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INNOVATION AND UNIVERSITY-INDUSTRY COOPERATION IN BRAZIL – A PORTRAIT FROM PINTEC 2005

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1. Introduction

In recent years, large credit has been given to knowledge due to its central role in economic growth and development. More specifically, technology – which is knowledge applied to productive purposes – has an important share in the innovative movements of firms and economies. Innovation, in its turn, as a key determinant of productivity growth, is seen as the engine that moves the economy, reshapes industries, firms and markets.

In connection to the innovation subject, cooperative arrangements for innovation have gained interest among scholars, interested in understanding in depth a growing phenomenon. In such arrangements, different agents of the economic system, such as firms, research institutes, universities, consultancies etc. gather together with a common purpose to produce applicable knowledge. They take various forms, from joint ventures to non-equity research agreements, and bring together agents at different positions of the productive chain.

The reasons why cooperative arrangements for innovation have gained importance originate from the very nature of knowledge. Nowadays knowledge and technology evolve at an extremely fast pace, making their dissemination, as well as its obsolescence, much faster, which increases the costs of producing knowledge. Moreover, knowledge creation is a risky endeavour, and its outcomes cannot be predicted at full length. Therefore, as agents get together with a common target to reach, they complement each other's knowledge assets as well as share the risks (and profits) of searching for innovation.

This paper addresses the linkages between science and technology, and how firms benefit from cooperative agreements with universities – the main generators of basic knowledge. The importance of universities and research institutes as engines or fuels for industrial innovation are broadly acknowledged nowadays. Numerous works have devoted to this sole subject, and proved that science, in special public science, has a positive impact on the performance of industries, and therefore, on economic development (Perez and Soete, 1988; Narin *et al.,* 1997; Cohen *et al.*, 2002).

We present data from the last Brazilian Innovation survey available – PINTEC 2005. The survey investigates the main sources of knowledge used for innovation, as well as cooperative arrangements of different sorts and between different agents. We draw a portrait of the state of cooperation between agents in Brazil, as well as with foreign partners. Special attention will be paid to cooperative agreements between firms and universities and public research institutes. Our main objective is to assess the role that cooperative agreements, and university-firm partnerships play in the Brazilian innovation system.

As an empirical exercise, we run a probit model in order to investigate which characteristics of firms increase their propensity to undertake research partnerships with universities.

The paper is structured as follows: next section presents the theoretical framework on university-industry cooperation and the new paradigm of open innovation, which has expanded the frontiers of firm R&D. Section 3 presents the general characteristics of innovation and cooperation in Brazil, as portrayed by PINTEC 2005, and the recent trends on university-industry partnerships in Brazil. Section 4 presents the model, hypotheses and results. A final section brings some final remarks and ideas for future investigation.

2. Theoretical framework

There is a great amount of literature stressing the role of external sources of knowledge to the firm as important inputs for innovation. Contemporary approaches reinforce the belief that the generation of knowledge and innovation occurs less and less behind the borders of the firm, especially in technology-intensive sectors (Benfratello *et al*, 2002; Chesbrough, 2003; Cortês *et al.*, 2005).

Among the reasons for that is the fact that it has become harder to find a company that possesses all the knowledge necessary to develop technologies and innovate. The growing speed of technological change, the increasing complexity of technical and scientific knowledge, together with the shortening of technological life cycles, increased dramatically the costs of innovation, due to, among other things, the speed with which knowledge becomes obsolete (Hagedoorn, 2002). This made innovation partnerships a preferred arrangement, both in terms of knowledge access and cost shrinking.. The search for complementary knowledge and skills are another very strong motivation behind R&D partnerships (Cassiman and Veugelers, 1993).

Moreover, uncertainty is inherent to innovation. Due to the fact that its outcome can hardly be predictable, R&D activities may be too expensive for some firms, and may become impracticable for a certain range of firms. For this reason as well, cooperation is an advantageous way to carry out R&D activities.

The capability to innovate depends, to a large extent, on the firm's ability to absorb knowledge and technology produced externally. As a consequence, there is a great correlation between a firm's technological background and the local system of innovation in which it is embedded – for a well-developed innovation system allows greater possibilities of knowledge exchange between its agents, constantly feeding and increasing its knowledge base. The frequency with which local firms take part in cooperative arrangements for innovation is a good measurement of the level of development and efficiency of a national innovation system.

Strategic R&D alliances have been the subject of academic research on innovation systems for quite some time (Hagedoorn, 1996; Hagedoorn, 2002); its interest has regained strength and attracted the attention of business studies after the 'open innovation' paradigm has caught up. The open innovation paradigm, as coined by Chesbrough (2003) acknowledges other sources of ideas and knowledge rather than the R&D boundaries, and that a successful innovative idea does not necessarily originate within the firm. Therefore, firms should not restrict to their own ideas, but look out, and also share some of the ideas that might not be fully convenient to the firm itself. The adoption of a more open approach to ideas and knowledge generation has reinforced the role of internationalization and off-shoring of R&D activities (Chesborough *et al.*, 2006).

Techno-scientific cooperation can involve private and public research institutes, domestic and foreign firms, universities and training centers. Cooperative R&D has gained importance as an external source of innovation, due to the advantages they present to the firm – reason why they are also called 'strategic technological partnerships' (Narula and Zanfei, 2006).

The propensity of firms to take part in R&D arrangements varies with technological intensity of the sector in question, and also with the speed of knowledge dissemination and obsolescence, as well as the level of t competition in the market. R&D partnerships are a better arrangement the more tacit knowledge is, which makes its transfer more difficult, especially when a certain level of capabilities is lacking. Hence, when two agents get together with the purpose to generate knowledge or innovation, they bring together their capabilities and might reach a better outcome.

Several studies show that the companies with higher propensity to take part in cooperative arrangements for innovation are those in sectors with higher technological intensity, such as biotechnology, new materials, information and communication technologies (Teece, 1992; Hagedoorn, 2002; Tether, 2002). Pharmaceuticals and IT are the leading sectors: 80% of alliances started from the 1990s took place in those sectors (Hagedoorn, 2002). In the same direction, cooperative firms are generally engaged in higher level innovative activities, in a kind of egg and chicken enigma (Tether, 2002; Belderbos *et al.*, 2004).

Firms from developed countries tend to engage in R&D cooperation more often than developing countries counterparts; they also tend to choose partners from the same group. The United States is the absolute leader in cooperative agreements (Hagedoorn, 2002). Larger firms, which also tend to spend more in R&D, have a significantly higher probability to engage in cooperative R&D agreements and tap better results from cooperation (Veugelers *et al.*, 1997). This argument supports the idea that absorptive capacity stimulates the interaction among actors in R&D activities.

Next item will discuss knowledge transfer, cooperative agreements and the role of universities and research institutes to technological development.

2.1. Cooperative agreements and the role of Universities for Innovation and Catching Up

The role of universities in providing inputs for technological advances goes beyond the provision of skilled human resources to the economy. Universities and research institutes are the main generators of new knowledge that is the essential input for new technological breakthrough - important vehicles for the promotion and support of innovation within the firms (Figueiredo *et al.*, 2005). The impact of universities and public knowledge on the outcomes of industrial R&D has been thoroughly documented by academics (Narin *et al.*, 1997; Cohen *et al.*, 2002). These studies find evidence of the linkages between technology and science through data on cited research (in patents, e.g.), the growing number of patents granted to universities and also the rise of research support. Whereas academic research might be seem too far from the needs of industries and the real world, they are the same time devoted to the creation of basic, long-term strategic knowledge, in prospective technologies – a sort of activity that is too costly for firms to undertake with their own means (Tether, 2002).

The role of science for economic development and growth of nations is a subject thoroughly investigated. There is, in special, evidence on the technological development of newly industrialized countries that makes clear links between their technological investments and their industrial advancements. Bernardes and Albuquerque (2003) highlight the role that a strong focus on the development of technological capabilities in Korea and Taiwan, by way of deep investments in science and basic knowledge, that led to a fast catching up. The most immediate relationship between basic knowledge and the real world is made through a concomitant evolution of papers and patents in those countries (Bernardes and Albuquerque, 2003: 871), relationship that was not observed in Brazil till the recent years.

Governments have tried to promote stronger ties between those who abstractly generate knowledge and those who need knowledge and technology to improve products and production processes. This has happened in the UK, USA, and several other developed nations since many years (Tether, 2002; Cohen *et al.*, 2002). It is not difficult to make the linkages between major technological discoveries and the universities where the research originated – especially in the high-tech sectors, usually clustered around universities.

Matthews and Hu (2007) stresses the role of public institutes and universities as knowledge creators in developing economies, where, in thesis, less firms might be able to afford to have a formal R&D department. Public research has a special impact on knowledge creation in high technology sectors, where uncertainty and risks are larger. Studies use evidence of academic knowledge citation in patents to show the direct relationship between basic knowledge and technology and economic growth (Narin *et al.*, 1997) Research carried out by Mansfield (1991) estimates that "10% of industrial innovation would not have occurred, or would have occurred with great delay, without the contribution of academic research (Narin *et al.*, 1997, pp. 318).

For instance, in Taiwan, a strong government support to the development of the basic research has contributed to the whole economic innovative capability. With such strong innovation system, the country was capable of going from imitator to innovator, through the development of highly innovative (and hence competitive) industry in state of the art technologies, such as semiconductors and other electronics (Matthews and Hu, 2007).

In Brazil, several studies have been carried in order to explain the main characteristics of cooperative R&D agreements, its determinants and main outcomes. Technological clusters are the main targets of academic scrutiny – such as the industrial agglomerations in Campinas, Recife, Belo Horizonte, among others.

In summary,

3. General characteristics of innovation and cooperation in Brazil

The Brazilian Innovation Survey (PINTEC) carried out by IBGE in 2005 contains important information on the origins of information for innovation, as well as on the cooperative arrangements that took place with the purpose to innovate. The survey follows the Oslo Manual, developed by OECD and widely applied on European innovation surveys.

The universe of the survey is of 89.162 domestic firms and 1.893 foreign firms, summing up 91.055 firms. The group of innovative firms is much smaller: 29.951 firms (32,9% of total) declared having performed product and/or process innovation between 2003 and 2005. Proper R&D activities are not the main innovative activity carried out in Brazilian firms; a great amount of innovation expenditures is through the acquisition of mew machinery and equipment. From the total of innovative firms, only 6.021 declared that their R&D activities had a strong or average role for innovation (IBGE, 2007).

The 2005 survey registered a rise in cooperative activities of firms, if compared with the previous survey (2003): the share of firms that declared to have participated in a cooperative arrangement , which was of 3,8% in 2001/2003, reached 7,2%, totalling 2.139 firms (IBGE, 2007). The growth was even stronger among small firms (up to 500 employees). In firms with more than 500 employees, there was a small decline in the percentage of cooperative firms.

Table 1: share of cooperative firms among innovators - selected sectors of industry - 2003/2005

Sector	Innovative	Cooperative	% C/I
Total Of Industry	29.951	2.139	7,14
Food and beverages	3.771	249	6,60

Clothing	3.403	109	3,20
Metal products	2.668	173	6,48
Furniture	2.304	43	1,87
Machinery and equipment	2.282	202	8,85
Chemical & pharmaceutical products	1.900	314	16,53
IT services	2.197	425	19,34
Total of Services	2.418	582	24,07

Source: IBGE, PINTEC 2005.

The number of innovative firms that have declared to have taken part in a cooperative agreement is quite low: 2.139 firms, or 7,1% of innovative firms. This share is much lower than the ones observed in surveys of developed countries; a recent study from OECD pointed that one in every 10 European firms cooperated in the period 2002-04, or one in every four of the innovative firms (OECD, 2007). In Germany, the share of cooperative firms reaches 50% (Fritsch and Lukas, 2001). Among services firms from Brazil, surveyed for the first time in the 2005 edition of the Brazilian survey, the share of cooperative firms reaches 24% (IBGE, 2007).

IT services are the leading sector in cooperation. Among the industrial sectors, chemicals & pharmaceuticals and food & beverages are the leaders in cooperation among Brazilian firms. They are followed by machinery and equipment, rubber and plastic products, and metal products (Table 1).

Vertical partnerships – those that occur between clients/ consumers and suppliers – are the most frequent in Brazil. More than half of the cooperative firms have associations of this nature. The second most usual type of cooperation is between firms and universities /research institutes – those are important partners for 29,5% of cooperative firms in Brazil. Partnerships with competitors are the less frequent cooperation, taking place in only 15% of associations (Table 3).

Table 2: Cooperation for Innovation - by type of partners and R&D partnerships (% of cooperative firms)

Partner	R&D Partnership	%	Other Partnerships	%
Clients/consumers	773	36.1 %	790	36.9 %
Suppliers	747	34.9	1083	50.6

		%		%
Competitors	146	6.8%	246	11.5%
Other firm group	294	13.7%	261	12.2%
Consultancies	339	15.8%	433	18.9%
Universities/Research institutes	663	31.0%	404	18.9%
Training Centres	207	9.7%	474	22.2%

Source: IBGE, PINTEC 2005.

The survey distinguishes the location of partners; as expected, most firms associate with domestic partners. The most frequent partnership with foreign partners is that of foreign firms and other firms from the group (Table 3).

Table 3: types of cooperation by capital ownership and location of partner

	Domestic		Foreign	
	Local	Abroad	Local	Abroad
Customers	1131	57	143	31
Suppliers	1087	107	138	51
Competitors	317	23	23	10
Another firm/group	79	39	23	220
Consultancies	428	22	53	11
Universities	599	14	113	-
Training Centers	461	-	58	4

Source: IBGE, PINTEC 2005.

In general, the cooperative arrangements for innovation undertaken by Brazilian firms follow the same patterns seen in other countries. Everywhere, it is the most knowledge-intensive sectors those to lead cooperation. However, both the share of innovative firms and of cooperative firms in Brazil are much lower than those of developed nations. The role of university as an important source of information and partnerships for innovation is still modest – facts that stress the fragility of the innovation system in Brazil and its immature relationships among the diverse actors.

Regarding government support policies, the most used – for both domestic and foreign firms – was the funding of R&D and technological innovation projects. The benefits of the Innovation Law, the Informatics Law, as well as R&D project funding when jointly undertaken by firms and universities/research institutes, still have a limited scope, due to not only the small innovative propensity of Brazilian firms but the lack of information on how such incentives work and can be accessed. Foreign firms have used relatively more of innovation support programs (Table 1).

Table 4: use of Innovation Support Programs, by capital ownership

Program	Domestic	% of firms	Foreign	% of firms
Innovation Law	164	0.184%	58	3.064%
Informatics Law	290	0.325%	54	2.853%
R&D Projects; U-I partnerships	420	0.471%	53	2.800%
Funding of R&D/ Innovation projects	3828	4.293%	102	5.388%
Researcher in-company scholarship	63	0.071%	11	0.581%
Venture Capital	395	0.443%	6	0.317%
Total of Firms by ownership	89162		1893	

Source: IBGE, PINTEC, 2005.

Next section describes more in depth the state of university-industry cooperation in Brazil, based on the 2005 innovation survey data.

3.1. U-I Cooperation – recent trends

PINTEC gives a portrait of the current state of cooperative agreements between firms in Brazil, and also specific information on cooperative agreements between firms and universities.

Research and development activities are the main type of cooperation between firms and universities/research institutes. But there are several other types of relationships that are important means of interaction university-industry (Table 5).

Table 5: Types of cooperative activities with Universities, by capital ownership

Activity	Domestic	Foreign
R&D	361	101
Technical assistance	71	14
Training	180	30
Industrial Design	60	8
Tests	336	76
Other	185	31
Total of firms	89162	1893

Source: IBGE, PINTEC 2005.

The sectors that cooperate with universities in Brazil are diverse; the chemical sector is the leader, for both R&D and other activities; food and beverages too – this is a sector that in Brazil tends to spend more in R&D than the world average for this industry (Table 6).

Table 6: University-Industry cooperation in Brazil - by selected sectors (2003-05)

Industry	R&D	other activities
Total Of Industry	663	404
Food and beverages	83	42
Leather products	35	37
Electrical equipment	38	25
Rubber and plastic	76	19
Machinery and equipment	46	46
Telecom equipment	39	12
Chemical & pharmaceutical products	134	63
Vehicles	27	15
Total of Services	128	120

Source: IBGE, PINTEC 2005.

When asked about the sources of information used for innovation, Brazilian firms declared to resort more to clients and suppliers; competitor firms come as the third source. Universities are ranked fourth as a source of knowledge for innovation (Table 7).

It is worth noticing that 'other firms from the group' have a very low importance as a source of information, which can be understood as, even though there are many groups in operation in Brazil (originated from local, usually family capital) their innovative activities tend to be concentrated in only one facility. On the other hand, when one looks only to foreign firms, the importance of other firms in the group for innovation are evident.

Table 7: Sources of Information for Innovation, by capital ownership

	Domestic	**Foreign**
Other firms/ group	563	852
Clients	18881	872
Suppliers	19740	789
Competitors	13749	495
Consultancies	3800	262
Universities	3686	231
Training centers	4832	231

Source: IBGE, PINTEC 2005.

Table 8: Main responsible for the development of the innovation (industrial firms) - percentage

	Product	Process
Firm alone	89.5	9.2
Another firm in the group	1.5	0.7
Firm in cooperation with other firms and institutes	5	3
Other firms and institutes	4	87.1

Source: IBGE,PINTEC 2005.

Some insights might come out of the information given on Table 8.

4. Econometric results

At this point we test what are the characteristics of firms that cooperate with universities - the characteristics that exert some influence on the probability to cooperate with universities. Other studies have done similar efforts to profile firms of this sort. For instance, Segarra-Blasco *et al.* (2008) carried out a study using data from the Spanish CIS and found out that Spanish firms cooperate more with universities when they also cooperate with other partners, as well as larger firms, and those with intramural R&D.

We use hypotheses similar to the Spanish study for the case of Brazilian firms surveyed in the PINTEC 2005.

Box 1: Hypotheses tested

H1: Cooperation with universities increase with firm size (measured in terms of net sales revenues)

H2: The propensity to cooperate with universities is higher the higher is R&D expenditure

H3a: Intramural R&D activities increase the propensity to cooperate;
H3b: in the same direction, continuous R&D activities increase the propensity to cooperate with Univ.

H4: The higher the degree of newness of the product, the higher the propensity to cooperate with universities

H5: Public funding programs affects the propensity to cooperate with universities

H6: Engagement in other forms of cooperation increase the propensity to cooperate with universities

H7: A higher number of employers with post-graduation degrees increase the propensity to cooperate with universities

A set of explanatory variables are used in order to test the above hypotheses. We use four sets of variables: firms' characteristics, sources of innovation, use of public funds and cooperation partners.

Box 2: Definitions of the independent variables

Variables	Description
Firm characteristics	
Net sales revenues	Log of sales revenues
Domestic	Dummy=1 for domestic firms
product innovation	Dummy=1 if the firm has performed product innovation
New national	Dummy=1 when innovation is new to local market
New world	Dummy=1 when innovation is new to world
masters employees	Log of the number of employees with at least a master degree
Innovation sources	
Intramural R&D	Log of internal R&D expenditures
Extramural R&D	Log of external R&D expenditures
Continuous R&D	Dummy=1 if R&D is a continuous activity
Use of public funds	
Gov support	Dummy=1 if firm obtained funding from any government program
Public_fund	Dummy=1 if firm had innovation publicly funded
Cooperation Partners	
Vertical cooperation	Dummy =1 if firm cooperated with clients and/or suppliers
Group	Dummy=1 if firm cooperated with other firm from the group
Competitors	Dummy=1 if firm cooperated with competitors

Table 9 presents the coefficients of the probit regression, and give some very interesting information on the profile of firms that cooperate with universities. First, the size of the firm does not seem to exert any influence on the propensity to cooperate. Domestic firms showed a positive propensity to engage in cooperative agreements with universities that foreign firms did not. Moreover, the existence of vertical cooperation for innovation increased the propensity to undertake R&D agreements with universities as well.

Interesting results were obtained regarding the innovative characteristics of firms. First, whereas product innovation does not have a significant effect over cooperation, innovation new to the world has a significant positive effect. This suggests that, the more breakthrough the innovative effort is, more firms are inclined to undertake innovative efforts jointly with universities and research institutes. This is also in line with the information on Table 8, which states that 89,5% of firms affirm to carry out product innovation by themselves. Process innovation, on the other hand, is an activity that prompts a higher cooperative behaviour from Brazilian firms.

The presence of government supported R&D activities also have a positive effect on cooperation with universities – possibly due to the incentives given to joint R&D projects with universities and/or scholarships grants for researchers working within the firm. This is similar to results found for other countries, where government funding also revealed a relationship with university cooperation (Segarra-Blasco *et al.*, 2008). On the other hand, the presence of publicly funded R&D showed a negative effect on the probability to cooperate with universities.

Another interesting result is the positive effect that the number of employees with at least a master degree played on the propensity to cooperate with universities. This has to do not only to the fact that more skilled personnel is probably related to higher knowledge and technology industries, but also that these personnel contribute to improving the capacity of learning from external sources of knowledge.

In general, cooperation with all sorts of partners had a positive impact on the probability to cooperate with universities.

Table 9: Cooperation with Universities (probit model)

Parameter	**Estimate (SE)**
Intercept	- 3.2068 *** (0.2089)
Vertical Cooperation	1.4553*** (0.0503)
Net Sales Rev	0.0152 (0.0112)
Cooperation Group	0.2429** (0.1087)
Cooperation Competitors	0.2272 ** (0.0840)
MastersEmploy	0.3382 *** (0.0477)
Domestic	0.2439 * (0.0963)
Innov_product	-0.0626 (0.0524)
Intern R&D	0.0182 ** (0.00612)
Extern R&D	0.0345 *** (0.00563)

R&D continuous	0.3125 ***
	(0.0752)
New world	0.7724 ***
	(0.0944)
New national	0.0177
	(0.0637)
Gov_support	0.4898 ***
	(0.0561)
Public_fund	- 0.1954 *
	(0.0720)
Hosmer-Lemeshow GOF test	DF (Pr> Chi2)
Chi2 34.0502	8 (<.0001)

* significance at 10%; ** significance at 5%; *** significance at 1%

4. Concluding remarks: the gap between science and technology in Brazil.

The purpose of this paper was to provide an overview of the state of cooperative agreements between Brazilian firms and other agents of the innovation system, with a special focus on industry-university linkages. The results have shown that the trends are directing to an increasing occurrence of cooperative agreements for innovation between the various agents of the national innovation system, especially between firms and universities. However, the amount of linkages are not yet enough to provide the Brazilian industry with the necessary dynamism of a true, innovative economy.

Continues.....

Any useful investigation aiming to contribute to understanding this still initial stage of a national innovation system in Brazil must have to deal with the gap that has been widened recently between scientific advances and the still low innovative profile of Brazilian firms. Recent data shows that, while Brazil jumped from position in the NSI

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