TECHNOLOGY TRANSFER FROM UNIVERSITIES AND PUBLIC RESEARCH INSTITUTES TO FIRMS IN BRAZIL: WHAT IS TRANSFERRED AND HOW THE TRANSFER IS MADE

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Abstract: This paper presents an analysis of the technology transfer process from universities and public research institutes to firms in Brazil. In particular, this study is concerned with the role of patents in this process. Although there is a certain enthusiasm in promoting technology transfer offices to manage university patents, the importance of patents to the technology transfer process is not well understood in the literature yet. We conducted a survey with leaders of research groups from universities and public research institutes that developed and transferred technology to firms. The results show that patents are one of the least used channels of technology transfer by universities and public research institutes. But the importance of the channels varies according to the kind of technology transferred and to the firms' industry.

Key words: Technology transfer; university; public research institutions, patent.

JEL Classification: O31; O34

Resumo: Este artigo apresenta uma análise do processo de transferência de tecnologia de universidades e institutos públicos de pesquisa para empresas no Brasil. Em particular, este estudo focaliza o papel das patentes neste processo. Embora exista certo entusiasmo em promover escritórios de transferência de tecnologia nas universidades para administrar suas patentes, o papel das patentes no processo de transferência de tecnologia ainda não está bem definido na literatura. Este trabalho apresenta os resultados de um *survey* com líderes dos grupos de pesquisa registrados no CNPq que desenvolveram e transferiram tecnologia para empresas. Os resultados indicam que as patentes são um dos canais de transferência menos utilizados pelas universidades e institutos de pesquisa. Entretanto, a importância dos canais varia de acordo com o tipo de tecnologia transferida e com o ramo de atividade econômica da empresa.

Palavras-chave: **Transferência de tecnologia; universidade; institutos públicos de pesquisa; patente.**

Classificação JEL: O31; O34

Área 8 - Economia industrial e da tecnologia

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1. Introduction

While there have been several studies that have analyzed university – industry interactions and the role of patents in those interactions, as far as we know there are still few studies that have looked at these issues in the context of a developing country. This paper presents an effort to fill this gap by presenting a study of technology transfer in Brazil, taking into account the channel of technology transfer and its relation to the kind of technology transferred.

Successful cases of technology transfer, like the Cohen-Boyer technology[3], stimulated universities around the world to create technology transfer offices and had a significant institutional influence. Enacted in 1980 in the United States, the Bayh-Dole Act aimed to stimulate commercialization of academic patentable discoveries, thus facilitating and allowing universities to patent research results supported by federal funds. The basic idea behind the Bayh-Dole Act is that universities are a repository of inventions, but firms are not willing to invest in these inventions to transform them into innovations if they have no ways to appropriate the returns from investments in R&D. Therefore, allowing universities to patent and license their inventions would give firms incentives to invest. So, patents could be seen as a channel of technology transfer from universities to firms.

In fact, the number of university patents and license agreements increased in the United States, although this was not exclusively due to the Bayh-Dole Act[4], and it stimulated universities and governments of other countries to use university patents as a channel of technology transfer (MOWERY et al. 2004). In 1998, the Brazilian Ministry of Science and Technology published a document entitled “Royalties to universities and public research institutes researchers” highlighting the fact that changes in Brazilian intellectual property law in 1996 (to comply with the TRIPS agreement) allowed researchers to share in the economic results generated by their patent-protected academic work. The document also highlights the fact that normative changes were made with the “aim to stimulate applied research, to avoid a drain of the knowledge and inventions generated in institutes, and to intensify relationships between research institutes and the productive sector” (VARGAS, 1998). As a result of many factors, including government incentives and a change in the researchers’ and the universities’ behavior towards the acceptance of patents, the number of university patens in Brazil increased significantly during the second half of 1990s (PÓVOA, 2008).

Although universities and governments are very enthusiastic about university patents, a growing literature is questioning the role of intellectual property rights as a technology transfer channel (AGRAWAL & HENDERSON, 2002; MOWERY et al., 2004; COLYVAS et al. 2002; COHEN et al., 2002; SAMPAT, 2002). According to Mowery et al. (2004, p. 2) “the Bayh-Dole Act was motivated by the belief that university patenting would spur and facilitate the transfer of university discoveries to industry for commercial development”. However, describing the interaction between universities and U.S. industry during the Twentieth Century, the authors state that there are several channels through which knowledge flows from universities to industry, like publications, consulting, and informal conversations. The authors conclude that “academic patenting and licensing are not the primary channels for technology transfer and knowledge exchange with industry” (MOWERY et al., 2004, p. 5). Colyvas et al. (2002) and Sampat (2002) point out that the importance of patents and exclusive licenses for technology transfer is not well understood in the literature yet.

The relatively low importance of patents in university-industry interaction is also suggested by Bekkers and Bodas Freitas (2008). The authors conducted a survey with Dutch industrial and university researchers on the channels of knowledge transfer and show that “it is remarkable that the instruments that are usually promoted by both policy makers and university management (…), and university patents receive rather low ratings from both groups of respondents” (BEKKERS and BODAS FREITAS, 2008, p. 1843).

[3] Stanford University was granted a patent in 1980 for recombinant DNA methods developed by Stanley Cohen and Herbert Boyer, which gave birth to the modern biotechnology industry (Feldman et al., 2005).
[4] For a detailed analysis of U.S. patents increase, see Mowery et al. (2004).

This paper aims to contribute to this literature by analyzing the technology transfer process form universities and public research institutes (PRI henceforth) to firms in Brazil. In order to analyze the relative importance of patents in this process, we studied the kind of technology generated by universities and PRI associated with the channels of technology transfer use in the interaction with firms. The results are from a survey conducted by one of the authors with answers from 178 research group leaders concerning 271 technology transfers. The main results are very close to findings for developed countries, especially the limited role of patents as a channel of technology transfer. The next section presents a literature review of the theories behind the notion of patents as technology transfer channels (or mechanisms), as well as other channels related in the literature. The third section describes the database. The survey's results are presented in the fourth section. The last section presents the conclusion.

2. Technology transfer channels

2.1. Conceptual aspects

The technology transfer concept embraces two broad issues and their meanings: how to define technology and the straight meaning of transfer. Barry Bozeman raises three difficulties to deal with this subject:

> "Anyone studying technology transfer understands just how complicated it can be. First, putting a boundary on "technology" is not so easy. Second, outlining the technology transfer process is virtually impossible because there are so many concurrent processes. Third, measuring the impacts of transferred technology challenges scholars and evaluators, requiring them to reach deep down into *their research technique kit bag"*. (Bozeman, 2000, p. 627).

In general, technology transfer studies circumvent these problems focusing on patent licensing, and do not devote space to conceptual discussion (HENDERSON et al., 1998; JENSEN & THURSBY, 2001; THURSBY & THURSBY, 2002). In this way, technology is simply the content of patents and their transfer is the licensing process.

Addressing technology in this way restricts the subject because not all technology generated in universities and PRI is patented. In other words, there is a lot of technology generated and transferred that is not addressed by the literature.

Bozeman (2000) stresses that few economists deal with the technology concept. Sahal (1981) discusses difficulties in defining technology that has an analytical meaning. For him, technology had an evolutionary nature. In neoclassical economics, technology is defined as a production function, and investigations are commonly focused on changes through production function, but not on production function evolution over time, which is the relevant question for technical progress (SAHAL, 1981:21).

The Pythagorian view of technology understands technology as a set of relevant events that shares features such as novelty and uniqueness (SAHAL, 1981: 10). In this view, changes in patent numbers are a way to measure technology change. Critics of this view are based on the limitations of considering patents as a technology indicator. In opposition, and as an alternative to these two views, Sahal presents a systemic view of technology. For him "technology is best understood in terms of certain measurable, functional characteristics of phenomenon under consideration. Briefly, a technology is as a technology does" (SAHAL, 1981:22). However the author does not define the "functional characteristics" of the phenomenon under investigation and shows a strong pragmatism by asserting synthetically that "a technology is as a technology does".

The definition of technology adopted in this paper is the one presented in Dosi (1982), which defines

> "(…) technology as a set of pieces of knowledge, both directly 'practical' (related to concrete problems and devices) and 'theoretical' (but practically applicable although not necessarily already applied), know-how, methods, procedures, experience of successes and failures and also, of course, physical devices ad equipment". (DOSI, 1982, pp. 151-152).

Dosi's definition recognizes that technology is a composition, and we could add harmonic, of knowledge. This harmonic composition can be physical artifacts or abstract methods. Arthur (2007, p 276) shows a definition that summarizes these ideas describing technology as "*means* to fulfill a human purpose (...) [a]s a means to fulfill a purpose, a technology may be a method or process or device".

Though Dosi includes “theoretical knowledge” in his definition, we can not misunderstand technological knowledge as being applied science[5]. In many cases, it’s known that a technology works, but we do not know why (ROSENBERG, 1982), while the applied science begins exactly from the knowledge of “why”.

In terms of technology transfer, it’s important to consider the inseparability of product and knowledge transfer, an idea that appears in Dosi’s definition. Even when technology is viewed as a physical entity, its transfer implies information and technology flow to the receptor (SAHAL, 1982, *apud* BOZEMAN, 2000). In this way, a minimum absorptive capacity is required to technology’s receptor.

As said before, technology transfer literature has been considering patent and its licensing as “the” transfer channel. However, some authors have stressed the importance of other channels, such as publications, consulting and informal information exchange (AGRAWAL & HENDERSON, 2002; MOWERY et al. 2004). Below, we analyze the main channels of transfer address in literature.

2.2. Patents as a channel of technology transfer: a criticism

After the Bayh-Dole Act, patent licensing has been considered as synonym of technology transfer in many studies (EISENBERG, 1996; HENDERSON et al., 1998). One of the most important organizations that deal with technology transfer, the AUTM (The Association of University Technology Managers) gives the following definition:

> “Technology transfer is the process of transferring scientific findings from one organization to another for the purpose of further development and commercialization. The process typically includes: (i) identifying new technologies; (ii) protecting technologies through patents and copyrights; (iii) forming development and commercialization strategies such as marketing and licensing to existing private sector companies or creating new start-up companies based on the technology”. (AUTM)[6]

This treatment of patents as the main technology transfer channel stimulated the creation of technology transfer offices in universities in several countries. These offices manage marketable inventions generated by researchers. They perform periodic consultancy about recent scientific discoveries with market potential, and take care of patenting processes and approach partners interested in licensing technology. However, besides university enthusiasm in technology transfer, it’s necessary to recognize that patents are just one of the channels of technology transfer.

This paper assumes that patents are a limited channel for the technology transfer process, and this limitation is associated with the following factors: (i) type of technology (product, process, etc); (ii) the need for more research to turn invention into a final process or product; and (iii) the appropriability of the regime of the firm’s industry to which the technology is transferred (how it sees the patent as a means of appropriating the returns of R&D). Each factor is discussed below.

Patents are just one of the several mechanisms for appropriating returns of inventions and, like other mechanisms[7], it is imperfect. Levin et al. (1987) conducted a study about the appropriation of returns from industrial R&D. Their results suggest that patents are considered by firms as one of the least effective mechanisms. Besides, product patents were considered more effective than process patents. So, it’s necessary to verify what kind of technology knowledge universities and public research institutions generate the most, order to evaluate the need for patents.

Regarding the second factor, the argument behind the Bayh-Dole Act was based on the assertion that most university inventions were in an embryonic state, requiring additional R&D spending to transform them into a commercial product. According to this argument, universities must patent their inventions in order to encourage firms to make subsequent R&D efforts. Colyvas et al. (2002) analyzed several

[5] As stressed by Pavitt (1998, p. 794), “technological knowledge is not ‘applied science’, but ‘a capacity to solve complex problems’”.
[6] http://www.autm.net/aboutTT/. Access in August, 2007.
[7] Some of those mechanisms are: the advantage of being the first; industrial secret; moving quickly down the learning curve; sales or service efforts (LEVIN et a. 1987).

academic inventions and indicated that patents were more important as a channel of technology transfer for embryonic inventions than for “ready to use” inventions.

The importance of patents as a technology transfer channel also varies significantly among industries. Levin et al. (1987), in their survey, pointed out that only one industry (drugs) regarded product patents as strictly more effective than other means of appropriation of R&D returns. Cohen, Nelson and Walsh (2002) show that patents and licenses are effective mechanisms of technology transfer in a few industries, like pharmaceuticals. They stressed that even in the pharmaceutical industry, informal mechanisms and publications were considered important.

In a previous work, Cohen et al. (2000) discuss other results from the same survey, emphasizing that motivation behind patenting goes beyond patenting to protect profits and preventing other firms to copy their inventions. Firms try to get patents from their inventions in order to prevent rival firms from getting patents in related areas, to use them in negotiations and to avoid judicial battles. While pharmaceutical firms patent to prevent competitors from patenting substitutive products, telecommunications and semiconductor firms use their patents to enforce negotiations.

Mazzoleni (2005) highlights two theoretical arguments of how patenting academic researches financed with public resources adds to generate more marketable innovations in a faster way. The first is based in technology transfer costs. Patents help to reduce costs because researchers have more incentive to get in technology transfer activities facilitating for firms absorbing scientific research results. This argument shows a contradiction, as licensing is a cost for companies that develop technology.

The second argument, presented in greater depth in Mazzoleni and Nelson (1998), can be treated as the induced commercialization theory. In many cases, universities and PRI patents are related to inventions in the embryonic stage, requiring R&D efforts to reach the commercialization stage. Patents would encourage interested firms to invest in subsequent R&D efforts. So, cost and uncertainty associated with subsequent R&D activities should be lower for firms when they license academic patents with exclusivity, than when knowledge is generated by universities and IPP are in the public domain. Criticism of this argument came from the most famous technology licensing. Cohen-Boyer technology has been used by firms before patent procurement – which generate altered litigation against those who were using it – and was not exclusively licensed.

So, patents seem to be necessary for technology transfer under constrained circumstances. Only a few industries consider it to be an effective channel; it depends on the invention characteristics (product, process, etc.); and it also depends on the stage of the invention (embryonic or ready to use).

2.3. Other channels of technology transfer

Mowery et al. (2004) led a broad-based study about the Bayh-Dole Act’s effects in patenting activities in North American universities and they questioned the role of patents as a necessary factor to transfer technology and to market academic inventions. For them, throughout the history of interactions between universities and North American industry, knowledge and research results flowed to industry through publications, conferences, consulting, personal exchange between universities and industry, among others (MOWERY et al. 2004, p. 2). Chemical engineering at MIT is an example of how results flowed over several channels, where professors provide consultancy to Standard Oil and take problems to be developed by their Ph.D. students. Subsequently, many of these students were hired by the same firms, maintaining a dialogue with their previous teachers.

While Mowery et al. (2004) papers show other channels to transfer knowledge and technology, Agrawal and Henderson (2002) goes beyond and compares the importance of these mechanisms. They do a more in-depth analysis of two departments at MIT (Massachusetts Institute of Technology) that are the most active in patenting with industry: the mechanical engineering and electrical engineering departments. Based on qualitative information and in interviews with department members that had generated at least one article or one patent between 1983 and 1997, the authors sought to evaluate the importance of patents as a mechanism to transfer technological knowledge and also other mechanisms. Results showed that patents have a relatively small role in transferring university technological knowledge. The principal mechanisms pointed to by 68 department members were consultancy (26%), publications (18%), hiring students (17%) and patents and licensing (7%).

In studies that investigate university perspectives, there could be expected to be a sub-evaluation of non academic mechanisms, such as patents, and a super-valuation of those like publications. However Agrawal and Henderson (2002) compare their results with those of Cohen et al. (1998), which investigate in manufacturing firms the importance of several technological knowledge transfer mechanisms from universities to their industrial sector. The results from Cohen et al. (1998) indicate that the role of patents, even when evaluated by technology receptor side is less important than those of other mechanisms, such as conversation, publications, conferences and consultancy.

3. Data and methodology

3.1. Database

In order to evaluate the mechanisms involved in the technology transfer process, it was necessary to obtain data on the occurrence of technology transfer. The Research Group Directory of CNPq provided a lot of useful information. CNPq is an organization of the Brazilian Ministry of Science and Technology founded in 1951, responsible for distributing research grants to Brazilian scientific and technological communities. Its Directory of Research Groups is a database, which was begun in the early 1990s and is renewed every second year. It comprises detailed information about research activities in Brazil using the "research group" as the unity of analysis. The Directory provides an excellent proxy for studying research activities in Brazil, even though adherence to it is voluntary. In fact, since the late 1990s, coordinators of research groups in public universities have been implicitly forced to send information to the directory, since their access to government funding implicitly depends on the information they send. Although there are intrinsic limitations to information collection, the database supplies some important evidence from recent university-industry interactions in Brazil that will be used in this paper.

CNPq's Directory of Research Groups was first set up as an attempt to gather and organize information regarding research activities in Brazil. In the first version of the directory, in 1993, 99 institutions and 4,402 research groups gave information about their research activities. The latest version, from 2004, comprises information about 375 institutions and 19,470 research groups. The total number of researchers is 77,649, and 47,973 of them (62%) hold a PhD degree. According to some estimates (CARNEIRO & LOURENÇO, 2003), at least 85% of all researchers in Brazil are included in the database. In 2004, fifty-two per cent of research groups were located in the richest part of Brazil, the Southeast. Twenty-two percent of the groups are located in the South, 6% are from the Center West, while 14% are from the Northeast and 4% from the North, the poorest areas.

Of all the registered research groups, only 11.1% (2,139), affiliated to 217 institutions, declared collaboration with firms in 2004. The analysis hereafter will concentrate on these groups and on the information they provided. Leaders of research groups were asked, first to inform if the group itself initiated the relationship or if a firm approached the institute. The database methodology proposes 14 types of possible relations between groups and firms. Each leader could list at most 3 types of relationship that were more frequent with firms.

The analyses will focus on research groups that declared that they "transfer technology" towards the productive sector. In the 2004 Census, 558 groups declared 969 technology relationship type transfers, which results in an average of 1.7 technology transfers per group. These groups are concentrated in the Southeast of Brazil, which accounts for 45% of them (São Paulo state, which is the most prosperous, alone accounts for 20.8%).

Each research group is classified into a scientific area by its leader in the Directory. It's reasonable to assume that the technology developed and transferred by the group would be related to its scientific field. The database show that 42.2% of technology transfers were from groups belonging to the engineering field, and 30.7% from agrarian sciences. In academic discipline level, agricultural science ranks first place in technology transfers, comprising 11.8% of the total.

It's also possible to estimate a linkage between the scientific field of the research group that transferred technology and the economic activity of firms that received this technology. Almost half of the technology developed by universities and public labs was transferred to manufacturing firms, which account for 47% of total firms. In second place are firms classified as "agriculture, farming, forestry, and fishing," which received 16% of the transfers. Given the importance and variety of manufacturing firms, it's necessary to take a closer look into this economic activity. There is a balanced distribution of technology transfers to firms in manufacturing sectors of "food", "chemicals", "machinery and equipment", "paper", "drugs", and "informatics, electronic, and optic equipment".

3.2. Questionnaire design

The CNPq's Research Groups Directory data enables identification of universities and PRI that made more technology transfers, firms that received the technologies, and the firms' industries. However it is not possible to address some important questions: kind of technology transferred (product, process, etc.); channels of technology transfer; and industries and scientific areas that rely more on patents to carry out transfer. In order to obtain this information, questionnaires were sent to 558 leaders of research groups that generated and transferred technology to firms. The contacts were made by e-mail.

The questionnaire design was based on theoretical and empirical results of literature on economics of science and technology (AGRAWAL & HENDERSON, 2002; COHEN *et al*. 2002; COLYVAS *et al.* 2002; DASGUPTA & DAVID, 1994; KLEVORICK *et al*. 1995; LEVIN *et al.* 1987; RAPINI *et al.* 2006; STEPHAN, 1996). Interviews were also conducted with researchers in the preliminary phase of the survey, as suggested in Converse *et al.* (1986). The pre-tested interviews were useful to suggest questions about groups' participation in developing technology to reach the market; the research funding by firms; and academic impact of research groups-firms interactions.

The questionnaire has five parts. The first part is related to the kind of technology developed and transferred by the group. The second part asks about the channels used to transfer technology. The transfer process is the subject of the third part, and role of patents (if there is one) is in the fourth part. Questions about features of firms' interaction, like academic benefits for the groups resulting from the process to transfer technology are asked in the last part. This paper analyzes questionnaire responses in parts one to four.

4. Survey results

4.1. General characteristics of technology transfer in Brazil

A total of 969 questionnaires were sent to all 558 group leaders, as leaders received one questionnaire related to each technology transferred declared in the CNPq Directory. A total of 271 questionnaires were returned (a return rate of 27.9%) belonging to 178 group leaders (a return rate of 31.9%). The first question asked about the kind of technology developed and transferred by the group. The leader was given the option to reconsider if whether what the group had transferred was really a technology by answering "it was not a technology". Since nine leaders marked this option, we had an adjusted response rate of 27% of questionnaires (262) and 31% of group leaders (173).

The total number of groups, as well as the number and the mean of total technology transfers in each Brazilian state[8] are presented in Table 1. Almost a half of the groups are from universities localized in the southeast region (49.1%), with one state, São Paulo, accounting for 24.3%. In second place is Rio Grande do Sul, in the southern region, with 15.6% of total groups. In terms of technology transfers, Minas Gerais occupies the second position with 16.4% of total. The states with the highest mean of technology transfer by group are Minas Gerais and Paraná.

[8] There are 27 states in Brazil, including the Federal District. Five states did not present data on technology transfer (Amapá, Maranhão, Piauí, Rondônia and Tocantins) and four (Mato Grosso do Sul, Sergipe, Rio Grande do Norte and Alagoas) did not have questionnaire answered by its research groups.

TABLE 1 – Number of groups that made technology transfer and total number of technology transfer by region and states

Region/ state	Research groups		Technology Transference		Mean
	N	(%)	N	(%)	
North	***7***	***4.0***	***8***	***3.1***	***1.1***
Acre	1	*0.6*	1	*0.4*	1.0
Amazonas	2	*1.2*	2	*0.8*	1.0
Roraima	1	*0.6*	1	*0.4*	1.0
Pará	3	*1.7*	4	*1.5*	1.3
Northeast	***24***	***13.9***	***37***	***14.1***	***1.5***
Bahia	13	*7.5*	22	*8.4*	1.7
Ceara	2	*1.2*	4	*1.5*	2.0
Paraíba	6	*3.5*	8	*3.1*	1.3
Pernambuco	3	*1.7*	3	*1.1*	1.0
Central- West	***9***	***5.2***	***11***	***4.2***	***1.3***
Distrito federal	6	*3.5*	9	*3.4*	1.5
Goiás	2	*1.2*	2	*0.8*	1.0
Mato Grosso	1	*0.6*	1	*0.4*	1.0
Southeast	***85***	***49.1***	***134***	***51.1***	***1.6***
Espírito Santo	2	*1.2*	2	*0.8*	1.0
Minas Gerais	23	*13.3*	43	*16.4*	1.9
Rio de Janeiro	18	*10.4*	21	*8.0*	1.2
São Paulo	42	*24.3*	68	*26.0*	1.6
South	***48***	***27.7***	***71***	***27.1***	***1.5***
Paraná	12	*6.9*	24	*9.2*	2.0
Rio Grande do Sul	27	*15.6*	38	*14.5*	1.4
Santa Catarina	9	*5.2*	9	*3.4*	1.0
Total	**173**	**100**	**262**	**100**	**1.5**

Source: Authors' elaboration.

Table 2 presents technology transfers by scientific field of research group. As is shown 37.8% of technology transfers were from groups belonging to the engineering field, and 35.9% from agrarian sciences. Although Brazil has a tradition in studies in health sciences, only 1.5% of the transfers were in this field. This can be an indicative of a weak connection with the productive sector. This picture suggests that two scientific fields, engineering and agrarian sciences, accounted for more than 70% of transfers.

TABLE 2 – Number of technology transfers by scientific area

Scientific field	Technology Transfers	(%)
Engineering	99	37.8
Agrarian Sciences	94	35.9
Hard Sciences	34	13.0
Biology	24	9.2
Health Sciences	4	1.5
Human Sciences	4	1.5
Social Sciences	3	1.1
Total	**262**	**100**

Source: Authors' elaboration.

Obs.: Hard Sciences includes: Mathematics, Physics, Chemistry, Statistics, Computer Science and Geology.

The relevance of agrarian sciences for Brazilian industry is highlighted when it is observed that agronomy is the academic discipline which made the most technology transfers (see Table 3). Agronomy accounts for 15.3% of total technology transfers. In second place is Forest resource and engineering with 7.6%, which is also a discipline from agrarian sciences. In agrarian sciences, the presence of public research institutes in technology transfer can be observed. The agroindustry in Brazil, since 1960, receives public support to develop and diffuse agricultural technology. An example is EMBRAPA - Brazilian Company for Agricultural Research – a public research corporation established in 1973 whose aim is "to provide feasible solutions for the sustainable development of Brazilian agribusiness through knowledge and technology generation and transfer" [9].

[9] Source: www.embrapa.br.

TABLE 3 – Number of technology transfers by academic discipline

Discipline	Technology Transfers	(%)
Agronomy	40	15.3
Forest resource and engineering	20	7.6
Civil engineering	16	6.1
Mechanical engineering	16	6.1
Electrical engineering	14	5.3
Computer science	13	5.0
Chemical engineering	12	4.6
Agriculture engineering	11	4.2
Material engineering and metallurgy	11	4.2
Chemistry	10	3.8
Others	99	37.8
Total	**262**	**100.0**

Source: Authors' elaboration.

Comparing the data presented in Table 2 to those in Table 4 it is possible to see that there is a relationship between the scientific field of research group that transferred technology and the economic activity of the firms that received technology[10]. Almost half of the technology developed by universities and public labs was transferred to manufacturing firms (46.9%). In second place are firms related to "agriculture, farming, forestry, and fishing", receiving 21.8% of the transfers.

TABLE 4 – Number of technology transfers by economic activity of recipient firm

Economic activity	Technology Transfers	(%)
Manufacturing	123	46.9
Agriculture, farming, forestry, fishing	57	21.8
Mining and quarrying	21	8.0
Electricity and gas	17	6.5
Information and communication	10	3.8
Construction	3	1.1

[10] The economic activity is determined according to CNAE (National Classification of Economic Activities), version 2.0. Available at www.ibge.gov.br/concla.

Others	31	11.8
Total	**262**	**100.0**

Source: Authors' elaboration.

Given the importance and variety of manufacturing firms, it is necessary to take a closer look into this economic activity. Table 5 presents the number of technology transfers made to firms in a more disaggregated classification of the manufacturing activity. The numbers show an equilibrated distribution of technology transfers to firms in the industries of "food", "chemicals", "machinery and equipment", "paper", and "informatics, electronic, and optic equipment".

One remarkable exception is the low number of technology transfers made involving firms in the pharmaceutical area. Possibly, this is due to the characteristic of non R&D intensity of the Brazilian pharmaceutical industry. Brazil has increased its production of generic drugs since the end of the nineties, but much of the interaction of research groups in fields related to pharmaceuticals are with hospitals (and are not yet appropriately covered by CNPq' Directory), and not with firms.

TABLE 5 – Number of technology transfers by manufacturing firms

Manufacturing	**Transfers**	**(%)**
Paper	20	16.3
Informatics, electronic, and optic equipment	16	13.0
Food	14	11.4
Machinery and equipment	14	11.4
Chemicals	12	9.8
Drugs	6	4.9
Rubber and plastic	7	5.7
Metallurgy	6	4.9
Furniture	6	4.9
Others	22	17.9
Total	**123**	**100**

Source: Authors' elaboration.

Table 6 shows the matrix for industry and academic discipline in technology transfer relations. The results show that in technology development and transfer from universities and research groups toward firms, the scientific knowledge involved tends to be more specific and concentrated in fewer areas than they are in general university-firms relationships (see Rapini *et al.*, 2006). This is the case of agronomy and zootechnics to agriculture; agronomy and forest resources and engineering to paper and cellulose; forest resources and engineering to wood and furniture, computer science to information technology services, as some examples. In the non-manufacturing sector, agriculture and electrical energy (production and distribution) demanded technology transfer from a variety of academic disciplines. There are presence of state owned enterprises in these industries (as in electricity), with strong public incentives to its development (as agriculture). In the manufacturing sector, machines and equipment, food and beverages and chemicals and drugs also demanded technology transference from diverse academic disciplines.

TABLE 6 – Matrix of technology transfer: industry and academic discipline

Sector	Agronomy	science	Food S&T	eng.	engineering	material eng.	and eng.	eng.	eng.	Mechanical	Chemical	Mining	Sanitary	Chemistry	Zootechnic	Ecology	Veterinary	Geoscienc	Genetics	Fishing	Others	**Total**
Agriculture	26		3	5			4				1			1	9		2			1	5	**57**
Extractive industry		1			2	2						6	1	2		3		1				**18**
Construction					3																	**3**
Information technology services		5						1	1													**7**
Electrical energy (production & distribution)		1			1	4		1	4	2						1		1			2	**17**
Water (production and distribution)										2			1					1				**4**
Manufacturing																						
Paper and cellulose	8			1			8									1			2			**20**
Plastic & Rubber					1			1		2		1	1							1		**7**
Food & Beverage	3		3					1	1	1			1	2						2	2	**16**
Machine & equipments		1		4		1		2	2	1	1										2	**14**
Informatics, electronic and optical equip.		4		1					6	3				1							1	**16**
Car & Trucks										3											1	**4**
Refined Petroleum					1					1									1	1	1	**5**
Wood and Furniture						1	5														1	**7**
Metal Products						1		1		2												**4**
Non-Metallic Mineral Products																					1	**1**
Chemicals & Drugs						1		1			6		1	2		1	1				5	**18**
Metallurgy					3	1						1		1								**6**
Other sectors	3				5		3	1			3		1	1				1	1		13	**32**
Total	**40**	**2**	**6**	**11**	**16**	**11**	**20**	**9**	**9**	**17**	**11**	**8**	**6**	**10**	**9**	**6**	**3**	**4**	**4**	**5**	**34**	**0**

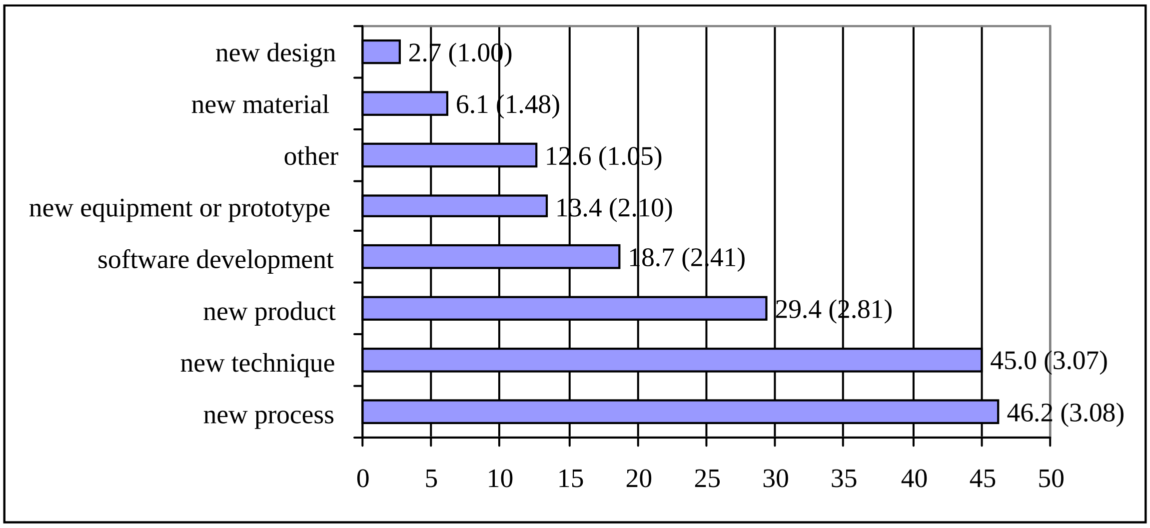
Source: Authors' elaboration.

4.2. Technologies and transfer channels

Since there are several types of technology and each group could have transferred more than one type to its partner during the interaction, the leader was given the option to indicate more than one technology on the questionnaire.

Figure 1 summarizes the answers about technologies developed at universities and PRI and transferred to firms in Brazil. According to the leaders' answers, new processes (46.2%) and new techniques (45%) were the most important types of technologies transferred. Due to the fact that it is difficult to distinguish between processes and techniques, it would be expected that the group leader would choose both. However, the correlation observed between these technologies is small and negative. So, it seems that group leaders understand processes and techniques to be distinct technologies and the similar results obtained were not due to their selecting both in the questionnaire. The transfer of new products appears in third place (29.4%). Although universities and PRI can contribute to generate new products, this is not the main kind of technology generated and transferred by them. The low rate of answers to new design was expected, as it is the kind of technology that requires strong communication with costumers to be developed, and this is common to be observed in firms instead of universities and PRI.

Figure 1 – Type of technology developed and transferred

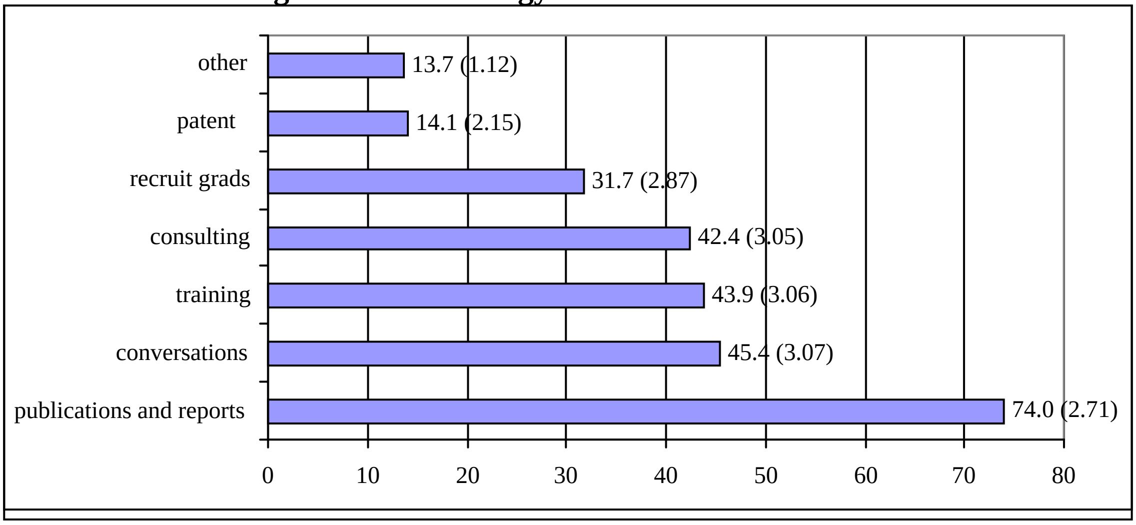


% of respondents indicating type of technology developed and transferred (N = 262; standard errors in parentheses).

Source: author's elaboration.

The results in Figure 2 shows that research groups used several channels to transfer technology, although the main channel was publications and reports, indicated by 70.4% of respondents. The other important channels were conversations (45.4%), training (43.9%), and consulting (42.4%). Only 14.1% of respondents pointed to the use of patents to transfer technology. These results suggest that patents are not a precondition to transfer a technology.

Figure 2 – Technology transfer channels



% of respondents indicating type of technology developed and transferred (N = 262; standard errors in parentheses).

Source: authors' elaboration.

Although the results suggest that patents are a channel of technology transfer that is used less frequently than others, it is necessary to consider that the channel's importance can vary according to technology type. To analyze this question, correlations among transfer mechanisms and technologies were calculated[11]. Table 7 shows that different types of technologies are related to distinct channels. While the transfer of new processes presents a higher correlation with training, the transfer of new products presents a higher correlation with patents. The data suggests that transfer of new techniques, new equipment and prototypes show distinct dynamics. For example, new techniques are negatively correlated to patents and positively correlated to consulting, while the opposite occurs with new equipment and prototypes. The transfer of new material shows a higher correlation with publications and reports.

Why are patents more important to transfer products, materials, and equipment and prototypes than to transfer processes and techniques? The results of Levin et al. (1987) about the forms of appropriating the returns of industrial R&D give some insights that help us to understand this question. In their survey, it is shown that product patents are considered by industry as more effective to appropriate the returns of R&D investment than process patents. According to the authors, in general, firms consider industrial secrets as more effective for new technological processes. Firms may fear that to patent processes they will have to disclose details of its technology. With regard to products, the logic is reversed. Firms want to disclose the quality of their new products and improvements to consumers, information that also goes to competitors (Levin et al. 1987). Thus, firms tend to patent products and keep processes in secrecy. This argument is corroborated by the low correlation found between patents and new processes and techniques.

The transfer of new techniques and new equipment and prototypes follows an opposite dynamic. New techniques are negatively correlated with patents and positively correlated with consulting, and the opposite is verified for new equipment and prototypes. The transfer of new software presents a higher correlation with training and consulting.

[11] Since the database is arranged in binary variables, it was calculated tetrachoric correlations.

TABLE 7 – Correlation between transfer channels and technologies

	new product	new process	new technique	new design	new equipment and prototype	software development	new material
patent	0.55	0.17	-0.32	0.02	0.35	-0.15	0.42
publications and reports	-0.07	0.21	0.21	-0.49	-0.05	0.15	0.59
conversations	-0.05	0.02	0.10	-0.30	0.04	-0.15	-0.15
recruit grads	0.09	-0.03	0.11	-0.38	-0.12	0.16	0.11
training	-0.07	0.31	0.04	-0.26	-0.34	0.26	-0.22
consulting	-0.08	0.11	0.26	0.03	-0.42	0.31	0.05
other	-0.03	-0.23	0.09	-1.00	0.21	0.03	-0.04

Source: Authors' elaboration.

4.3. Technology transfer process and industrial sectors

During the technology transfer process there is, obviously, interaction between research groups and firms, requiring a certain absorptive capacity from the firm. To evaluate this point, some questions were asked about firm characteristics. According to the answers, in 88.6% of transfers, firms had qualified human resources to absorb the technology and in 47.2% of transfers they had an R&D department. In only 18.8% of transfers, was the existence of some difficulty to absorb the technology reported, normally due to the lack of qualified human resources.

In 56.5% of the cases, further developments in technology were necessary in order to reach the market or to improve the firm's production process. Two thirds of developments occurred through joint work between the research group and a partner. Only 15.2% of technologies transferred that needed some development were improved without the group's support. This fact suggests that interaction between groups and firms does not end after technology transfer. The interaction is generally extended to technology development.

The results presented in Table 8 shows that the importance of the transfer channel varies considerably according to the firm's economic activity. Nevertheless, two facts deserve attention. First, "publications and reports" was the main channel used by almost all economic activities. The exception was "information and communication" which was used more than "conversations". Second, patents were one of the less used channels by all economic activities. In "manufacturing", for example, 75% of transfers were by "publications and reports" (the main channel) and only 14.8% by patents (the sixtieth channel).

TABLE 8 – Transfer channels and firm's economic activity (%)

Economic activity	patent	publications and reports	conversations	recruit grads	training	consulting	Others
Manufacturing	14.8 (6)	75.0 (1)	47.7 (2)	31.3 (5)	41.4 (4)	42.2 (3)	14.1 (7)
Agriculture, Farming, Forestry, Fishing	11.9 (7)	62.7 (1)	50.8 (2)	32.2 (4)	49.2 (3)	32.2 (4)	22.0 (6)
Mining and Quarrying	14.3 (6)	100.0 (1)	19.0 (5)	28.6 (4)	42.9 (2)	38.1 (3)	0.0 (7)
Electricity and Gas	0.0 (6)	82.4 (1)	35.3 (4)	35.3 (4)	41.2 (3)	70.6 (2)	0.0 (6)
Information and Communication	27.3 (5)	45.5 (2)	54.5 (1)	45.5 (2)	36.4 (4)	27.3 (5)	9.1 (7)
Health and Social Services	18.2 (5)	45.5 (1)	9.1 (7)	36.4 (2)	27.3 (4)	36.4 (2)	18.2 (6)
Others	11.5 (6)	84.6 (1)	61.5 (2)	19.2 (5)	50.0 (3)	42.3 (4)	11.5 (6)

Source: Authors' elaboration. In parenthesis is the ranking of transfer channels by economic activity.

4.4. When is a patent a relevant channel?

In section 2.2, it was stated that patents are effective as a channel of technology transfer only in certain specific circumstances: (i) it will depend on the type of technology (product, process, etc); (ii) if the technology in question is at an embryonic stage; and (iii) the industry of the firm to which the technology is transferred.

To test these hypotheses, we estimated the effect of the kind of technology transferred and the characteristics of the research group and firms on the probability that the group has used patents as a channel of technology transfer. The technology characteristics used were not only its type, but also its stage of development. The group's characteristic used was its scientific field. The firm's characteristics were its absorptive capacity (measured by the proxy "existence of R&D department in the firm"), and its economic activity sector (dummies for manufacturing and agricultural, the most representative sectors in the sample).

Probit regression results for two models are presented in Table 9. Model 1 represents the probability that the research group used patents as a channel for technology transfer, while model 2 presents the same for publications and reports as a channel. The most impressive result suggested by these models is that the use of patents and publications and reports as channels of technology transfer follow distinct paths according to the type of technology developed and transferred by the group. For example, when the technology is a new product, it has a highly significant and positive effect on the probability that the group has used a patent. On the other hand, the probability of having used publications and reports as a channel is increased significantly when the technology transferred is a new process or technique. These results are according to the argument presented in section 4.2.

Table 9 – Estimates of the probability that a research group has used patents or publications and reports as a channel of technology transfer – Probit models on the group, technology and firm characteristics (marginal effects)

Dependent Variable	Model 1- Patent	Model 2- Publications and Reports
Type of technology transferred		
Product	0.154***	0.010
Process	-0.008	0.244***
Technique	-0.090**	0.181***
Design	-0.034	-0.329
Equipment of prototype	0.167**	-0.010
Software	-0.052	0.104
Material	0.085	0.208**
Other	-0.098*	0.242***
Research group's scientific field		
Agricultural science	-0.188*	-0.163
Biology	-0.068	-0.152
Health science	-0.022	-0.523
Hard science	-0.071	-0.076
Engineering	-0.146	-0.156
Technology's stage		
Embryonic	-0.008	-0.060
Absorptive capacity		
R&D lab	0.077**	0.117**
Firm's economic activity		
Manufacturing	0.040	-0.038
Agriculture	0.122	-0.175*
Observations	257	257
Pseudo R2	0.203	0.178
Obs. P.	0.144	0.739
Pred. P.	0.909	0.789

Obs.: ***, p < 0.01; **, p < 0.05; *, p < 0.1.

The second interesting result suggested is that the use of distinct channels of technology transfer is not affected by the research group's scientific field. We understand that the scientific field of the group is a proxy for the scientific content of the technology transferred. The probability of having used patents is negatively affected when the technology generated comes from groups in the field of agricultural science, but it is only significant at the 0.10 confidence level.

One of the arguments of the Bayh-Dole Act was the fact that the technology stage of development would have a positive effect on the use of patents. But model 1 suggests that there is no such effect, since embryonic technologies did not affect the probability estimated. The firm' absorptive capacity (measured by the existence of R&D department in the firm receiving the technology) increases the probability of the group having used patents, and also publications and reports. Our model was not able to capture any significant effect of the difference in the firm's economic activity in the probability of having used patents.

5. Concluding remarks

Technology transfer processes involves several channels. Though literature has given more emphasis to patents and licensing, recent studies, as Agrawal and Henderson (2002) and Mowery et al. (2004), highlight patent limitations as a channel to transfer technology. This paper presented an attempt to contribute to this literature showing a joint analysis of channels for transfer, and types of technology transferred, in the context of a developing country. The findings are very similar to those achieved for developed countries.

From the CNPq Directory of Research Groups 2004 Census, engineering and agrarian science were the scientific fields that were most involved in technology transfer in Brazil. Technology transfer interactions occur mostly with partners from manufacturing and agricultural activities.

The applied survey contributes to gathering information regarding technology transfer process features, not present in the CNPq Directory. The survey results suggest that patents are a less used technology transfer channel by Brazilian research groups. Transfer interactions embrace mostly publications and reports, informal information exchange, training and consulting. These channels point to an active participation of universities and PRI researchers in the technology transfer process. A technology can take time to be assimilated by partners. During this process, the group's researchers take part through general guidance about technology, personal training, and technology adaptation to the firms' productive processes.

Another important result concerns the type of technology developed and transferred by groups. About 45% of interactions refer to the transfer of new process and techniques, while new product transfers account for 29.4% of total interactions. This information demonstrates that universities and PRI generate technologies that are used to prepare products, instead of being sources of new products ready to commercialization. So, although there are examples of products ready in the lab shelf only waiting for a firm to invest in their commercialization, this is far from being the rule. Academic technologies tend to be embryonic, requiring efforts in research and financing resources to reach the final product.

Information collected about technology transferred and mechanisms used enable us to analyze connections between these two factors. Patent use as a transfer mechanism has a higher correlation with physical technologies (products, equipment or prototypes and materials). Yet, new process and techniques were more correlated with consulting and training mechanisms, respectively. Indeed, literature from R&D investments appropriability points to a higher use of patents in terms of product, as firms have to disclose to their consumers advantages of their product over that of their competitors. New processes and techniques tend to be kept in secret (LEVIN et al., 1987). So, results suggest that there are different transfer dynamics for each type of technology.

Nevertheless, publications and reports are more commonly used technology transfer mechanisms in almost all industries examined (except for the information and communication industries, which used more informal conversations), there are differences in mechanisms used for ranking between sectors. So, different industries show a slight differentiation in terms of receiving technology mechanism.

The hypotheses raised about patent use to transfer technology were tested by a *probit* model. The results suggest that the use of patents is influenced by technology type (when it is products and equipment or prototypes), not being relevant to technologies in embryonic stages. The results indicate that the partner's absorptive capacity increases the probability of using a patent in the technology transfer process. In other words, patents embed a type of technology knowledge that requires a firm to have a capacity to assimilate technology.

A patent is not a requirement for a technology transfer relation. However, the results suggest that depending on the type of technology involved, patents can be a facilitator channel, or may even be necessary. This last observation requires more analyses, maybe through case studies. Public policies that aim to approach universities and productive industries should consider the existing channels to transfer technology.

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