge needs in terms of teaching and research for economic development at the local, regional and national levels (Geuna, 1999).

Mowery and Sampat (2005) summarize the reasons attributed to the approximation of universities with the productive sector. From the business side:

- the rising costs of research associated with the development of products and services, which are necessary to ensure advantageous positions in an increasingly competitive market;
- the need to share the cost and risk of pre-competitive research with other institutions that have government financial support;
- the high rate of introduction of innovations in the productive sector and the reducing interval of time between obtaining the first results of research and its application;
- the decrease in government funding for research in sectors that were previously fostered strongly, such as those related to the military industrial complex.

From the university perspective, the main motivations are:

- the increasing difficulty in obtaining public funding for university research; and
- the interest of the academic community in legitimizing its work by the society that is largely responsible for the maintenance of universities.

According to Nelson (1990), private firms fund research at universities to receive some sort of advantageous access to that research or its findings. When funding academic research, private firms expect to affect not only the results but also the benefits of this action. From an evolutionary economics perspective, the search for differentiation and innovation leads the competition mechanism in the market, and cooperation is a vital ingredient in complex adaptive systems (Beinhocker, 2007), so firms are incentivized to seek interactions with other actors, including universities and research institutes.

Geuna and Muscio (2009, p. 97) suggest other important factors, such as pecuniary ones:

> [. . .] the move towards reduced and more efficient government intervention in the economy [. . .]; government budget constraints due to the cap imposed by the new view on the role of the state [. . .], and the high spending on health and pensions [. . .].

Empirical data from the past 30 years show a decrease in the importance of government funds for academic research. Taking into consideration the higher education expenditure on R&D (HERD) by the source of funds, one can find that France, Germany, Italy, the UK and the USA, without exception, witnessed a decrease in the importance of government funds (from the 1980s to the 2000s), remaining above 60 per cent (Geuna & Rossi, 2015).

The rise in the share of the other sources of funds, such as business, has compensated for the declining importance of government funding. The German[1] HERD, for instance, at 2010 prices and PPPs, in 2000 was US$11,496m, of which 11.6 per cent was provided by firms. In 2010, the total HERD was US$15,028m, of which the business sector funded 13.8 per cent [2] (Geuna & Rossi, 2015).

The shift in the economy in the late 1970s (economic crises and inflation elevations, putting national budgets under strain) put pressure on public university research funding (Geuna, 2001). Science and innovation policy pressures to "make scientific research more relevant than in the past" (Goldfarb, 2008, p. 43) strengthened the new rationale for resource allocation. Thus, universities had to contribute more directly to industrial innovation and to (local) economic growth and had to be engaged in the commercialization of knowledge (Reddy, 2011).

This complex relation is investigated following different approaches (Etzkowitz & Leydesdorff, 2000; Lundvall, 1992; Nelson, 1993), and the empirical evidence in the literature is vast. However, empirical evidence of the impact of industry-funded research on university research is ambiguous. Generally, the literature focuses on changes in publishing performance (; Gulbrandsen & Smeby, 2005; Hottenrott & Thorwarth, 2011; Perkmann & Walsh, 2009; Van Looy et al., 2004) and on the research agenda – commonly called the "skewing problem" (Florida & Cohen, 1999; Van Looy *et al.*, 2004).

Some authors focus on the changes in the research agenda and on the conflicts between the open science culture and the pressure to commercialize (Gulbrandsen & Smeby, 2005). Policies focusing on the commercialization of academic research results can undermine the "public commons of science" and weaken the open science institutions through the imposition of private norms on public activities (Nelson, 2004). It, perhaps, achieves some efficacy in the short-term exploitation of the stock of scientific knowledge, but in the long term, there is a risk of the fragmentation of networks of tacit knowledge. These would put at risk not only the growth of this knowledge base but also the flow of economic benefits derived from the existence of this base (Dasgupta & David, 1994). Thus, the short-term orientation of projects with firms could affect the research agenda and the generation of knowledge in universities (Feller, 1990).

Another implication is the education of students. Stephan (2001, pp. 200-201) analyses the impact of technology transfer on curricula and programmes. She points out that there is the potential for technology transfer to "divert faculty away from students and curriculum" and a propensity to "withhold information from colleagues and students", delaying the speed of publications.

Hottenrott and Thorwarth (2011), analysing the responses of 678 professors from research units in German higher education institutes, find that professors with industry funds publish less, reinforcing the "skewing problem". Czarnitzki, Wolfgang, and Hussinger (2009) analyse 3,000 German researchers and find that patenting with non-profit organizations does not reduce the publication output and even increases citations' impact, but collaborations with corporations have a negative impact on the publication outcome. They conclude that the underlying effort involved in generating such patents distracts scientists from their other more fundamentally orientated research tasks.

According to other authors, industrial funding could increase flexibility and autonomy for researchers (Benner & Sandstrom, 2000), enhance academic groups' publications (Godin & Gingras, 2000; Ranga et al., 2003) and improve the impact and quality of applied research (Hottenrott & Thorwarth, 2011), reinforcing academics' research mission. Industrial funding is also important to provide access to better equipment and additional financial resources for conducting a larger number of experiments and to supply new ideas (derived from industrial demands) (Siegel, Waldman, Atwater, & Link, 2003).

Gulbrandsen and Smeby (2005), investigating professors in Norway, find that industry funding does not seem to conflict with more traditional academic goals and rewards. Moreover, they do not find a negative relationship between academic and commercial efforts, so professors are able to combine entrepreneurial activities with an average level of scientific publishing. Industry-funded research contracts also introduce new and interesting research topics. Furthermore, they are related to a highly collaborative mode of research and to high publication proliferation[3]. Finally, industry-funded research contracts are correlated with the production of patents and commercial products, the creation of spin-off companies and involvement in consulting work, which are commercial/entrepreneurial results.

Van Looy, Ranga, Callaert, and Zimmermann (2004, p. 439), investigating the Catholic University of Leuven (in Belgium), find no evidence for the so-called "skewing problem" in terms of shifting towards a more applied spectrum at the expense of more basic publications. They conclude that it is feasible to combine scientific and entrepreneurial activities "without one jeopardizing the other". Thursby et al. (2007) find that the research output and the stock of knowledge are generally larger with licensing than without it, concluding that the applied research effort contributes to the stock of knowledge.

The literature also highlights that industrial and public funds are complementary for university research. They are strategic complements (Jensen, Thursby, & Thursby, 2010; Muscio et al., 2013). For some areas (especially the ones in Pasteur's quadrant[4]), there is no substitution effect between commercialization (technology transfer and patents) and publishing (Murray & Stern, 2005; Geuna & Nesta, 2006). There are complementarities, as practical knowledge has consequences for basic research.

As we showed in the literature review briefly presented above, there is no consensus about the impact of industrial funding on universities' activities in developed countries. Regarding Brazil, there are some recent studies on the impacts of U-F interactions on researchers' productivity (Alvarez, Kannebley, & Carolo, 2013; Carolo, 2011), on firms' innovative efforts (Esteves & Meirelles, 2009; Spricigo, Monteiro, & Freguglia, 2016) and on firms' motivation to interact (Rapini, Oliveira, & Silva Neto, 2014). However, after a systemic review, we identified a gap in the literature that deals with private funds' impacts on U-F interactions in Brazil. In this article, we address that neglected issue and provide some elements to fill the gap.

3. U-F interactions in Brazil

3.1 Brazilian U-F interactions and innovation stylized facts

The Brazilian innovation system shows some specificities. According to the Brazilian Ministry of Education and Culture (INEP/MEC), in 2013, there were 195 Brazilian universities, of which approximately 57 per cent were public (federally, state or municipally funded) and about 43 per cent were private. Nevertheless, if all higher education institutions (universities, university centres and colleges) are considered, there were 2,391 institutions, of which only about 13 per cent were public. In the 2000s, 22 federally funded universities were legitimized and established (of which 3 were created in 2013), accounting for 62 federally funded universities, which are unequally distributed throughout the Brazilian territory: 31 per cent of those universities are concentrated in the southeast region, while only 8 per cent are in the central-west region.

Despite the initiatives to increase the number of public universities, the knowledge production is highly uneven. Only four states (the "scientific quartet", formed by Sao Paulo, Rio de Janeiro, Rio Grande do Sul and Minas Gerais) accounted for 57.7 per cent of all Brazilian research and 73.3 per cent of all domestic production of papers published in national and international journals in 2010. The four states form the epicentre of Brazilian science, thanks to a few high-standard institutions, such as the *Universidade de São Paulo* (USP), *Universidade Estadual de Campinas* (UNICAMP), *Universidade Estadual Paulista* (UNESP), *Universidade Federal de Minas Gerais* (UFMG), *Universidade Federal do Rio de Janeiro* (UFRJ), *Universidade Federal do Rio Grande do Sul* (UFRGS) and *Fundação Oswaldo Cruz* (FIOCRUZ) (Chiarini et al., 2013).

Another particularity of the Brazilian innovation system is the lack of a budget for research in universities, even though professors have to conduct research among their statutory activities. Research activities are funded by competitive public resources or partnerships with companies (and in many cases by competitive bids)[5]. Paranhos (2010), for example, investigates U-F interactions in the pharmaceutical sector in Brazil and finds a weak relation between firms and universities. One of the reasons pointed out is the absence of a research budget. According to Paranhos (2010, p. 304), this may be:

> [. . .] one of the reasons why researchers often transform their partnership projects in basic research. This trend, widely criticized by companies, makes the partnership of government-funded projects often end up far from any use or commercial application.

This differs from other countries, in which universities have a budget for research and the enterprise resource "can really be considered an extra resource".

Another characteristic of the Brazilian innovation system is that Brazilian firms face shortages of appropriate sources of funding for innovation. According to the Brazilian Innovation Survey (PINTEC), in 2000 47.3 per cent of innovative firms attributed "high importance" to the shortage of appropriate funding sources as an obstacle to innovation, and in 2011 the figure was 42.6per cent[6]. Besides this, innovative Brazilian firms spend more on machine and equipment acquisition than on activities related to knowledge generation and absorption, such as R&D.

In 2011, for example, 46.9 per cent of innovative firms' expenditure on innovative activities resulted from the purchase of machines and equipment, while 29.8 per cent was devoted to indoors R&D activities (Table I). Internal R&D activities are important to contribute to firms' absorptive capacity (Cohen & Levinthal, 1989) and are relevant to searching for and monitoring knowledge generated outside the firm, especially from universities (Rosenberg, 1990). The other activities are the ones that firms could acquire from universities (though not necessarily) as external R&D, other external knowledge and training[7].

Various studies (Chaves, Carvalho, Silva, Teixeira, & Bernardes, 2012; Fernandes et al., 2010; Suzigan, Albuquerque, Garcia, & Rapini, 2009) show that interactions with firms are less complex and focus on the routine production of the company (such as testing and

Variables	2000	2003	2005	2008	2011
Total firms	72,005	84,265	95,301	100,496	116,632
Innovative firms/total firms (%)	31.5	33.3	34.4	38.1	35.5
Expenditure on innovative activities/total expenditure (%)					
Machines and equipment	52.2	49.7	48.4	49.2	46.9
Internal R&D	16.8	22.0	20.9	24.5	29.8
External R&D	2.8	2.9	2.8	4.0	4.4
External knowledge acquisition	5.2	3.4	4.7	2.7	2.8
Training	1.9	2.0	1.8	2.1	1.2
Cooperation with universities and research institutes					
Total innovative firms that cooperate	867	539	1,067	1,540	3,039
Innovative firms that cooperate (%)	11.0	3.8	7.2	10,1	15.9
Cooperation goal: R&D and product tests	–	354	663	924	1,626
Cooperation goal: other activities	–	185	404	626	1,413

Source: Authors' own. Data sourced from the PINTEC database

Table I.
Innovative efforts of Brazilian firms, 2000-2011

assistance in quality control)[8]; however, since 2003 innovative firms have cooperated relatively more with universities and research institutes. In 2011, they represented 15.9 per cent of the total innovative firms (Table I). According to PINTEC, firms' goal in cooperation with a university embraces R&D and tests for products and other activities. The R&D and test goals are slightly more numerous than other cooperative activities, representing 53.5 per cent of the total cooperation goals in 2011.

There is empirical evidence that shows that Brazilian innovative firms cooperate more with universities, and there is some evidence that shows that firms see universities as partners for knowledge generation (Fernandes et al., 2010; Suzigan & Albuquerque, 2011). However, there are no data regarding the Brazilian higher education expenditure on R&D (HERD) by source of funds. A recent survey realized by IPEA (De Negri & Squeff, 2016) to map the scientific infrastructure (laboratories) in Brazilian institutions shows that only 7.36 per cent of the funding for scientific infrastructure are from private firms. The other 92.6 per cent are from public sources (national, regional or public enterprises, especially Petrobras). Due to this lack, there is no statistical evidence to track the degree to which Brazilian universities rely on industry funding.

The rise in U-F cooperation in Brazil can be explained by the upsurge of public programmes and instruments to foster innovation and interaction between firms and universities/research institutes. This will be described in the next subsection, and elements to characterize the funding system in Brazil will be provided.

3.2 Characteristics of the funding sources of Brazilian U-F interactions

Araujo (2007) and Paranhos (2010)) find that public funding in Brazil acts as a sort of catalyst to bring universities and firms closer together. The public funds come from institutions that support scientific and technological development through non-recoverable funds and began in the 1950s. For example, the National Council for Scientific and Technological Development (*Conselho Nacional de Desenvolvimento Científico e Tecnológico*, CNPq) and the Coordination for the Improvement of Higher Level Personnel (*Coordenação de Aperfeiçoamento de Pessoal de Nível Superior*, CAPES) were both created in 1951 to build human resources' capabilities in research and to finance scientific research projects. Later, the National Fund for Scientific and Technological Development (*Fundo Nacional de Desenvolvimento Científico e Tecnológico*, FNDCT)[9] was established to finance initiatives for building enterprises' productive and technological capacities (Ferrari, 2002).

On the same track, the Finance Agency for Studies and Projects (*Financiadora de Estudos e Projetos*, FINEP) was created in 1967, whose aim was to finance science, technology and innovation in firms, universities and research institutes. The FINEP has a set of different programmes and modalities for finance and fund innovation as credit, non-reimbursable resources and venture capital funds (Ferrari, 2002). The FINEP operationalizes different funds, such as the Green-Yellow Fund (*Fundo Verde-Amarelo*), which aims to foster U-F cooperation (Centro de Gestão e Estudos Estratégicos [CGEE], 2002).

The National Bank of Economic and Social Development (*Banco Nacional de Desenvolvimento Econômico e Social*, BNDES) was created at the beginning of the 1950s, aiming fundamentally to finance tangible assets, investment in infrastructure and both the creation and the expansion of production capacity in national enterprises. In 2004 the BNDES started to finance innovative projects and intangible assets (Além & Giambiagi, 2010; Fingerl, 2004).

State agencies (*Fundações de Amparo à Pesquisa*, FAPs) were created with the same objective, and the São Paulo Research Foundation (*Fundação de Amparo à Pesquisa de São Paulo*, FAPESP) is by far the most important of them[10]. They also foster U-F cooperative projects. The FAPESP, for example, operates the Research Partnership for Technological Innovation Program (*Programa de Apoio à Pesquisa em Parceria para Inovação Tecnológica*, PITE) with this goal and an innovative research programme for small enterprises (*Pesquisa Inovativa em Pesquenas Empresas*, PIPE). The FINEP deploys the Research Support Programme for Micro and Small-Sized Enterprises (*Programa de Apoio à Pesquisa para Micro e Empresas de Pequeno Porte*, PAPPE) to promote the technological development of enterprises, inducing them to approach teaching and research institutions (Carrijo & Botelho, 2013; Torres & Botelho, 2018).

In 2008, the CNPq created the Training Programme for Human Resources in Strategic Areas (*Programa de Formação de Recursos Humanos em Áreas Estratégicas*, RHAE). This programme uses a set of scholarships, especially created to provide companies with highly qualified personnel in R&D activities, in addition to forming and training human resources to act in projects for applied research or technological development.

The Innovation Law (*Lei da Inovação*), approved in 2003, introduced a change into the intellectual property management and technology transfer systems in Brazilian universities, as it provided legal support and set incentives for the commercialization of the results of scientific and technological research. With this new milestone, the creation of technology and transfer offices (*Núcleos de Inovação Tecnológica*, NITs) in public universities became mandatory. Additionally, the Innovation Law set guidelines for technology licensing and the distribution of royalties in universities. The Brazilian Congress reviewed the Innovation Law in 2016, and a new legal framework (*Marco Legal da Inovação*) was approved to solve some of the legal problems identified, especially regarding NITs' operation (Rauen, 2016).

Recent empirical studies show that there is a positive influence between U-F interactions and the results of firms' innovation activities in Brazil, which are positively affected by the use of public funds (Puffal et al., 2016; Silva, Furtado, & Vonortas, 2017). Other studies focus on the evaluation of some of the programmes presented above. Arbix and Consoni (2011), for instance, investigate the institutional changes at the *Universidade Estadual de Campinas* (UNICAMP), *Universidade de São Paulo* (USP) and *Pontifícia Universidade Católica do Rio Grande do Sul* (PUC-RS) with the creation of NITs. They find that all the activities related to the protection of intellectual property and to the transfer of know-how have been accelerated. Additionally, there was an important increase in the patent applications filed at the National Institute of Industrial Property (*Instituto Nacional de Propriedade* Industrial, INPI).

Carrijo and Botelho (2013) in turn investigate the PAPPE programme in three Brazilian states and find that it is important to maintain and/or strengthen partnerships. In another study, Torres and Botelho (2018) found that interactions with university foster more radical innovations in medium and small-sized firms, as it reduces the technical and technological risk. Salles-Filho (2011) evaluates the PITE and finds that the programme stimulated new partnerships between firms and universities (about 75 per cent of the total firms relate more intense and frequent partnerships with universities/research institutes and 40 per cent of firms that did not routinely make contact with universities/research institutes started to do so because of the programme).

Public funds were decisive in fostering partnerships in highly innovative projects, and private funding was often used for incremental innovations in firms (Araujo, 2007; Paranhos, 2010). On the same track, Rapini, Oliveira and Silva Neto (2014) conclude that collaborative projects that are funded 100 per cent by Brazilian private firms aim to achieve incremental improvements, which are less costly and less risky and have higher appropriability.

The previous studies show the importance of public funds and government-designed programmes to foster the approximation and the interactions between firms and universities. Although this is not a new phenomenon in Brazil, as interactions with public firms have existed since the 1970s, interaction on this scale (Table I) is new. Therefore, it is relevant to investigate the impacts of private funding on universities' results and research.

Alvarez, Kannebley, & Carolo (2013), for example, investigate the impact of interactions with firms for 316 researchers in exact and earth science from Sao Paulo State universities. They find positive relationships between interactions with firms and scientific productivity, measured in articles' number and impact. In turn, Carolo (2011) investigates 394 studies that interacted directly or indirectly with Petrobrás and finds that research projects with CT-Petro[11] resources experience an increase in researcher productivity of 10.4 per cent. In addition, regarding Petrobrás, Gielfi, Furtado, & Tijssen (2017) show that the enlargement of Petrobrás's collaborative network is a result of the R&D funding policy and that there is an upward trend in Petrobrás–university inventive collaboration.

However, as already mentioned, there is a gap in the literature that deals with private funds' impacts on U-F interactions in Brazil, and in the next section, we present some empirical data from the "BR Survey" that can help in filling out this gap. We use an econometric model to infer statistically whether the intensity of private funds matters to the results of U-F interactions.

4. Database and models

4.1 The university "BR survey"

The organization of the university survey involved two steps. The first one was the construction of a database from the Directory of Research Groups (DRG) of the National Council for Scientific and Technological Development (CNPq) embracing all research groups with interactions with firms and other institutions. The CNPq's DRG gathers information from public and private universities, public scientific research institutes and public technology institutes. In the 2004 Census, there were 375 universities and research institutions and 19,470 research groups in Brazil. This directory, since the 2002 Census, has held information about the interactions established between these research groups and firms and other institutions.

The questionnaire involved some key questions about the nature of the interactions with firms:

- modes of interaction;
- results from the interaction;
- benefits for the university group;
- difficulties with the interactions; and
- channels of information flow from research groups towards firms.

Groups were requested to answer the questionnaire considering the interaction that took place in the past three years. The survey was conducted in 2008-2009. The questionnaires were sent to the leaders of 2,151 research groups, and answers were received from 1,005 research groups (46.7 per cent of the total), located in all the Brazilian federal states. Each question presents a four-level scale embracing "not important", "not very important", "moderately important" and "very important".

Taking into account data from the "BR Survey", we found that most of the collaborative projects were financed with public funds (51.3 per cent), especially through public agencies such as the FINEP, CNPq, FAPs and BNDES, demonstrating the role of the Brazilian Government in supporting scientific projects. This is also a particularity of peripheral economies where the state has to provide support for public research (either in the federal or the state sphere) (Cassiolato, Lastres, & Maciel, 2003). However, the participation of firms (46.7 per cent) and the resources of their own institutions (33.8 per cent) are also relevant in Brazil. International agencies fund over 20 per cent of collaborative projects (Table II).

4.2 Models and variables

To verify the impact of some variables on the perception of the main results of U-F interactions, highlighting the impact of funding sources, we present an econometric model (logit model) in this section. The main intent is to answer the following question: is there a difference between funding sources and the type of results achieved by research groups when interacting with firms? This statistic exercise has the clear intent to corroborate the previous discussion presented on this paper.

From the "BR Survey", we extracted the questions answered by research group leaders. The main objective here is to verify the importance of distinct sources of funding to the interaction results.

We defined a logit model[12] with binary dependent variables (0 or 1). The null value is categorized as a "scientific result" (new scientific discoveries and research projects; publications, theses and dissertations; human resources' and students' education) and the value 1 is classified as an "innovative/technological result" (new products, artefacts and processes; improvement of industrial products and processes; patents, software, design and

Table II. Average percentage of collaborative projects funded by different sources, Brazil, 2009

Source	Average (%)
University or research institute	33.8
Industry	46.7
National public institutions (FINEP, CNPq, FAPs, BNDES)	51.3
International funding agencies (World Bank, IDRC, IDB)	20.6

Source: Authors' own. Data sourced from the "BR Survey", 2009 spin-off firms). We also readjusted the answers provided by those respondents, as shown in Table III.

Therefore, we have y = 1 if an innovative/technological result is achieved and y = 0 if the result obtained is scientific. The logit model proposed is then defined as[13]:

$$logit\{P(Y=1|X)\} = G(x\beta) \equiv p(x),$$

where x is *1xK*, b is *Kx1* and we take the first element of x to be unity. *G(z) =z* is the identity function. In the specific logit case, $G(z)$ takes the following usual form:

$$G(z) = \wedge(z) \equiv \exp(z)/[1+\exp(z)].$$

Error term e (from $y^* = x\beta + e,\ y = 1[y^* > 0]$) is normally distributed. The model is estimated by the maximum likelihood function with a log-likelihood function for each observation i, so the density of y_i given x_i is:

$$f(y|x_i;\beta) = [G(x_i\beta]^y[1-G(x_i\beta]^{1-y},\ y = 0, 1.$$

Thus, the log-likelihood function for each observation i is a function of *Kx1* parameters from x_i and y_i. The econometric models' specification follows as below:

$$\begin{aligned} result\ (science\ or\ technology) = {} & \alpha_1 + \alpha_2 \cdot (funding\ sources) + \alpha_3 \cdot (scientific\ factor) \\ & + \alpha_4 \cdot (relationship\ with\ firms) \\ & + \alpha_5 \cdot (relationship\ types) + \alpha_6 \cdot (scientific\ areas) \\ & + \alpha_7 \cdot (knowledge\ transfer\ channel\ type) + \varepsilon_i \end{aligned}$$

Main results of the interaction ("BR Survey")	Own classification
New scientific discoveries	Scientific (0)
New research projects	Scientific (0)
New products and artefacts	Innovative/technological (1)
New industrial processes	Innovative/technological (1)
Improvement of industrial products	Innovative/technological (1)
Improvement of industrial processes	Innovative/technological (1)
Human resources' and students' education	Scientific (0)
Theses and dissertations	Scientific (0)
Publications	Scientific (0)
Patents	Innovative/technological (1)
Software	Innovative/technological (1)
Design	Innovative/technological (1)
Spin-off firms	Innovative/technological (1)

Source: Authors' own

Table III. Main results of the interaction ("BR Survey") versus the new classification for the logit model

The explanatory variables are the following:

(1) *Funding sources:* the "BR Survey" allowed us to define four funding sources:
   - public funding;
   - university/research institute funding;
   - firm funding (private funding); and
   - international agency funding.

Unfortunately, just four groups in the "BR Survey" present the funding type "international agencies of funding" as the most important funding source, and 94 per cent of the research groups have values for this funding source equal to zero. Considering the low relevance of this source and the little information that we had about it, it was removed from the analysis.

At this point two possible specifications are set for the consideration of funding sources in the logit model:

- *Specification 1:* The share of each funding source in the total research group funding.
- *Specification 2:* A dummy variable to specify the main type of funding received by research groups, according to the possible sources specified above. The main funding source is defined as the one that has the highest percentage of funding.

All the other dependent variables are defined equally for the two models.

(2) *Scientific factor:* the factor obtained by the method of factor analysis (FA)[14] with the following variables (for each research group):
   - Number of articles indexed in ISI;
   - Number of articles indexed in Scielo; and
   - Number of researchers.

The first factor for the FA method allowed us to explain 91.56 per cent of the cumulative proportion of variance of the variables. Some articles show that innovative firms mostly use university research that is performed in high-quality research universities and published in qualified academic journals (Mansfield, 1995; Narin, Hamilton, & Olivastro, 1997; Pavitt, 2001). Therefore, the quantity and quality of scientific academic research influence the U-F relations.

(3) *Relationships with firms:* the number of relationships between research groups and firms. Interactions with firms increase the experience of collaboration, reducing the transaction- and orientation-related barriers (Brunnel, D'este, & Salter, 2010), and thus raise the propensity to have innovative/technological results.

(4) *The relevance of relationship types*: a variable constructed from the reclassification of the importance given to the different relationships types. Some studies show that the interaction results depend on the modes of interaction (Perkmann & Walsh, 2009) and that the modes of interaction are related to different funding sources (Jensen et al., 2010). Using the "BR Survey", we could classify eleven types of relationship, and then there was the possibility to determine the relevance of these relationships on a discrete scale from one to four, that is, from the most important to the least important. We thus reclassified the eleven types of relationship into four new categories, based on Arza (2010) (Table IV):

Modes of interaction	Type	Category
Technology transfer (licensing)	Technology transfer	1
Short-term R&D collaborative projects	R&D	2
Long-term R&D collaborative projects	R&D	2
R&D projects that complement innovative activities in firms	R&D	2
R&D projects that substitute innovative activities in firms	R&D	2
Tests	Services	3
Technical evaluations, project management	Services	3
Engineering services	Services	3
Consultancy	Training/consultancy	4
Training and courses	Training/consultancy	4
Temporary personnel exchanges	Training/consultancy	4

Source: Authors' own

Table IV. Modes of interaction and classification

- Category 1: technology transfer;
- Category 2: R&D;
- Category 3: services; and
- Category 4: training/consultancy.

With the classification proposed above, we defined the simple average for each one of the new categories and used the results as the explanatory variable in the model.

(5) *Scientific areas*: a dummy variable for knowledge fields:

- agricultural sciences;
- biological sciences;
- health sciences;
- exact and earth sciences;
- humanities;
- social sciences;
- engineering; and
- linguistics, literature and arts.

The base category is the knowledge area agricultural sciences. Some papers show that the specificities of scientific area and sector influence U-F interactions and results (Cohen, Nelson, & Walsh, 2002). In addition, the share of industrial funding varies according to the technical field (Meyer-Kramer & Schmoch, 1998) and public funding and private funding vary according to the scientific area (Goldfarb, 2008; Muscio *et al.*, 2013).

(6) *Most important knowledge transfer channel type*: the "BR Survey" presents 16 types of knowledge transfer channels. Therefore, this variable concerns the most important knowledge transfer channel according to the leader of each research group. The inexistence of a main channel is the base category for comparison (Table V). Types of governance for knowledge transfer are related to the funding structure and to different results in U-F interactions (Freitas et al., 2010). In addition, different channels are related to different benefits and results from U-F interactions (Arza, 2010).

Table V.
Channels of knowledge and information exchange

Type	Channels of information
Open science	Public conferences and meetings Publications and reports
Educational channel	Training Recently hired graduates
Commercial channels	Temporary personnel exchange Patents Licensed technology
University–firm research collaboration channels	R&D cooperative projects Research contracts Spin-offs from universities Engagement in networks with firms Incubators Individual consulting Informal information exchange Science and/or technology parks

Source: Authors' own

Table VI.
Explanatory variables and theoretical justification

Variables	Theoretical justification
Funding sources	–
Scientific factor	Mansfield (1995), Narin, Hamilton, and Olivastro (1997), Pavitt (2001)
Relationships with firms	Brunnel, D'este, and Salter (2010)
Relevance of relationship types	Perkmann and Walsh (2009), Jensen, Thursby, and Thursby (2010)
Scientific areas	Cohen, Nelson and Walsh (2002), Meyer-Kramer and Schmoch (1998), Goldfarb (2008), Muscio, Quaglione and Vallanti (2013)
Most important knowledge transfer channel type	Freitas et al. (2010), Arza (2010)

Source: Authors' own

We present the explanatory variables and their theoretical justifications in Table VI, as a way to facilitate the understanding.

After the definition of models and variables, we are able to present the results. Among the 1,005 respondents groups in the "BR Survey", some groups were excluded from the sample for the following reasons:

- *Linguistics, literature and arts groups*: only six groups belong to this knowledge field, and, as the amount of information is less than the degrees of freedom of the econometric model, these groups had to be removed from the analysis;
- In 333 groups, the sum of the percentages of funding sources does not equal 100 per cent.

In the end we considered 662 research groups for our estimation models (Specification 1 and Specification 2). A descriptive analysis of the dependent variable shows that 522 groups (78.9 per cent) indicate a "scientific result" as the main result of the interaction and 144 groups report a "technological result" as the main result of the interaction (21.1 per cent).

5. Results and discussion

We found that the two models (Specification 1 and Specification 2)[15] have similar results regarding the statistical significance of the models as well as the coefficients' values and the statistical significance of the dependent variables (Table VI).

The modes of interaction (relationship types) and some knowledge transfer channels, besides the number of interactions with firms, have statistically significant coefficients, so their values present different impacts on the results of the interaction.

In a nutshell, the coefficients for the modes of interaction "technological transfer" and "services" can indicate an improvement in innovative/technological results. Fernandes et al. (2010), for example, find that services and technological transfer are modes of interaction used by firms to solve productive problems (services) and to raise innovative efforts (technological transfer), which explains the propensity to obtain innovative/technology results. For the case of R&D projects and training/consultancy, there is no statistical significance for the coefficient results.

The knowledge transfer channels – research contracts, spin-offs, patents, R&D cooperative projects and individual consultancy – are significant. With the exception of consultancy, which is historically the most-used channel to transfer knowledge from universities to other agents in Brazil, the others have been stimulated by S&T policies in recent years. Consequently, our results suggest that the Brazilian innovation policy towards a more active and entrepreneurial role of universities is fostering innovative/technological results from U-F interactions.

There is no empirical evidence, however, that other variables included in the model have impacts on the interaction results. The scientific factor of research groups (a proxy for the scientific scale) and the knowledge areas of these groups have no impact on determining the distinction of scientific and innovative/technological results.

Specifically regarding funding sources, the analysis of the two distinct specifications indicates that these sources do not show statistical significance that allows us to distinguish the perception of scientific results or innovative/technological results. In other words, the results show that there is no difference of importance in the source of funding in the definition of scientific or innovative/technological results. Otherwise, the intensity of private funding does not define a more scientific or more technological result for research groups.

To confirm this finding about the irrelevance of private funding's intensity in the definition of the principal results of U-F interaction, a new analysis was performed with Specification 2. The probability of obtaining innovative/technological results for each source of funding, considering all the other variables in their average values, is now verified.

The results point out that the predicted probability of having innovative results across the three different funding sources is 16.4 per cent for public funds, 18.0 per cent for university/research institutes and 20.0 per cent for firms (private funds) (Table VII). Similarly speaking, the findings indicate that the predicted probability of achieving scientific results as the principal result from U-F interaction is greater for all funding types to the order of 83.5, 81.9 and 79.9 per cent, respectively, for public financing institutions, universities/research institutes and firms. We can remember that 78.9 per cent of the U-F interactions' results from the 662 observations are in the category of scientific results (Table VIII).

Thus, the proximity of the probability predictions for the types of results by different funding sources can corroborate the result concerning little differentiation of these sources

Variables	Specification 1 Coefficients	Specification 1 Odds ratio(a)	Specification 2 Coefficients	Specification 2 Odds ratio
a. Funding source				
Public	0.0023	1.0023	–	–
Universities/research institutes	0.0006	1.0006	0.1470	1.1584
Firms (private)	0.0027	1.0027	0.4699	1.5999
b. Scientific factor	−0.1754	0.8391	−0.1681	0.8453
c. Relationship with firms	0.0105**	1.0105**	0.0100**	1.0101**
d. Relevance of relationship types				
Category 1 (technology transfer)	0.3137*	1.3686*	0.3253*	1.3844*
Category 2 (R&D)	0.2480	1.2814	0.2731	1.3115
Category 3 (services)	0.3119**	1.3660**	0.3040**	1.3553**
Category 4 (training/consultancy)	−0.3539	0.7018	−0.3618	0.6914
e. Scientific areas				
Biological sciences	−0.0798	0.9232	−0.0189	0.9812
Health sciences	0.6591	1.9330	0.6632	1.9410
Exact and earth sciences	0.1019	1.1073	0.1696	1.1848
Humanities	−0.6443	0.5250	−0.6546	0.5197
Social sciences	−0.9837	0.3739	−0.9467	0.3879
Engineering	0.4040	1.4979	0.4807	1.6173
Linguistics, literature and arts	–	–	–	–
f. Most important knowledge transfer channel type				
Congress and seminars	0.6947	2.0032	0.6943	2.0023
Hiring of graduates	−0.1441	0.8657	−0.1294	0.8785
Research contracts	1.2006*	3.3223*	1.2250*	3.4043*
Spin-offs	1.1193**	3.0628**	1.1336**	3.1069**
Net of firms	0.5011	1.6506	0.4203	1.5225
Incubators	0.4644	1.5911	0.5073	1.6608
Publications	−0.2975	0.7426	−0.3078	0.7350
Temporary exchange of workers	−0.4111	0.6629	−0.2816	0.7545
Licensing	–	–	–	–
Technological parks	−0.0646	0.9374	0.0219	1.0222
Patents	2.1011*	8.1759*	2.1288*	8.4049*
R&D cooperative projects	1.1683*	3.2167*	1.2120*	3.3604*
Training	0.5319	1.7022	0.5152	1.6739
Informal exchange of information	0.0507	1.0520	0.0781	1.0812
Individual consultancy	1.8875*	6.6028*	1.9427*	6.9776*
Others	2.2186***	9.1943***	2.3286**	10.2639**
Constant	−3.6049**	0.02718**	−3.6297*	0.0265*
Observations	666		662	
	LR (X^2) = 109.20		LR (X^2) = 110.57	
	Prob. > X^2 = 0.0000		Prob. > X^2 = 0.0000	
	Pseudo-R2 = 0.1527 (b)		Pseudo-R^2 = 0.1551	

Notes: Dependent variable: "scientific result" (*dummy* = 0) and "innovative/technological" result (*dummy* = 1). Base groups at comparative interaction (*dummies*): Funding: *public institutions of funding*; relevance of relationship types: *category 1*; scientific areas: *agricultural sciences*; most important knowledge transfer channel type: *absence of a principal source. Observations:* *, ** and *** significant at 1, 5 and 10%, respectively. The odds ratio varies between 0 and infinity and is defined as the ratio of the relative probability of an event occurring in one group (the treatment group, in this case innovative/technological results) relative to another group (the control group, in this case scientific results). If the result of the likelihood ratio is equal to one, the variable's occurrence is identical in the two groups. If it is larger than one, the variable increases the probability of research groups having innovative/technology results. If it is less than one, the probability of research groups obtaining scientific results is increased. According to Veall and Zimmermann (1996), the pseudo-R^2 in logit models does not have a valid meaning
Source: Authors' own

Table VII.
Logit model results – Specifications 1 and 2

in the definition of the interaction results. According to this analysis, private funding does not affect or bias the generation of knowledge in universities, as projects financed with private resources also resulted mainly in academic results.

6. Final considerations

There are some recent studies on the impacts of U-F interactions, some of which deal with the impacts of U-F interactions on researchers' productivity, firms' innovative efforts and firms' motivation to interact. However, as mentioned before, there is a gap in the literature about the impacts of private funds on U-F interactions in Brazil, and our contribution in this article was to address that neglected issue and provide some elements to fill the gap.

To reach the goal proposed, we presented primary data from a survey conducted with research group leaders from universities and research institutes, undertaken in 2008-2009 in Brazil (the "BR Survey"). As a methodological strategy, we used econometric logit techniques to determine whether the intensity of different funding sources mattered or not to the result of U-F interactions. Accordingly, we found that the intensity of private funding does not affect the generation of knowledge in universities and research institutes, as projects financed with private resources also resulted mainly in academic results.

These findings contribute to the understanding of the dynamics of innovation through the mechanism of U-F financing in Brazil, as they show that, regardless of the funding source, U-F interactions performed at the national level predominantly have scientific purposes – instead of technological ends – which are less prone to result in innovation. Therefore, funding sources established between interacting agents show no statistically significant difference, indicating that they do not define a funding bias towards "innovative/technological" results or "scientific" results. Therefore, the intensity of private funding does not seem to pervert the university mission oriented towards knowledge creation and human resource training in Brazil.

Given the fact that private funding sources do not affect the conventional mission of Brazilian universities – teaching and research – university research groups should be even more incentivized to search for private funds to carry out their research. This may be a solution to the public fund scarcity and may help in reducing the historical distance between universities and firms in Brazil. Obviously, we do not mean a market solution for universities; we still believe that it is the responsibility of the federal government to provide most of the funds for keeping basic research at universities.

Finally, it is important to mention that successful firms rely on their ability to innovate, which in turn depends on the combination of many firm capabilities, including the ability to access financing, to understand the market needs, to recruit a qualified workforce and to establish effective interactions with other agents in the innovation system. Moreover, in an innovation system, interactions among firms and other agents is a *sine qua non* for

Funding type	Marginal prob.	Standard error	P > z
Public institutions	0.164	0.0251	0.000
Universities/research institutes	0.180	0.0244	0.000
Firms	0.200	0.0471	0.000

Source: Authors' own

Table VIII. Probability of innovative/technological results (from the logit model) knowledge transfer, especially tacit ones. That is the reason why a clear agenda for interaction promotion that can promote inventive and innovative activities should be fostered by the government.

Notes

1. According to Geuna and Rossi (2015), Germany is an exception with a constant increase in HERD by firms, whereas other OECD countries experienced their share of university research funded by firms growing in the 1980s and to a lesser extent in the 1990s\a then levelling out or at times falling throughout the 2000s.
2. OECD. *Main Science and Technology Indicators*, Volume 2016/1.
3. Even when adjusting for types of publication and co-authorship.
4. Stokes (1997) plots a graph of scientific relevance by technological relevance and calls the locus in the figure where both the scientific relevance and the technological relevance of the research are addressed Pasteur's quadrant, which is the right mix between basic and applied research. The other quadrants that he defines are not ideal, such as Bohr's and Edison's quadrants.
5. Dagnino (1984) highlights that research and post-graduates' formation in Brazil was only possible because of parallel sources of funds, generally in an "agreement" format (*convênios*), from the government and public firms.
6. Besides the reduction in relative terms, it is important to mention that 12,411 innovative firms responded to the questions about 'innovation obstacles' presented in PINTEC in 2000, while in 2011 the number of innovative firms that responded was 20,760.
7. The remaining activities are industrial projects and commercialization.
8. There are also more complex interactions involving bi-directional flows of knowledge, such as cooperative R&D projects. We can also see examples that demonstrate a close relationship between some Brazilian universities (and research institutes) and industry. However, the maturation of successful cases of U-F interactions took time and was the result of a process of long-term institutional building with strong support from and intervention by the Brazilian Government. Examples of such a successful U-F relation include the case of the Brazilian Aeronautical Company (*Empresa Brasileira de Aeronáutica*, Embraer), which benefited from the proximity to the Technological Institute of Aeronautics (*Instituto Tecnológico de Aeronáutica*, ITA) and the rich interaction between the National Steel Company (*Companhia Siderúrgica Nacional*, CSN), Companhia Vale do Rio Doce and the Department of Metallurgy and Material Engineering of the Federal University of Minas Gerais (UFMG), which resulted in good performance for mining and the Brazilian steel industry (Suzigan & Albuquerque, 2011). Another example is the management of cooperative R&D projects by the state-owned operator, Petrobras, involving two Brazilian universities (Ferreira & Ramos, 2015).
9. Decreto-Lei n. 719/1969. available at http://www.planalto.gov.br/ccivil_03/Decreto-Lei/Del0719.htm
10. According to the FAPESP, in 2015 the investments in the higher education institutions and research institutes located in São Paulo State amounted to US$354m, of which 11.87% were directed to research on technological innovation. available at: http://www.fapesp.br/9948
11. CT-Petro is a sectorial fund designed to stimulate private investment and public–private partnerships in the oil and gas productive chain.
12. The Shapiro–Wilk and Shapiro–Francia tests for normality indicate that the dependent variable is not normally distributed, which is the reason why we opted to use a logit model.
13. Based on Wooldridge (2002).

14. For more information about factor analysis, we suggest Mingoti (2005).
15. One important limitation of the models is that the "BR Survey" was not constructed to make inferences about the funding sources in collaborative projects. Therefore, the answers regarding this information were not complete, and we found considerable inconsistencies in 333 responses. Another important limitation concerns the methodological choice in classifying scientific or technological results, as relationships about science and technology are not as direct and excluding as our proposed classification. These problems, however, may be seen as a challenge for further efforts to understand the role played by private funding in U-F interactions in developing countries.

References

Além, A. C., & Giambiagi, F. (Org.). (2010). *O BNDES em um Brasil em transição*. Rio de Janeiro, Brazil: BNDES. Retrieved from http://web.bndes.gov.br/bib/jspui/handle/1408/1083

Alvarez, R. B., Kannebley, S. Jr., & Carolo, M. D. (2013). O impacto da interação universidade-empresa na produtividade dos pesquisadores: uma análise para as ciências exatas e da terra nas universidades estaduais paulistas [The impact of the university-industry interaction in the academic productivity: an analysis for the exact and earth sciences at São Paulo universities]. *Revista Brasileira de Inovação*, *12*, 171–206. https://doi.org/10.20396/rbi.v12i1.8649058

Araujo, A. L. (2007). How institutions shape the formation of R&D partnerships – evidence from Brazil (Master thesis), Alborg: Aalborg University.

Araujo, B. C., Pianto, D., De Negri, F., Cavalcante, L. R., & Alves, P. (2012). Impactos dos fundos setoriais nas empresas [Impacts of the Brazilian science and technology sectoral funds on the industrial firms' R&D inputs and outputs]. *Revista Brasileira de Inovação*, *11*, 85–112. https://doi.org/10.20396/rbi.v11i0.8649038

Arbix, G., & Consoni, F. (2011). Inovar para transformar a Universidade brasileira [Innovate to transform the Brazilian university]. *Revista Brasileira de Ciências Sociais*, *26*, 205–251. http://dx.doi.org/10.1590/S0102-69092011000300016

Arza, V. (2010). Channels, benefits and risks of public–private interactions for knowledge transfer: Conceptual framework inspired by Latin America. *Science and Public Policy*, *37*, 473–484. https://doi.org/10.3152/030234210X511990

Beinhocker, E. D. (2007). *The origin of wealth: Evolution, complexity and the radical remaking of economics*. US: Random House Business Books.

Benner, M., & Sandstrom, U. (2000). Institutionalizing the triple helix: Research funding and norms in the academic system. *Research Policy*, *29*, 291–301. https://doi.org/10.1016/S0048-7333(99)00067-0

Brudenius, C., Lundvall, B., & Sutz, J. (2009). The role of universities in innovation systems in developing countries: Developmental university system – empirical, analytical and normative perspectives. In B.-A. Lundvall, K. J. Joseph, C. Chaminade, & J. Vang (Eds.), *Handbook of innovation systems and developing countries: Building domestic capabilities in a global setting*, Cheltenham, United Kingdom: Edward Elgar.

Brown, R. (2016). Mission impossible? Entrepreneurial universities and peripheral innovation systems. *Industry and Innovation*, *23*, 1–17. https://doi.org/10.1080/13662716.2016.1145575

Brunnel, J., D'este, P., & Salter, A. (2010). Investigating the factors that diminish the barriers to university–industry collaboration. *Research Policy*, *39*, 858–868. https://doi.org/10.1016/j.respol.2010.03.006

Brundenius, C., & Goransson, B. (2011). The three missions of university: A synthesis of unidev project findings. In C. Brundenius & B. Goransson (Eds.), *Universities in Transition – The Changing Role and Challenges for Academic Institutions* (pp. 329–352). New York, NY: Springer-Verlag.

Carvalho, L. (2018). *A valsa brasileira*. São Paulo, Brazil: Todavia Livros.

Carolo, M. D. (2011). O impacto da interação universidade-empresa na produtividade dos pesquisadores: uma análise dos docentes coordenadores de projetos com apoio da Petrobrás/ ANP (Master thesis), Ribeirão Preto (SP), Brazil: Faculdade de Economia, Administração e Contabilidade (FEA), Universidade de São Paulo (USP).

Carrijo, M., & Botelho, M. (2013). Cooperação e inovação: uma análise dos resultados do Programa de Apoio à Pesquisa em Empresas (Pappe) [Cooperation and innovation: an analysis of the results of the Programa de Apoio à Pesquisa em Empresas (PAPPE)]. *Revista Brasileira de Inovação*, *12*, 417–448. https://doi.org/10.20396/rbi.v12i2.8649067.

Cassiolato, J. E., Lastres, H. M. M., & Maciel, M. L. (Eds). (2003). *Systems of innovation and development: Evidence from Brazil*. Cheltenham, United Kingdom: Edward Elgar.

Centro de Gestão e Estudos Estratégicos [CGEE]. (2002). Diretrizes estratégicas para o fundo verde-amarelo. *Programa de estímulo à interação universidade-empresa para apoio à Inovação. Documento básico*. Brasília, Brazil: CGEE. Retrieved from ftp://ftp.mct.gov.br/Biblioteca/45233-Fundo_Verde-Amarelo.pdf

Chaves, C. V., Carvalho, S. S. M., Silva, L. A., Teixeira, T. C., & Bernardes, P. (2012, November). The point of view of firms in Minas Gerais about the contribution of universities and research institutes to R&D activities. *Research Policy*, *41*, 1683–1695. https://doi.org/10.1016/j.respol.2012.07.008

Chiarini, T., & Vieira, K. P. (2012). Universidades como produtoras de conhecimento para o desenvolvimento econômico: Sistema superior de ensino e as políticas de CT&I [Universities as producers of knowledge for economic development: Higher education system and ST&I policies]. *Revista Brasileira de Economia*, *66*, 117–132. http://dx.doi.org/10.1590/S0034-71402012000100006

Chiarini, T., Oliveira, V. P., & Do Couto E Silva Neto, F. C. (2013). Spatial distribution of scientific activities: An exploratory analysis of Brazil, 2000–10. *Science and Public Policy*, *41*, 625–640. https://doi.org/10.1093/scipol/sct093

Cohen, W., & Levinthal, D. A. (1989). Innovation and learning: The two faces of R&D. *Economic Journal*, *99*, 569-596. Retrieved from https://www.jstor.org/stable/2233763

Cohen, W., Nelson, R. R., & Walsh, J. P. (2002). The influence of public research on industrial R&D. *Management Science*, *48*, 1–23. Retrieved from https://www.jstor.org/stable/822681

Czarnitzki, D., Wolfgang, G., & Hussinger, K. (2009). Heterogeneity of patenting activity and its implications for scientific research. *Research Policy*, *38*, 26–34. https://doi.org/10.1016/j.respol.2008.10.001

Dagnino, R. P. (1984). A universidade e a pesquisa científica e tecnológica [The university and scientific and technological research]. *Revista de Administração*, *19*, 60–77.

Dasgupta, P., & David, P. A. (1994). Toward a new economics of science. *Research Policy*, *23*, 487–521. https://doi.org/10.1016/0048-7333(94)01002-1

De Negri, F., & Squeff, F. H. S. (2016). (org.). *Sistemas setoriais de inovação e infraestrutura de pesquisa no Brasil* (p. 637). Brasília, Brazil: IPEA: FINEP: CNPq.

Esteves, L. A., & Meirelles, J. G. P. (2009). Innovation and cooperation between firms and universities: Evidence from Brazil. *Third Conference on Micro Evidence on Innovation and Development – MEIDE, Rio de Janeiro (Brazil)*.

Etzkowitz, H., & Leydesdorff, L. (2000). The dynamics of innovation: From national systems and 'Mode 2' to a triple helix of university–industry–government relations. *Research Policy*, *29*, 109–123. http://dx.doi.org/10.1016/S0048-7333(99)00055-4

Feller, I. (1990). Universities as engine of R&D-based economic growth: They think they can. *Research Policy*, *19*, 335-348. https://doi.org/10.1016/0048-7333(90)90017-Z

Fernandes, A. C., Campello De Souza, B., Stamford Da Silva, A., Suzigan, W., & Albuquerque, E. (2010). Academy–industry links in Brazil: Evidence about channels and benefits for firms and researchers. *Science and Public Policy*, *37*, 485–498. https://doi.org/10.3152/030234210X512016

Ferrari, A. F. (2002). O Fundo nacional de desenvolvimento científico – FNDCT e a Financiadora de estudos e projetos – FINEP [The national fund for scientific development - FNDCT and the financier of studies and projects - FINEP]. *Revista Brasileira de Inovação*, *1*, 151–188. https://doi.org/10.20396/rbi.v1i1.8648855

Ferreira, M. L. A., & Ramos, R. R. (2015). Making university–industrys technological partnerships work: A case study in the Brazilian oil innovation system. *Journal of Technology Management and Innovation*, 10, 173–187. http://dx.doi.org/10.4067/S0718-27242015000100013

Financiadora de Estudos e Projetos [FINEP]. (2014). Relatório de gestão do exercício de 2013. *Fundo nacional de desenvolvimento científico e tecnológico – FNDCT*. Rio de Janeiro, Brazil: FINEP/MCTI. Retrieved from http://www.finep.gov.br/acesso-a-informacao-externo/transparencia/114-relatorios/relatorios-de-gestao

Financiadora de Estudos e Projetos [FINEP]. (2016). Relatório de gestão do exercício de 2015. *Fundo nacional de desenvolvimento científico e tecnológico – FNDCT*. Rio de Janeiro, Brazil: FINEP/MCTI. Retrieved from http://www.finep.gov.br/acesso-a-informacao-externo/transparencia/114-relatorios/relatorios-de-gestao

Fingerl, E. R. (2004). Considerando os intangíveis: Brasil e BNDES Rio de Janeiro: Coppe/UFRJ (Dissertação de Mestrado).

Florida, R., & Cohen, W. (1999). Engine or Infrastructure? The university¨s role on economic development. In L. Branscomb, F. Kodama, & R. Florida (Eds.), *Industrializing knowledge* (p. 589–610). Cambridge, MA: MIT Press.

Freitas, I. M. B., Geuna, A., & Rossi, F. (2010). University–industry interactions: the unresolved puzzle. Working Papers Series no. 9, Dipartimento di Economia 'S. Cognetti de Martiis'.

Geuna, A. (1999). *The economics of knowledge production: Funding and the structure of university research*. Cheltenham, United Kingdom: Edward Elgar Publishing Limited.

Geuna, A. (2001). The changing rationale for European university research funding: Are there negative unintended consequences? *Journal of Economic Issues*, *35*, 607–632. https://doi.org/10.1080/00213624.2001.11506393

Geuna, A., & Muscio, A. (2009). Governance of university knowledge transfer: A critical review of the literature. *Minerva*, *47*, 93–114. https://doi.org/10.1007/s11024-009-9118-2

Geuna, A., & Nesta, L. J. J. (2006). University patenting and its effects on academic research: The emerging European evidence. *Research Policy*, *35*, 790–807. https://doi.org/10.1016/j.respol.2006.04.005

Geuna, A., & Rossi, F. (2015). The university and the economy. *Pathways to growth and economic development*. Cheltenham, United Kingdom: Edward Elgar Publishing Limited.

Gielfi, G. G., Furtado, A., & Tijssen, R. J. W. (2017). A interação universidade-empresa na indústria de petróleo brasileira: O caso da Petrobrás [The university-cindustry interaction in the Brazilian oil industry: The case of Petrobrás]. *Revista Brasileira de Inovação*, *16*, 325–350. https://doi.org/10.20396/rbi.v16i2.8650114

Giuliani, E., Morrison, A., Pietrobelli, C., & Rabellotti, R. (2010). Who are the researchers that are collaborating with industry? An analysis of the wine sectors in Chile, South Africa and Italy. *Research Policy*, *39*, 748-761. https://doi.org/10.1016/j.respol.2010.03.007

Godin, B., & Gingras, Y. (2000). The place of universities in the system of knowledge production. *Research Policy*, *29*, 273–278. https://doi.org/10.1016/S0048-7333(99)00065-7

Gulbrandsen, M., & Smeby, J. (2005). Industry-funding and university professors' research performance. *Research Policy*, *34*, 932–950. https://doi.org/10.1016/j.respol.2005.05.004

Goldfarb, B. (2008). The effect of government contracting on academic research: Does the source the funding affect scientific output? *Research Policy*, *37*, 41–58. https://doi.org/10.1016/j.respol.2007.07.011

Hottenrott, H., & Thorwarth, S. (2011). Industry funding of university research and scientific productivity. *International Review for Social Science*, *64*, 534–555. https://doi.org/10.1111/j.1467-6435.2011.00519.x

Jensen, R., Thursby, J., & Thursby, M. C. (2010). University-industry spillovers, government funding, and industrial consulting. NBER Working Paper, 15732. Cambridge (USA): National Bureau of Economic Research (NBER).

Klevorick, A. K., Levin, R. C., Nelson, R. N., & Winter, S. G. (1995). On the sources and significance of inter-industry differences in technological opportunities. *Research Policy*, *24*, 185–205. https://doi.org/10.1016/0048-7333(93)00762-I

Lundvall, A. B. (1992). National systems of innovation. *Towards a theory of innovation and interactive learning*. London, United Kingdom: Pinter Publisher.

Maculan, A. M., & Mello, J. M. C. (2009). University start-ups for breaking lock-ins of the Brazilian economy. *Science and Public Policy*, *36*, 109–114. https://doi.org/10.3152/030234209X406791

Mccullagh, P., & Nelder, J. A. (1989). *Generalized linear models* (2nd Ed.), New York, NY: Chapman and Hall.

Mansfield, E. (1975). Academic research underlying industrial innovations: Sources, characteristics, and financing. *Review of Economics and Statistics*, *77*, 55–65. https://doi.org/10.2307/2109992

Mello, J. M. C., Maculan, A. M., & Renault, T. (2009). Brazilian universities and their contribution to innovation and development. In B. Goransson, & C. Brundenius (Eds.), *Developing universities: The changing role of academic institutions in development* (pp. 1–25). London, United Kingdom: Routledge/IDRC.

Meyer-Kramer, F., & Schmoch, U. (1998). Science-based technologies: University–industry interactions in four fields. *Research Policy*, *27*, 835–851. https://doi.org/10.1016/S0048-7333(98)00094-8

Mingoti, S. A. (2005). *Análise de dados através de métodos de estatística multivariada: Uma abordagem aplicada*. Belo Horizonte, Brazil: UFMG.

Mowery, D., & Sampat, B. (2005). Universities in national innovation systems. In J. Fagerberg, D. Mowery, & R. Nelson (Eds.), *The Oxford handbook of innovation*. Oxford, United Kingdom: Oxford University Press.

Murray, F., & Stern, S. (2005). Do formal intellectual property rights hinder the free flow of scientific knowledge? An empirical test of the anti-commons hypothesis. NBER Working Paper # 11465. Cambridge (USA): National Bureau of Economic Research (NBER).

Muscio, A., Quaglione, D., & Vallanti, G. (2013). Does government funding complement or substitute private research funding to universities? *Research Policy*, *42*, 63–75. https://doi.org/10.1016/j.respol.2012.04.010

Narin, F., Hamilton, K. S., & Olivastro, D. (1997). The increasing linkage between U.S. technology and public science. *Research Policy*, *26*, 317–330. https://doi.org/10.1016/S0048-7333(97)00013-9

Nelson, R. (1990). Capitalism as an engine of progress. *Research Policy*, *19*, 193-214. https://doi.org/10.1016/0048-7333(90)90036-6

Nelson, R. (1993). *National innovation systems: a comparative analysis*. New York, NY: Oxford University Press.

Nelson, R. (2004). The market economy, and the scientific commons. *Research Policy*, *33*, 455–471. https://doi.org/10.1016/j.respol.2003.09.008

Oliveira, J. F., & Moraes, K. N. (2016). Produção do conhecimento na universidade pública no Brasil: Tensões, tendências e desafios [Production of knowledge in the public university in Brazil: Tensions, trends and challenges]. *Educação em Revista*, *32*, 73–95. http://dx.doi.org/10.1590/0102-4698161626

Paranhos, J. (2010). Interação entre empresas e instituições de ciência e tecnologia no sistema farmacêutico de inovação brasileira: Estrutura, conteúdo e dinâmica. *Tese de doutorado*. Rio de Janeiro, Brazil: IE/UFRJ.

Pavitt, K. (2001). Public policies to support basic research: what can the rest of the world learn from US theory and practice? (And what they should not learn). *Industrial and Corporate Change*, *10*, 761–780. https://doi.org/10.1093/icc/10.3.761

Perkmann, M., & Walsh, K. (2009). The two faces of collaboration: Impacts of university-industry relations on public research. *Industrial and Corporate Change*, *18*, 1033–1065. https://doi.org/10.1093/icc/dtp015

Petersen, I., Kruss, G., Mcgrath, S., & Gastrow, M. (2016). Bridging skills demand and supply in South Africa: The role of public and private intermediaries. *Development Southern Africa*, *33*, 407–423. https://doi.org/10.1080/0376835X.2016.1156518

Puffal, D. P., Spricigo, G., & Ruffoni, J. (2016). Public funding, university–industry interaction and innovation outcome: Empirical evidence for Brazilian firms. *XIX Encontro de Economia da Região Sul (ANPEC-Sul), Florianópolis, Brazil.*

Ranga, L. M., Debackere, K., & Tunzelmann, N. V. (2003). Entrepreneurial universities and the dynamics of academic knowledge production: A case study of basic vs. applied research in Belgium. *Scientometrics*, *58*, 301–320. https://doi.org/10.1023/A:1026288611013

Rapini, M. S. (2018). Cooperação universidade-empresa: realidade e desafios. In M. V. Andrade & E. M. Albuquerque (org.), *Alternativas para uma crise de múltiplas dimensões*. Belo Horizonte, Brazil: Cedeplar/UFMG.

Rapini, M. S., Chiarini, T., & Bittencourt, P. F. (2017). Obstacles to innovation in Brazil: The lack of qualified individuals to implement innovation and establish university–firm interactions. *Industry and Higher Education*. v. *31*, 168–183.

Rapini, M. S., Oliveira, V. P., & Silva Neto, F. C. C. (2014). A natureza do financiamento influencia na interação universidade-empresa no Brasil? [Does the funding source matter in university-firms interaction in Brazil?]. *Revista Brasileira da Inovação*, v. *13*, pp. 77–108. https://doi.org/10.20396/rbi.v13i1.8649072

Rauen, C. V. (2016). O novo Marco Legal da Inovação no Brasil: O que muda na relação ICT-empresa? Radar: Tecnologia, produção e comércio exterior: Brasília: Instituto de Pesquisa Econômica Aplicada (IPEA), Diretoria de Estudos e Políticas Setoriais de Inovação, Regulação e Infraestrutura.

Reddy, P. (2011). The evolving role of university in economic development: The case of university industry linkages. In B. Goranson, & C. Brudenius (Eds.), *University in transition: The changing role and challenges for academic institutions*. Ottawa, Canada: IDRC.

Rosenberg, N. (1990). Why firms do basic research (with their own money)? *Research Policy*, *19*, 165–174. https://doi.org/10.1016/0048-7333(90)90046-9

Rosenberg, N. (1992). Scientific instrumentation and university research. *Research Policy*, *21*, 381–390. https://doi.org/10.1016/0048-7333(92)90035-3

Rosenberg, N., & Nelson, R. (1994). American university and technical advance in industry. *Research Policy*, *23*, 323–348. https://doi.org/10.1016/0048-7333(94)90042-6

Rossi, P., & Dweck, E. (2016). Impacts of the new fiscal regime on health and education. *Cadernos de Saúde Publica*, *32*, 1–5. http://dx.doi.org/10.1590/0102-311x00194316

Salles Filho, S. (2011). Quanto vale o investimento em ciência, tecnologia e inovação? ComCiência, n. 129, 10 June. Retrieved from http://www.comciencia.br/comciencia/?-section=8&edicao=67&id=848

Siegel, D. S., Waldman, D. A., Atwater, L. E., & Link, A. N. (2003). Commercial knowledge transfer from universities to firms: Improving the effectiveness of university–industry collaboration. *Journal of High Technology Management Research*, *13*, 111–133. https://doi.org/10.1016/S1047-8310(03)00007-5

Silva, D. R. M., Furtado, A. T., & Vonortas, N. S. (2017). University–industry R&D cooperation in Brazil: A sectorial approach. *Journal of Technology Transfer*, *42*, 1–31. https://doi.org/10.1007/s10961-017-9566-z

Spricigo, G., Monteiro, S. M. M., & Freguglia, R. S. (2016). The university industry linkages and the firm's innovative performance: Evidence from Brazil. *XLIV Encontro de Economia (Anpec)*, Foz do Iguaçú (Brasil).

Stephan, P. E. (2001). Educational implications of university–industry technology transfer. *Journal of Technology Transfer*, *26*, 199–205. https://doi.org/10.1023/A:1011164806068

Stokes, D. E. (1997). *Pasteur's quadrant: Basic science and technological innovation* (p. 196). Washington, DC: Brookings Institution Press.

Suzigan, W., & Albuquerque, E. M. (2011). The underestimated role of universities for development. *Brazilian Journal of Political Economy*, *31*, 3–30. http://dx.doi.org/10.1590/S0101-31572011000100001

Suzigan, W., Albuquerque, E. M., Garcia, R., & Rapini, M. S. (2009). University and industry linkages in Brazil: Some preliminary and descriptive results. *Seoul Journal of Economics*, *22*, 591–611.

Thursby, M., Thursby, J., & Gupta-Mukherjee, S. (2007). Are there real effects of licensing on academic research? A life cycle view. *Journal of Economic Behavior and Organization*, *63*, 577–598. https://doi.org/10.1016/j.jebo.2006.05.016

Van Looy, B., Ranga, M., Callaert, J., & Zimmermann, E. (2004). Combining entrepreneurial and scientific performance in academia: Towards a compounded and reciprocal Matthew-effect?" *Research Policy*, *33*, 425–441. https://doi.org/10.1016/j.respol.2003.09.004

Vedovelho, C. (1998). Firms' R&D activity and intensity and the university–enterprise partnerships. *Technological Forecasting and Social Change*, *58*, 215–226. https://doi.org/10.1016/S0040-1625(98)00019-5

Veall, M. R., & Zimmermann, K. F. (1996). Pseudo-R2 measures for some common limited dependent variables. *Journal of Economic Surveys*, *10*, 241–259. https://doi.org/10.1111/j.1467-6419.1996.tb00013.x

Wooldridge, J. M. (2002). *Econometric Analysis of Cross Section and Panel Data*. (3rd ed. p. 735). Cambridge, MA: The MIT Press.

Corresponding author
Tulio Chiarini can be contacted at: tulio.chiarini@int.gov.br

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