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University-Industry Collaboration and the Development of High-Technology Sectors in Brazil

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1. Introduction

Collaboration with university and other public research organisations seems to have become increasingly important for firms, as the technological interdisciplinarity and complexity, and the competitive pressures to shorten product life increased (Hagedoorn, 1996; Caloghirou et al., 2003). By collaborating with universities, firms may reduce uncertainty inherent from the innovation process, as well as expand their markets, access to new or complementary resources and skills, keep up with evolution of scientific knowledge, and create new technological learning options on future technologies (Hagedoorn *et al*., 2000; Lee, 2000; Fritsch and Lukas, 2001).

In particular, in the new industrialized countries (NIC), as their economy and their technological capabilities improve, national public research and educational organisations (PREOs) are expected to play an increasing important role in supporting indigenous firms to move into more dynamic and higher-opportunity industries (Mathews and Hu, 2007; Mazzoleni and Nelson, 2007; Wu, 2007). Indeed, firms (especially small firms) active in high-technology sectors were found to achieve higher productivity through university-industry collaboration (Motohashi, 2005). Consequently, following the innovation policies of developed countries, governments in the new industrialised countries are launching policies fostering science-industry

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interactions and the development of high-technology sectors (Wong et al, 2007; Gouvea and Kassicieh, 2007).

In Brazil, policy-makers are engaged in improving the technological capabilities of national firms and in developing high-technology industries, especially biotechnology, nanotechnology, renewable energies and information and communication technologies (Gouvea and Kassicieh, 2007; Brazilian Government, 2003). The adoption of OECD best-practices in technology transfer policies, such as TTOs, IPR of university results, support to spin off creation, might be per se inefficient to support university-industry collaboration and the growth of national high-technology sectors (Najmabadi and Lall, 1995; Goldman *et al.*, 1997; OECD, 2005). The design and implementation of appropriate science and technology policies require in-depth information on the national context and characteristics of university-industry collaboration. In particular, the understanding of the differences in the characteristics of PROEs collaboration with firms active in mature and emergent sectors is required. However, few studies have explored this issue. This paper is an attempt to fill this gap, and provide evidence supporting science and technology policy in Brazil.

This paper analyses the evolution and context of science-industry collaboration, in Brazil. In particular, it investigates the motivations, goals, outputs, and main barriers and facilitators of that collaboration. In particular, the paper explores the specificities of university-industry collaboration in emergent sectors, such as biotechnology, nanotechnology, and Information and Communication Technologies (ICT), when compared to collaboration in mature sectors. Moreover, it analyses how PREOs have engaged in organisational change to encourage cooperation with industry, for example through the development of assistance services and adaptation of incentives. To undertake this research, we use data from face-to-face interviews with a sample of 24 coordinators of research groups at PREOs.

This paper shows that in Brazil, informal and professional academic network of contacts with firms in emergent sectors is underdeveloped; students play a major role in mediating university and industry interaction. Moreover, the major national public research sponsors seems not to have yet adapted their financing procedures to finance projects of firms active in emergent sectors. This paper suggests that public support to university-industry collaboration through adoption of the OECD best practices of technology-transfer policies is not per se enough to encourage the development and growth of national high-technology activities.

This paper is organised as follow. Section 2 reviews the literature on the role of PREOs on the process of catching up and in the growth of high-technology sectors. Section 3 reviews the context of university-industry interaction in Brazil. Section 4 presents the data and methodology used in this paper. Section 5 explores the pattern of the university-industry collaboration in Brazil in terms of motivations, objectives and output of collaboration, as well as the efforts of PREOs to provide assistance services and incentives for researchers to cooperate with industry. Moreover, differences in the specificities of university collaboration with firms active in emergent and mature sectors are examined. Section 6 concludes the paper.

2. University-industry interaction and high-technology industries in the new industrialised countries

Given the established gap in the innovative capability with developed countries, the process of catching-up in developing and new industrialised countries is a long, difficult and costly process of learning-by-doing and by-interacting (Dahlman et al., 1987; Lall, 1992, 1998; Hobday, 1995; Montobbio and Rampa, 2005). Catching is particularly difficult because of the sticky relationship between export performance and innovative capability. Indeed, Montobbio and Rampa (2005) show that NIC concentrate still their innovative activities in industries which are technologically stagnant at the world level. [3] This specialisation in non-sophisticated products with low income and high price elasticities limits their internal resources for investing in skills development and technological development. Therefore, for not losing their development race, NIC, which have already accumulated a certain level of innovative capability also in some medium-high technology industries, need to keep upgrading

[3] "In developing countries, technological activity generates export gains in high technology sectors if a country expands in industries with increasing technological opportunities, in medium technology sectors if it moves away from low industries losing in terms of relative innovativeness, in low technology sectors if it is initially specialized in sectors with a greater growth of their world share. In high-tech and low-tech sectors, export performance is also affected by the growth of technical capabilities, foreign direct investments, productivity, and the initial level of technical skills and in medium tech by the growth rates of foreign direct investments" (Montobbio and Rampa, 2005).

their capabilities, and to restructure their industrial and export composition (Montobbio and Rampa, 2005; Robertson and Patel, 2007).

Catching up seems to rely on the access to foreign technologies and equipment, on the development of capabilities to produce, invest, cooperate and innovate, as well as on the development of national infrastructures and incentives (Dahlman et al., 1987; Lall, 1992, 1998; Hobday, 1995). Catching-up seems to require not only the development of technological but also of organisational and management capabilities. In particular, the design of effective industrial, educational, and science and technology policies as well as the restructuring of market and non-market/social institutions (such as laws, standards, codes of good business practice, and so on) are crucial (Dahlman et al., 1987; Lall, 1992; Mazzoleni and Nelson, 2007). Governmental policies may play a great role (positive or negative) in the development of human skills, technological infrastructures, in creating macroeconomic stability, and in launching selective industrial incentives and non-market institutions (Dahlman et al., 1987; Lall, 1992). Still, there is not a single way for catching up (Lall, 1992; Najmabadi and Lall, 1995; Goldman *et al*., 1997).

According to Mazzoleni and Nelson (2007) successful catch-up in Germany, Japan, and Korea and in Brazil (aerospace and oil prospecting/offshore) have relied on a combination of factors, in particular on cross-border flows of people, government policies supporting industrial development and protecting domestic industry, and regimes of intellectual property rights, which allowed imitations of advanced technologies. However, developing countries and the NIC are increased limited to reproduce most of these catching-up strategies (Brahm, 1995; Wen and Kobayashi, 2002; Gouvea and Kassicieh, 2005; Mazzoleni and Nelson, 2007). In particular, these countries are restricted by the World Trade Organisation from protecting or subsidizing specific products or firms, and from preventing foreign firms' access to domestic markets, although they can provide incentives and subsidies to R&D activities. Moreover, firms in advanced economies are increasingly focused on enforcing their intellectual property rights and on exploiting local natural resources in developing countries (Gouvea and Kassicieh, 2005), which includes the exploitation of local knowledge and the local government incentives and subsidies to R&D activities. The globalization of production, investment and research activities in many industries might punctually support this process of catching-up, but often it creates obstacles to further technological development in developing countries, especially in industries with higher-technological opportunities. FDI seems a good means for the truncated transfer of "the results of innovation rather than the innovative process itself" (Lall, 1992, p. 170,179).

National targeting policies to high-technology industries may be ineffective because, combined with technological characteristics of these industries, they can reinforce over-investment and excessive competition (i.e. abnormal excess capacity, high sunk costs, and sustained subnormal profits), especially because national governments tend to target the same high-technology industries (Brahm, 1995). Moreover, the performance and growth of high-tech industries depend on the speed of customisation and diffusion of high-technologies and products, and consequently on the technological updating of the low and medium technology industries (Robertson and Patel, 2007). In the NIC, which have already achieved a certain level of their economies and technological capabilities, domestic industrial demand for some high-technology products may exist, but it has a narrower spectrum than in developed countries. Moreover, NIC have a relatively smaller population of sophisticated end-users, which may also be a problem for the development of high-technology industries.

Despite these recent trends, governments in developing countries have still scope to support the development of infrastructures, training and research capabilities that support the needs of specific sectors (Lall, 1992, 1998; Montobbio and Rampa, 2005; Mazzoleni and Nelson, 2007). In particular, several authors stress that PREOs, which played an important role in the successful development of specific industrial sectors (for example in electronics in Taiwan and Korea and aircraft in Brazil), will be crucial for successful catching-up, in the current international economic and technological context (Mazzoleni and Nelson, 2007; Robertson and Patel, 2007). In East Asia, public research and technology diffusion programmes is argued to have contributed to their specialization in the high-technology industries (Mathews and Hu, 2005; Eun et al., 2006; Wonk et al. 2007).

PREOs can support the catching up process by training national scientist and engineers, by supporting exchange with international research centres of researchers, experts and students, by accessing international research networks where new technologies are being developed, and acquiring advanced knowledge and skills in the relevant fields of science and engineering (Pavitt, 1998; Mazzoleni and Nelson, 2007). Scientists and engineers with capabilities for mastering basic sciences and connected with international networks are fundamental for learning-by-doing, by-searching and by-interacting in developing and NIC countries because technological problem-solving capabilities rely heavily on mastery of basic sciences (ibid.). Moreover, PREOs can help firms and governments to develop and employ technologies avoiding infringement of intellectual property rights (Gouvea and Kassicieh, 2005; Mazzoleni and Nelson, 2007). Therefore, in the NIC, national governments are called to set effective science and technology policies supporting indigenous firms to enter in dynamic sectors with high technological opportunities, as well as to export more technological sophisticated product (Wen and Kobayashi, 2002; Mathews and Hu, 2005; Montobbio and Rampa, 2005).

However, the national research system per se cannot foster the emergence and growth of technological capabilities, especially in high-technology sectors. In developing countries, the R&D expenditure is low and is concentrated in PREOs, usually centrally managed by governments and with little incentives for technology transfer (Montobbio and Rampa, 2005; Wu, 2007). Moreover, the firms' efforts in R&D and in the adoption of external knowledge are crucial for the catching-up and accumulation of technological capabilities (Hobday, 1995; Pavitt, 1998). Therefore, policies efforts for developing high-technology secotrs and and fostering university-industry collaboration need to be complemented with the provision of direct incentives to improve the demand (firms') capabilities of production, investment, linkage and innovation (Dahlman et al., 1987; Lall, 1992).

Indeed, several authors stress that PREOs can only contribute to economic development and catch up if they concentrate in problem-solving research projects rather than in behaving as "ivory tower" (Ekboir, 2003; Mazzoleni and Nelson, 2007). Only by supporting the development of advanced technological capabilities did public research in agriculture in the US, in electronics in Taiwan and Korea and aircraft in

Brazil succeeded (Mazzoleni and Nelson, 2007). An important aspect of these cases is that PREOs have fostered two-way communication with industrial users (a well-defined community) and they were responsive and sensitive to their needs by tailoring and developing relevant technologies, and supporting problem-solving (Ekboir, 2003). The linear concept of science and innovation development prevailing in most PREOs, as well as the collision between policy and research objectives and tools, may lead to a scientific research planning that has little interaction with industry needs and with other PREOs in specific areas of expertise (Ekboir, 2003; Eun et al., 2006).

Thus, fighting economic and technological stagnation requires strengthening investment in basic scientific capabilities, in the interaction among agents and in making/creating right institutions throughout the process of industrial development. Similarly, transparent legislation, protecting the rights of traditional knowledge and natural resources, and stimulating industrial technological and innovative investments is vital for the further development of industries with high-technological opportunities. In particular, Gouvea and Kassicieh (2005) stressed the importance of legislation for the case of the Brazilian biotechnology industry, where some collaborative projects between local firms and multinationals were cancelled due to lack of defined parameters in the existing legislation.

Moreover, lack of interaction among agents deters the speed of technological accumulation. Consequently, some researchers argue that even programs for technology diffusion need to be set encouraging interactions among public and private agents and problem-solving research, but not selecting *a priori* particular technologies (Wen and Kobayashi, 2002; Ekboir, 2003).

Furthermore, NIC need to be able to upgrade the role of PREOs in providing fundamental R&D, and incubating new knowledge-based firms (Etzkowitz et al., 2005; Eun, et al., 2006; Wong et al, 2007). In most of developing countries and NIC, PREOs tend to be centrally managed by the government and to operate with incentives for reproducing technologies developed in the advanced countries (Ekboir, 2003; Wu, 2007). These forms of organising research and education, which do not preview local evaluation and rewarding system of the quality of academic research results and of the level of interactions with other agents, seem to reduce the potential of PREOs to participate in knowledge development and transfer (Ekboir, 2003; Wong et al., 2007). Therefore, some authors stress the need to decentralise decision-making in order to foster interaction and customisation to industry needs, and risk-taking by researchers, as well as to monitor the quality of research programs (Ekboir, 2003; Mazzoleni and Nelson, 2007).

In East Asia, a movement towards “entrepreneurial university’’ has already started through the creation of technology transfer and licensing offices, and incubators, as well as the introduction of an entrepreneurial dimension into their training programmes (Eun et al., 2006; Mathews and Hu, 2007; Wong et al., 2007). These efforts may give a greater visibility of PREOs in knowledge development and commercialization, and encourage PREOs to keep focus on technologies needed for the development of strategic industries. In particular, central rewards to basic research outputs and discoveries of new commercially useful knowledge, as well as to the development and diffusion of advanced technologies, in combination with local efforts in developing entrepreneurial universities and regional technological support infrastructures seem to have enhanced the role of PREOs for catching up and industrial development in some fields and regions in East Asia (Wong et al., 2007; Wu, 2007).

In sum, the review of the literature suggest that in the current economic and technological global environment, there is still scope for developing countries and NICs to undertake science and technology policies aimed at supporting and strengthening catching up, also in industries with higher-technological opportunities. Governmental policies may play an essential role in fostering private R&D investment, in accumulating competencies in basic research, in multiplying programs for technology diffusion, in fostering interaction among private and public agents, and in reorganising PREOs research and training activities.

In particular, science and technology policy-makers are suggested to encourage PREOs to focus on the quality of their research and training programs, on applied – oriented and problem-solving research customised to their industrial partners, and on interaction with other private and public agents. Still, the design of effective science and technology policies to support university-industry interaction as well as to enhance the PREOs’ contribution to the development of national technological capabilities, especially in high-technology industries, involve the detailed analysis of the context of university-industry interaction and the characteristics of the collaborative projects.

This paper explores the evolution and international context of industrial and technological catching up, as well as the context of university-industry collaboration in Brazil. In particular, it analyses the characteristics of collaborative projects, university motivations for engaging in industry collaboration, as well as the organisational change at the PREOs to encourage and facilitate knowledge transfer to industry. Additionally, this paper investigates whether and how university's collaboration with firms in high-technology sectors differ from collaboration with firms active in more mature sectors.

3. University-Industry Collaboration and High technology sectors in Brazil

Brazil is a NIC which has achieved high technological competences in some high or medium-high technologies such as aerospace. Still, contrary to Asian countries such as China, Malaysia, or Thailand, Brazil experience small shifts in the sectoral composition of export and stagnant export performance (decrease) (Montobbio and Rampa, 2005). Indeed, from the early 1970s to the early 1980s, Brazil observed a significant shift in revealed comparative advantages from primary goods to consumption goods and basic manufacturing. From the 1980s, with the gradual elimination of mechanisms supporting industry, and an extended period where macroeconomic instability weakened investment, this industrialisation movement has been reversed, and it became again more profitable to produce and export agricultural goods and raw materials than to produce industrial goods. By 1998 primary goods had once again become Brazil's top comparative advantage; still it exports sophisticated industrial products, such as road vehicles, and aircrafts" (OECD, 2001, 142-3). The main comparative export disadvantages were telecommunications, specialised machinery, and computers (ibid.).

Concentration of research in PREOs rather than on private firms, slow adaptation of public research funding and institutions to support growth in sectors with higher technology opportunities, and slow building of university-industry links with firms in emergent sectors seem to be main causes for this stagnation in the export structure (IBGE, 2002; OECD, 2005).

In 2000, Brazil is spending 1% of GDP in R&D, slightly bellow China (1.29) and Russia (1.24), but above India (0.8) (IBGE, 2002; OECD, 2005). By the late 1990s, Brazilian public R&D expenditures are still higher than business expenditures, and 58% of R&D is still performed by PREOs, still 99.6% of R&D is civil (IBGE, 2002; OECD, 2005). Contrary in China, over half of scientists and engineers worked in enterprises, representing a considerable change from the early 1990s when state institutes employed most R&D workers (OECD, 2005). This change has still not been observed in Brazil.

Until the end of the 1990s, the capability to tap international knowledge have increased substantially in Brazil as payments abroad for royalties for technology transfer increased substantially from 1995 until 2000. The opportunity to tap foreign knowledge started slowing down (decreasing) in the beginning of the twenty-first century, as the technological gap was narrowing. In particular, licensing costs reduced, passing from 20% of payments in 1995 to 4% in 2002 (IBGE, 2002). Great part of payments abroad for royalties for technology transfer refer to provision of technical assistance services(60%), supply of technologies (30%), and use of brands (1%).

Concerning the invention output, the large numbers suggest that Brazil is doing worst that other NICs. Brazil had 53, 88 and 220 patent applications in 1980, 1990 and 2000, respectively, while China had 7 and 111, and 469. Moreover, only 35% of Brazilian domestic patents have a foreign ownership, while in Russia foreign ownership accounts for 60% of domestic patents, 50% in China and 40% in India (OECD, 2005).

However, according to the PINTEC survey in 2003 and 2005, the innovative capability of Brazilian industry is quite high; one-third (33-4%) of manufacturing firms surveyed developed a product or/and a process innovation.[4] Surprising as well is the fact that circa 20% of innovative firms received some type of public support to innovation, and 1% received public support for collaboration with universities. On

[4] In particular, 20% of total surveyed firms developed a product, 27% a process and 14% developed both a product and a process innovation.

average, innovative firms that received some type of public support for innovation, benefited on average of 1.2 types of public helps (PINTEC, 2003, 2005)

Circa of 7% of Brazilian manufacturing innovative firms, in the period from 2003 to 2005 (4% from 2001 to 2003) cooperated with other organisations to innovate.[5] More than one-third of these firms that cooperate (38%) used university as innovation partner. In particular, 34% of firms that collaborate to innovate collaborate for research and development activities as well as for product testing with the university, while 18% collaborate with university for other activities such as technical assistance, industrial design, and others (PINEC, 2005). Brazilian scale-intensive industries such as coke and oil, metals, pulp and paper present high penetration of the practice to collaborate to innovate, also with universities, and of public support to collaboration with university. To a certain extent, this evidence seems related to the fact that PINTEC addresses mainly large firms; consequently leaving out many small high-technology firms especially in science-based industries.

In particular, collaboration with Brazilian universities is particularly important for coke and oil, metals, electronic equipment, instruments, machinery, chemicals, pharmaceutical, and printing. Moreover, the share of innovative firms, which benefit from public support for collaboration with university, is higher in electronic equipment, machinery, metals, pulp and paper, coke and oil, pharmaceuticals, and transport equipment (PINTEC, 2005). However, from 2003 to 2005, the share of firms that benefited from public support to collaboration with university increased especially in high-technology sectors pharmaceuticals, electronic equipment and instruments, and decreased in metals, other transport equipment, paper and pulp and printing. Moreover, university as source of information is particularly important for firms active in pharmaceuticals, electronic equipment, instruments, chemicals, automobile, oil and coke, metals and beverages (PINTEC, 2003, 2005).

[5] On average, 3-5% per cent of product innovators innovated in cooperation with other firms or organisations, while 90% of firms develop them on their own and 5% adopted new products developed by other firms. Cooperation to develop new products is particular relevant for firms in automobile industry, electronic equipment, coke, metals, pharmaceutical and other transport equipment activities. When looking instead at process innovations, we find that 2-3% of cases process innovation resulted from collaboration with other firms and organisations, while 6-9% of processes resulted only from the firms internal development efforts and 90 % of firms adopted processes developed by other firms. Cooperation for process innovation is especially important for automobile industry, electronic equipment, pulp and paper, metallurgy, coke, and beverages .

Concerning the quality and quantity of research resources, Brazil also does not do as good as other NIC. In 2002, Brazil is the 17th in the ranking of countries with higher number of ISI published papers, while China is the sixth, Russia the ninth, and India the 13th. Similarly the number of scientist and engineers is relatively low, 1.5 researchers per 1000 active population, even compared with some others NICs (IBGE, 2002). Moreover, the number of Brazilian students in US from 1995-2004 grew almost 3%, much less than Chinese students (almost 5%), Indians (6%) or Russians (7%) (OECD, 2005).

Despite these indicators suggesting a centralized and not greatly efficient research system, a group of 48 large multinational firms in Brazil consider the excellent interaction university-industry in Brazil the main reason for their willingness to increase their investment in R&D in Brazil (ABDI and ANPEI, 2007). Still, none of these multinational firms interviewed have basic research activities in Brazil, one sixth of firms have applied research activities, and two thirds experimental development activities.

Public policies aimed at developing institutions and creating incentives for technology transfer have been in place for some decades in Brazil. In particular, public incentives to university-industry collaboration through sectoral funds and public research sponsors date from the 1970s. They emerged to support to metals sector through collaborative Master and Doctoral projects. Given their success, since then and in particular in the late 1990s, these efforts have been adopted in many other sectors, and the number of other supportive mechanisms increased. In the beginning of the twenty-first century, support to university-industry collaboration in high-technology sectors starts being partly encouraged as public support is increasingly provided on the basis of value-chain rather than on the branch of activity of the firm.

Moreover, efforts to facilitate the institutional set up of university-industry context have been put in place. In 2001, the *Innovation law* sets the general laws for property rights of knowledge developed, share of infrastructure, and mobility of researchers. In addition, in 2005, the *Lei do Bem* set large financial incentives (tax deductions) for investments in innovation, contracting of PhDs, and filing patents, among other innovative investments.

4. Data and Methodology

To analyse in detail the motivations, objectives and organisation of university-industry collaboration in Brazil as well as to compare whether and how university's collaboration with firms in emergent sectors differ from collaboration with firms active in more mature sectors, we rely on data collected with face-to-face interviews with the coordinator of twenty-four research groups at universities.

We use data collected through face-to-face interviews with the coordinators of twenty-four research groups at PREOs, in Mathematics, Physics, Chemistry and Engineering. As Table 1 reports eight interviews were done with research departments in Physics, six in Chemistry, six in Engineering, and three in Mathematics. Each interviewed provided general information on the department, its relationships with industry, and the incentives provided by their PREOs for pursuing collaboration with industry. Moreover, each interviewed provided specific and detail information on the origin, management and results of one real university-industry collaborative project.

Table 1. Number of Cases per Disciplinary Area

Discipline	Total number of collaborative cases	Collaborative cases with firms active in emergent sectors
Physics	8	5
Chemistry	3	1
Mathematics	6	4
Engineering	6	1

From the 24 mentioned collaborative projects, 10 were in areas of information technologies, biotechnology, and nanotechnology, with firms active in emergent sectors. Instead, five projects were undertaken with firms in oil industry (two of which with Mathematics groups related to extraction of petroleum), three projects undertaken with firms in equipment and machinery, one in textile, electricity, chemical and other on telecommunications.

On the strength of this data collected through face-to-face interviews with coordinators of twenty-four research groups at universities and at PREOs, we analyse the motivations, barriers and facilitators of university-industry collaboration, as well as the auxiliary services provided by the PREOs to facilitate and encourage researchers to collaborate with industry. Focusing on the details of one specific model collaborative project in each research group, we explore the most common forms of setting up and management a collaborative project with industry as well as the principal outcomes of these university-industry collaborative projects. In particular, we try to identify differences between projects undertaken with firms in emergent sectors and those with firms in more mature sectors.

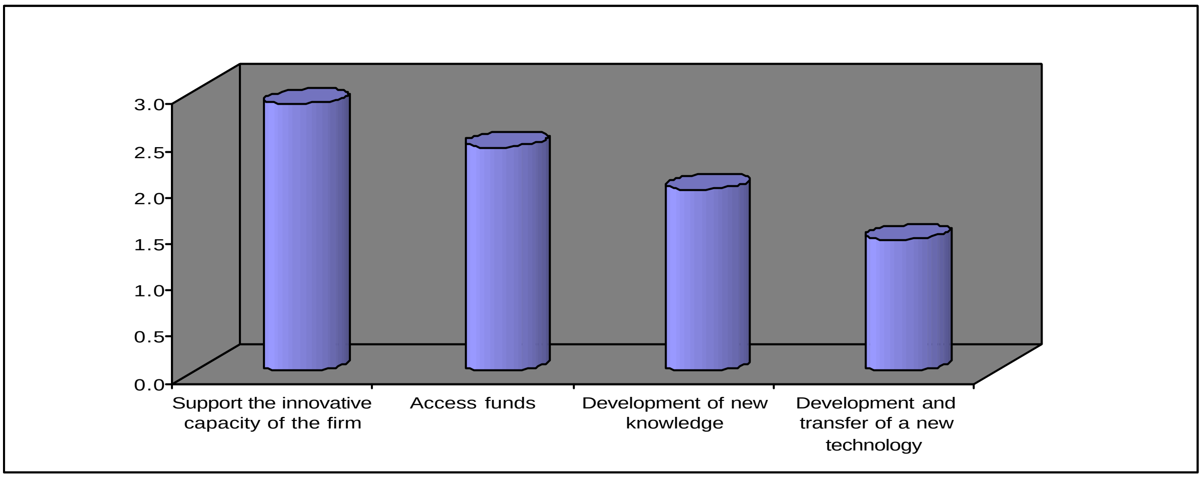
5. University-industry collaboration in Brazil

5.1 Context and technological and managerial characteristics of University-Industry collaboration in Brazil

"Development and transfer of a new technology" and "development of new knowledge" are the most important motivations for Brazilian research departments to collaborate with industry. Thus, both the first (knowledge development) and the third (economic development) missions of universities seem to be well interiorised by Brazilian researchers. As expected, support for the innovative capabilities of national firms per se is on average the least important motivation for collaboration with industry. Graph 1 shows the average ranking order of the main motivations of research groups to engage in collaboration with industry[6].

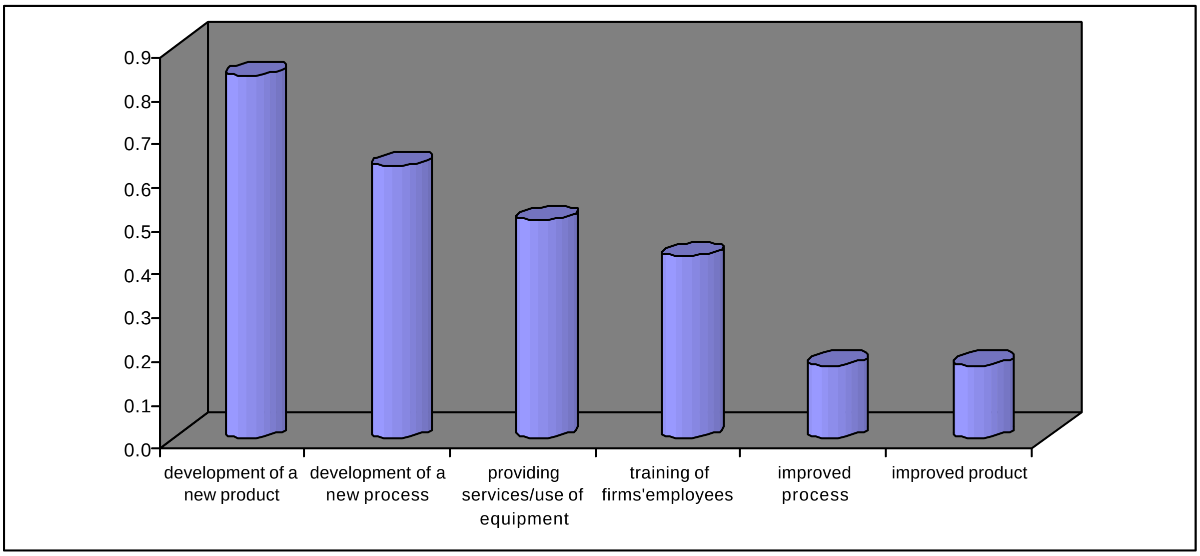
Graph 1. Motivations of the research groups to engage in collaboration with industry

[6] Research Coordinators were asked to identify by order of importance the main motivation to collaborate with industry. Being 1 the most important motivation and the 4 the least important.



The order of importance of university motivations to collaborate with industry is in line with the more common objectives of university-industry collaboration. As graph 2 shows, collaboration with industry aims more often at supporting firms in the development of new products and processes. Training of firms' employees and allowing industrial use of infrastructures at the university are less often the focus of university-industry collaboration. Instead, improvement of existing products and processes are among the least cited objectives of university-industry collaboration.

Graph 2. The three more common types of university-industry collaboration



After having analysed the academic' motivations for collaboration with industry and the most common objects of that collaboration, we identified the major identified barriers and facilitators to that relationship. We have asked research co-ordinators to characterise the most cited factors affecting collaborative R&D projects as facilitators or barriers to university-industry collaboration, according to their experience. Table 2 reports the number of research groups that identified each factor as barriers or as facilitators of collaboration with industry. Proximity, public research sponsoring, TTOs and other similar offices supporting knowledge transfer, and to a lesser extent, tax incentives, are mainly considered as facilitator of university-industry collaboration. Instead, high technical uncertainty, bureaucracy imposed by the sponsor, the time required by the firm, and the long-time frame of collaborative projects are seen as barriers to the completion and success of collaborative research projects. Most interesting is the fact that university administrative support services to project management and the setting of ownership of project's results are grey areas, as an almost similar number of departments recognised their enhancing and inhibiting effect on university-industry collaboration.

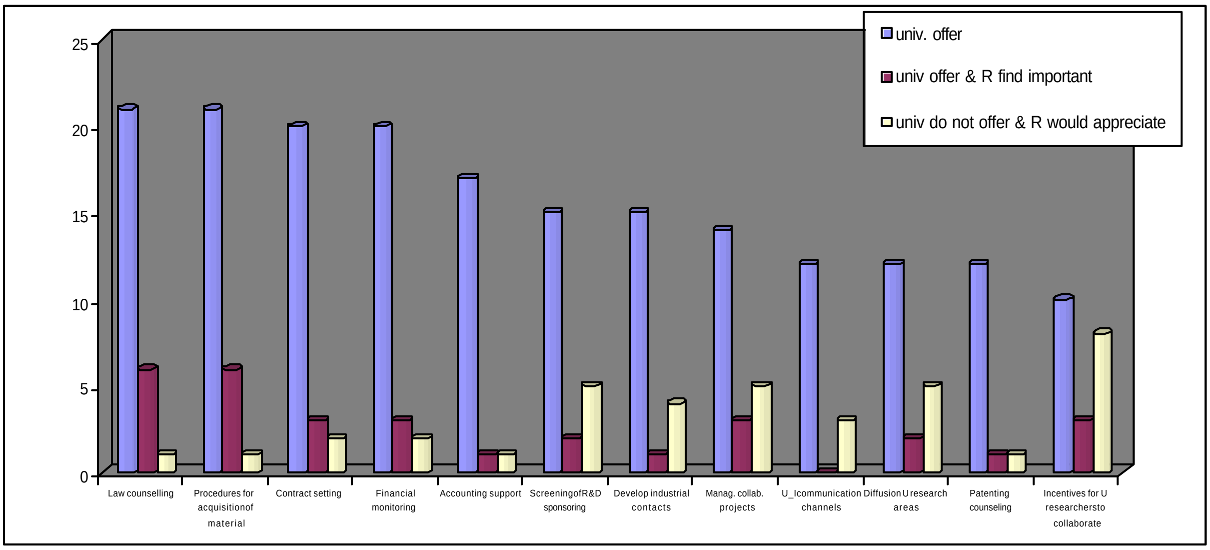
Table 2. Barriers and Facilitators of university-industry collaboration

	Facilitators	Barriers
Location of the university	18	2
Public Research sponsoring	17	4
TTOs and similar offices	15	6
Tax incentives	10	5
Administrative support to project management	10	7
Ownership of project's results (patents)	8	11
Long-term projects	4	12
Time required by the firm	2	11
Uncertainty	0	13
Bureaucracy	0	20

The management of university-industry collaborative projects tends to be the responsibility of the involved academic researchers (with support from auxiliary staff) or a shared responsibility of the involved university and the industrial executive or researcher. Research groups usually need to have formal processes for managing contracts and follow the exigencies of funding institutions (government or firms).[7] Moreover, many research groups are assisted by the university services or the university's foundation to deal with finance, intellectual property rights and contractual procedures.

In order to analyse the response of PREOs to the need of facilitating university-industry collaboration, we asked research coordinators to identify whether the administration of their PREOs was providing a list of services to support university-industry collaboration and whether these services were addressing important barriers of university-industry collaboration. Graph 3 shows the number of PREOs that offer specific services of support for collaboration with industry, the number of respondents that acknowledge the provision of those services important to address collaboration barriers, and the number of respondents that do not benefit from those services but recognise them as desirable.

Graph 3. The Offer of supporting services to University-Industry collaboration



Responses suggest that the most often PREOs' services offered to academic researchers relates to contractual and financial aspects of university-industry

[7] Research groups performing research with Petrobras, the Brazilian petroleum corporation, need to follow the procedures set by the firm: submit a proposal; once approved, organize documents and sign the contract; manage the research according the timetable, including the steps, specified in the approved project.

interaction: law-counselling, procedures for acquisition of material/equipment, financial monitoring and control, contract setting, accounting. These *contractual and financial services* are recognised as supporting collaboration with industry and as overcoming identified barriers. Screen of R&D sponsoring for collaboration with industry, development of industrial contacts, and management of collaborative projects are services provided in more than half of the organisations interviewed. These more pro-active services of *searching and management of industrial collaboration* are not highly recognised as addressing barriers of knowledge transfer by those that benefit from them, but those that are not offered these services recognise their importance to address specific identified barriers.

Instead, *personal and professional incentives* and services of diffusion of their research areas to industry are not widely offered by PREOs. However, academic researchers consider that the provision of services to *improve industrial awareness on the university research*, as well as of *professional incentives* for collaboration could foster collaboration with industry. Strangely, patenting counselling is among the least often services provided and the least ranked as desirable to address barriers to collaboration with industry. This requires further investigation.

In sum, university-industry collaboration focus mostly in the development of new products and processes, and the main motivations of Brazilian PREOs are the development and transfer of a new technology and new knowledge. Following the trend in OECD countries, Brazilian PREOs are already providing researchers with contractual and financial services, which are highly considered by researchers. Most of PREOs are also providing some services supporting the establishment and management of industrial collaboration, which are not so highly considered by researchers. Despite the quite good provision of auxiliary management services, Brazilian PREOs seem not having created specific incentives for public researchers to collaborate with industry, which is a major barrier to collaboration. Besides not adapting the organisational incentive system to encourage collaboration with industry, PREOS have also been slow in providing services addressing industrial awareness on the university research. However, research coordinators recognise great potential of these services of raising the industrial awareness on university research as well as of specific incentives for researchers to engage in collaboration with industry.

5.2. University-Industry collaborative projects: which difference can be found in projects established with firms in emergent sectors?

To have a more detailed view on the process of university-industry cooperation, we have asked the coordinator of research groups to choose one specific collaborative research project and to characterise its design as well as its main results. In particular, ten projects of the 24 analysed were undertaken with firms active in emergent sectors: 6 in biotechnology, 2 in nanotechnology, and 3 in information technologies.

When analysing differences between research groups that hosted a project with a firm in an emergent sector and research groups that hosted projects with firms in mature industries, we have some interesting results, which however need to be interpreted with cautious given the limited number of cases. Research groups that have a lower number of licensing agreements, but higher number of patents are more likely to have run a project with a firm active in a mature industry. Instead, research groups that run a R&D project with a firm active in an emergent sector rates slightly lower the importance of developing new knowledge and slight higher the motivation of accessing funds, and developing and transferring new technologies. These results seem to suggest that university patenting is a signalling device to attract firms in mature industries. Collaboration with firms competing in mature industries seem to be more challenging in terms of research, while collaboration with firms active in emergent sectors seem to be still catching up and reproducing technologies developed abroad.

Information on the 24 specific university-industry collaborative R&D projects conforms to the general overview of university-industry collaboration analysed in the previous section. Table 3 provides the number of projects that addressed each of the listed objectives, for the whole sample and for the sub-sample of projects undertaken with firms active in emergent sectors. New product development is the objective of 14 projects, followed by new process that is the objective of 10 projects. Four projects aimed at new product and process development, three of which were undertaken by research groups in Chemistry. Instead, only 3 projects aimed at improving existing process.

Projects undertaken with firms active in emergent sectors seem less likely to focus on improving processes, and to a lesser extent on the development of new processes.

Instead, relatively more projects with firms in emergent sectors focus on the development of new products than projects with firms in mature sectors. In 22 of the 24 projects (8 of the 10 projects with firms in emergent sectors), some research activities involved the use of specific machinery and equipment at the university or the firm.

Table 3. Objectives of the 24 specific projects analysed

	ALL	EMERGENT SECTOR
New product development	14	7
New process development	10	3
Services/use of equipment	3	2
Training of firms' employees	1	1
Improved process	3	0
Improved product	0	0
Other objectives	3	2
Total number of projects	24	10

The main financing entity was the FINEP, financing 11 projects, followed by CNPq financing 8 projects. FAPES financed only two projects. 18 projects were undertaken with other private or public funding sources, but only 8 were financed without financing from FINEP, CNPq or FAPES. Three of the 10 projects that were undertaken with firms in emergent sectors used FINEP as source of financing, while 9 used other public and private funding sources. Thus, projects with firms in emergent sectors seem to be mainly financed by other private and public sources and to a less extent by FINEP, but not by CNPq or FAPES. The existing public R&D sponsors, with exception of FINEP, seem not to have adapted their sponsoring procedures and objectives to support R&D in emergent sectors.

Table 4 identifies the origin of the 24 collaborative projects for the whole sample and for the sub-sample of projects undertaken with firms active in emergent sectors. One third of the projects analysed were originated by the firm, who identified its own needs and interest in collaborate with that research department to get support for its internal R&D activities. One fourth of projects came out from an idea of the university, as the research group identified a possibility of supporting firms to develop new or to improve existing processes (also the market position of the firm) and contacted the firm. The other cases emerged from a less clear mix of initial intentions involving informal and professional contacts, application to R&D sponsoring, and students' thesis and projects. In particular, informal contacts via graduate and post-graduate students are unanimously identified as essential for doing the contact at the university or at the firm.

When comparing the origin of collaborative cases with firms in mature and emerging sectors, it is noteworthy the fact that university identifies and proposes relatively less projects addressing an industrial R&D need of firms in emergent sectors. Half of projects with firms in emergent sectors were initiated by the firm. Moreover, the network of informal, professional and other collaborative contacts of university researchers in emergent sectors is less developed than in mature sectors. Students, in particular postgraduate ones are the major link between university and firms in emergent sectors, both because they propose new projects and because they go to work in firms and they recognise the importance of universities in supporting product development.

Table 4. The origin of the collaborative project

	ALL	EMERGENT SECTOR
Firm contacted university	8	5
University contacted the firm/ proposed a project	6	1
Informal contacts and Others	7	2
Co-application to R&D sponsoring	4	0
Students thesis and projects	3	2
Employee training	1	1
Conferences	1	0

Finally, we have also inquired on the outputs of the 24 collaborative projects. Table 5 shows the outputs of the university-industry collaborative projects in the twenty-four research groups, for the whole sample and for the sub-sample of projects undertaken with firms active in emergent sectors. Papers and post-graduation thesis are the most often referred outputs of collaborative research, followed by new products to the market, patents, and new processes. Instead, books, improved processes, licensing, spin off creation, seem to be the least common outputs from university- industry collaborative projects.

Table 5. Outputs of the 24 University- Industry collaborative projects

	ALL	EMERGENT SECTOR
Thesis	20	9
Publications	19	8
New product	13	6
Patent application by the PREOs	12	5
New process	9	5
Spin-off	8	4
Services	7	4
Licensing	6	2
Improved process	4	3
Books	3	3
Average number of outputs	4.2	4.9

Project with firms in emergent sector have a slight higher average number of outputs than projects with firms in mature activities. Books and improved processes, and to a less extent new processes are more likely outputs of the projects with firms in emergent sectors than of projects with firms in mature industries. In particular, improved and new processes seem to be a side-output of collaborative projects with firms active in emergent sectors, which were less likely to have them as major goals. Projects with emergent firms produced slightly more often thesis and new products than in projects with firms in mature industries.

Eleven projects lead to the start of new collaborative project, eight of which derived from supporting the finalisation of the project with the firm. Five projects with firms in emergent sectors were finalised with the firm and two of which lead to the start of a new collaboration. This apparently reduced possibility of starting a new collaboration with firms, active in emergent sectors, after the project completion might be related to the fact that these projects are more likely to be fund by other sources than the main public research sponsors.

In sum, the network of network of informal, professional and other collaborative contacts of PREOs with firms in emergent sectors is less developed than with firms in mature sectors. Consequently, collaborative projects with firms in emergent sectors are less likely to be originated by the university, or by the network of informal, professional and other collaborative contacts. Collaborative projects with firms in emergent sectors seem more likely to be initiated by the firm (eventually through former post-graduate students) and by current post-graduate students, who propose a specific project with a firm in an emergent sector. Moreover, there are some indications that collaboration with firms competing in mature industries might be more challenging in terms of research, as well as that firms in emergent sectors may be still catching-up and reproducing technologies developed abroad. Therefore, university patenting seems to be mainly a signalling device to attract firms in mature industries.

Projects undertaken with firms active in emergent sectors focus more on the development of new products and have a slight higher average number of outputs than projects with firms in mature activities. Improved and new processes seem to be often side-outputs of collaborative projects with firms active in emergent sectors, which were less likely to have them as major goals. Similarly, books, and to a lesser extent, thesis and new products seem more often achieved than in projects with firms in mature industries. Thus, despite focusing on product development, projects with firms in emergent sectors seem to be more productive. However, the starting of a new collaboration after the project completion with firms in emergent sectors seems less common than in mature sectors. This might be related to the fact that the existing public R&D sponsors, with exception of FINEP, seem not to have adapted their sponsoring procedures, objectives to R&D in emergent sectors.

6 Conclusions

Brazil is a NIC, which has achieved high technological competences in some high or medium-high technologies, but has experienced small shifts in the sectoral composition of exports and a stagnant export performance (Montobbio and Rampa, 2005). Given the acknowledged importance of university-industry collaboration in the process of catching up in some of sectors, also in Brazil (Mazzoleni and Nelson, 2007), this paper has aimed at mapping the context of university-industry collaboration in Brazil, as well as to explore how PREOs could support development and growth of high-technology industries.

This paper shows that, following the trend in OECD countries, Brazilian PREOs are already providing researchers with contractual and financial services, which are highly considered by researchers as supportive of interaction with industry. Some are also providing services supporting the establishment and management of university-industry collaboration, which are not so highly considered by researchers. Brazilian PREOs have not yet adapted their organisational incentive framework to encourage collaboration with industry. Moreover, they have also been slow in providing services addressing industrial awareness on the university research. Efforts to address these issues are expected to foster university-industry interaction, in particular with emergent sectors, as the network of contacts is found to be still underdeveloped.

Moreover, this paper shows that Brazilian researh groups collaborate with firms mostly for entrepreneurial reasons as supporting the development and transfer of new technologies and knowledge to industry. This suggests a more entrepreneurial attitude of Brazilian researchers than of researchers in developed countries (Lam, 2005; Bodas Freitas and Verspagen, 2008). This needs however a further investigation given the qualitative nature of the studies and the reduced sample used in all these empirical works.

This paper also shows that Brazilian PREOs seem to be supporting innovation and technological development in mature sectors with which they have established contacts and to whom existing public research sponsoring seem to be customised. PREOs are still customising (when customising) their research to mature sectors. Consequently, public research efforts are being still mainly absorbed by large firms competing in mature sectors. In particular, our evidence shows that university R&D projects with firms active in emergent sectors are more often proposed by firms rather than by university researchers, and not being financed by the major public research sponsors. Still, we find, as expected, that university collaborative projects with firms active in emergent sectors are relatively more productive than those with mature industries. In particular, university R&D projects with firms in emergent sectors tend to focus on new product development and to have as a side-output the development of new or improved processes and books.

Lack of technological, financial and market capabilities of firms in emergent sectors as well as delay in adapting the public research sponsoring frameworks and lack of PREOs' sensitivity to these industries seem to be slowing down the growth of emergent sectors, in Brazil. Technological opportunities in most dynamic sectors can benefit from the great existing demand from mature sectors and from PREOs competences, but these opportunities are still mainly appropriated by large firms in mature sectors rather than supporting the growth of emergent sectors.

Our evidence allows us to derive some policy implications. It urges to adapt public research funding and institutions to support R&D activities and growth in sectors with higher technology opportunities, and to build university-industry networks with firms in emergent sectors. In particular, the technology transfer services of PREOs could support this process by mapping the industrial actors and needs in emergent sectors and diffuse the university expertise to this population of firms. Moreover, PREOs in combination with policy-makers should keep providing incentives for university-industry interaction and for university applied oriented research with indigenous users industries. Additionally, they should put efforts to raise the quality of research and training in basic sciences, in order to keep fuelling university-industry interaction. Finally, other issues not covered in this paper, but very important for investment and development in high-technology industries is the setting of a transparent and adequate IPR policy (Gouvea and Kassicieh, 2005; Mazzoleni and Nelson, 2007).

Thus, organisational and managerial capabilities at central governmental and local PREOs level to customise the OECD technology-transfer best practices to the Brazilian university-industry context and objectives are needed. Imitation per se is not enough, and it might even be contra-productive.

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