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What is transferred and how the transfer is carried out**

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Technology transfer from universities and public research institutes to firms in Brazil: what is transferred and how the transfer is carried out¹

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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.

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 yet well understood in literature. 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 type of technology transferred and to the firms' industry.

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

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1. INTRODUCTION

While there have been several studies that analyzed university – industry interactions and the role of patents in those interactions, as far as we know there are still few studies that have overseen 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 transfers from universities and public research institutes to firms in Brazil, taking into account the channel of technology transfer and its relation to the kind of technology transferred.

Successful cases of technology transfer, such as the Cohen-Boyer technology², stimulated universities around the world to create technology transfer offices and had a significant institutional influence. Enacted in 1980 in 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 in order to transform them into innovations if they have no ways to appropriate the returns from R&D investments. Therefore, allowing universities to patent and license their inventions would give firms the 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 United States, although this was not exclusively due to the Bayh-Dole Act³, and it stimulated universities and governments of other countries to use university patents as a channel of technology transfer (Mowery *et al*, 2004; Kneller, 1999). 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 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 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 researchers’ and the universities’ behavior towards the acceptance of patents, the

² 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).

³ For a detailed analysis of U.S. patents increase, see Mowery *et al* (2004).

number of university patents in Brazil increased significantly during the second half of the 1990s (Póvoa, 2008).

In the specific case of Brazil, university patents are an interesting object of study due to the unusual participation of universities in the patent system. The data regarding patent applications made by residents in Brazil during the 2000-2005 period⁴, shows four universities among the top 20. Most strikingly is that the second place is occupied by the University of Campinas, coming second to Petrobras, a major firm in Brazil (Albuquerque *et al*, 2009). In the United States for example, there was only one university in the top 20 in 2007 (The University of California), and far from the first place.

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 and Henderson, 2002; Mowery *et al*, 2004; Colyvas *et al*, 2002; Cohen *et al*, 2002; Sampat, 2002). According to Mowery *et al* (2004: 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, such as 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: 5). Colyvas *et al* (2002) and Sampat (2002) point out that the importance of patents and exclusive licenses for technology transfer is not yet well understood in literature.

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: 1843).

⁴ Patent applications made at INPI (National Institute of Industrial Property).

This paper aims to contribute to this literature by analyzing the technology transfer process from 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 used in interactions with firms. The results are from a survey conducted by one of the authors with answers from 178 research group leaders concerning 262 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 results of the survey 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 forward meaning of transfer. Barry Bozeman raises three difficulties when dealing 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: 627).

In general, technology transfer studies circumvent these problems focusing on patent licensing, and do not devote space to conceptual discussion (see for example Henderson *et al*, 1998; Jensen and Thursby, 2001; Thursby and Thursby, 2002). This way, technology is simply the content of patents and their transfer is the licensing process.

To address technology in this way restricts the subject as not all technology generated in universities and PRI is patented. In other words, there is a vast amount of technology generated and transferred that is not covered by the literature.

Bozeman (2000) stresses that few economists deal with the technology concept. One of them is Sahal (1981) who discusses the difficulties in defining the term technology with an analytical meaning. Sahal discusses the neoclassical definition of technology and what he called the Pythagorean view of technology. 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 Pythagorean view of technology understands technology as a set of relevant events that share 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 and equipment”. (Dosi, 1982: 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: 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”.

In terms of technology transfer, it is 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 the receptor of technology.

As mentioned before, the technology transfer literature has been considering the patent and its licensing as “the” transfer channel. However, some authors have stressed the importance of other channels, such as publications, consulting and informal exchange of information (Agrawal and Henderson, 2002; Mowery *et al*, 2004). Below, we analyze the main channels of transfer addressed in literature.

2.2. Patents as a channel of technology transfer: some critiques

After the Bayh-Dole Act, patent licensing has been considered a 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)⁵

This treatment of patents as the main technology transfer channel has stimulated the creation of technology transfer offices in universities in several countries. These offices manage marketable inventions generated by researchers. They perform periodic consultancy regarding recent scientific discoveries with market potential, and handle the patenting processes and approach partners interested in licensing the technology.

However, despite universities’ enthusiasm in technology transfer, it is necessary to recognize that patents are just one of the channels of technology transfer.

The main critiques to the excessive attention that universities around the world are giving to patents, as they were the main channel of technology transfer, are based on the argument that patents are a limited channel for the technology transfer process. This limitation is associated with the following factors: (i) type of technology (product, process,

⁵ <http://www.autm.net/aboutTT/>. Access in August, 2008.

etc); (ii) the need for more research to turn invention into a final process or product; and (iii) the appropriability of the regime concerning 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 of these factors is discussed below.

Patents are just one of the several mechanisms for appropriating returns of inventions and, like other mechanisms⁶, are 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 of appropriation. Moreover, 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 in 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 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 (pharmaceutical) 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 few industries, such as the pharmaceutical one. They stressed that even in the pharmaceutical industry, informal mechanisms and publications were considered important.

So, in the critiques, pointed out above, 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).

⁶ 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 al*, 1987).

As it was stated before, the firms' absorptive capacity is a very important factor in the technology transfer process. It is recognized that firms in developing countries have a weak absorptive capacity compared to firms in most advanced countries. How are patents evaluated as a technology transfer channel in the context of a developing country? What are the other technology transfer channels? What are the most important channels used? Does the use of the channel change according to the kind of technology transferred? The rest of this paper intends to shed light on these questions.

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 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: 2). Chemical engineering at MIT is an example of how results flowed through several channels, where professors provided consultancy to Standard Oil and took problems to be developed by their Ph.D. students. Subsequently, many of these students were hired by the 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 carry out 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 out 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 sectors. The results from Cohen *et al* (1998) indicate that the role of patents, even when evaluated by the 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 substantial amount 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. The Directory of Research Groups Census is a database, which begun in the early 1990s and is renewed every second year. It comprises detailed information regarding research activities in Brazil using “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, research groups’ leaders from public universities have been implicitly forced to send information to the Directory, since their access to government funding depends on this information. 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 regarding their research activities. The 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. 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 region of Brazil, the Southeast. Twenty-two percent of the groups are located in the South, 6% are from the Mid-West, while 14% are from the Northeast and 4% from the North, the necessitous region of the country.

Of all registered research groups, only 11.1% (2,139), affiliated to 217 institutions, declared collaboration with firms. The analysis hereafter will concentrate on these groups and on the information they provided. The database methodology proposes 14 types of possible relationships between groups and firms. Each research group's leader was able list at most 3 types of relationship that were more frequent with firms.

The relationships could be bidirectional, from groups to firms and from firms to groups, or unidirectional from groups to firms. Bidirectional relationships embrace technology transfer, training, software development, non-routine engineering, and material supply. Unidirectional relationships embrace consultancy, long term scientific research, short term scientific research and other types not previously covered.

The analyses will focus on research groups that declared that they "transferred technology" to firms. In the 2004 Census, 558 groups declared 969 technology transfer relationships, which results in an average of 1.7 technology transfers per group. These groups are concentrated in the Brazilian Southeast region, which accounts for 45% of them (São Paulo state, which is the most prosperous, accounts for 20.8%).

Each research group is classified into a scientific area by its leader within the Directory. It is reasonable to assume that the technology developed and transferred by the group would be related to its scientific field. The database shows 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 in "agriculture, farming, forestry, and fishing" sectors 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 the identification of universities and PRI that made more technology transfers, firms that received the technology, and firms’ sectors. However it is not possible to address some important questions such as: the kinds of technology transferred (product, process, etc.); channels of technology transfer; and industries and scientific areas that rely more on patents to carry out transfers. In order to obtain this information, questionnaires were sent to 558 research group leaders 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 and Henderson, 2002; Cohen *et al*, 2002; Colyvas *et al*, 2002; Dasgupta and 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 and Presser (1986). The pre-tested interviews were useful in suggesting questions regarding the groups’ participation in developing technology to reach the market; the research funding by firms; and academic impact of research groups-firms interactions.

The questionnaire consists of five parts. The first part is related to the kind of technology developed and transferred by the group. The second part enquires 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) in the fourth part. Questions regarding features of the firms’ interaction, such as academic benefits for the groups resulting from the technology transfer process are asked in the last part. This paper analyzes questionnaire responses in parts one to four.

The major limitation of the results presented below results from the fact that this study focuses on universities and public research institutions points-of-view. Thus, it does not take into account the possible differences in rating the different technology transfer channels between university and industry.

4. SURVEY RESULTS

4.1. General characteristics of technology transfer in Brazil

A total of 969 questionnaires were sent to all 558 group's leaders, as leaders whom 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 the kind of technology developed and transferred by the group. The leader was given the option to reconsider 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 means of total technology transfers in each Brazilian state⁷ are presented in Table 1. Almost a half of the groups are from universities located 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, which embraces 15.6% of the total of all groups. In terms of technology transfers, Minas Gerais occupies the second position with 16.4% of the total. by groups are Minas Gerais and Paraná.

TABLE 1 – Number of groups that carried out technology transfer and the total number of technology transfers by regions and states

Region/ state	Research groups		Technology Transference		Means
	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

⁷ 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 a questionnaire answered by its research groups.

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
<i>Southeast</i>	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
<i>South</i>	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 fields of research groups. 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 the 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.

Table 3 shows the matrix for industry and academic discipline in technology transfer relations. The relevance of agrarian sciences for Brazilian industry is highlighted when it is observed in the matrix that agronomy is the academic discipline which carried most of the technology transfers. Agronomy accounts for 40 technology transfers (15.3% of total). In second place is Forest resource and Engineering with 20 technology transfers (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, ever since 1960, has received 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”⁸.

The data presented in the matrix allows us to see that there is a relationship between scientific field of research group that transferred technology and economic activity of the firms that received technology⁹. 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 3 also presents the number of technology transfers made to firms in a more disaggregated classification of manufacturing activity. The numbers show an equilibrated distribution of technology transfers to firms in 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 (chemical & medicine). Possibly, this is due to the characteristic of non R&D intensity of the Brazilian pharmaceutical industry. Brazil has increased its production of generic medicine 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.

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

⁸ Source: www.embrapa.br.

⁹ The economic activity is determined according to CNAE (National Classification of Economic Activities), version 2.0. Available at www.ibge.gov.br/concla.

disciplines. There are presence of state owned enterprises in these industries (as in electricity), with strong public incentives to its development (as in agriculture). In the manufacturing sector, machines and equipment, food and beverages and chemicals and medicine also demanded technology transference from diverse academic disciplines.

TABLE 3 – Matrix of technology transfer: industry and academic discipline

Sector	Agronomy	Computer science	Food S&T	Agriculture eng.	Civil engineering	Metallurgical and material eng.	Forest resource and eng.	Production eng.	Electrical eng.	Mechanical engineering	Chemical engineering	Mining eng.	Sanitary eng.	Chemistry	Zootechnics	Ecology	Veterinary	Geosciences	Genetics	Fishing eng.	Others disciplines	Total
Non-manufacturing (total)																						113
Agriculture	26		3	5			4				1			1	9		2			1	5	57
Extractive industry		1			2	2						6	1	2		3		2		1	1	21
Construction					3																	3
Information technology services		5						1	1												3	10
Electrical energy (production & distribution)		1			1	4		1	4	2						1		1			2	17
Water (production and distribution)	1									2			1					1				5
Manufacturing (total)																						149
Paper and cellulose	8			1			8									1			2		0	20
Plastic & Rubber					1			1		2		1	1							1	0	7
Food & Beverage	3		3					1	1					1	2					2	3	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	3
Wood and Furniture						1	5														1	7
Metal Products						1		1		2											0	4
Non-Metallic Mineral Products																					1	1
Chemicals & Medicine						1		1			6		1	2		1	1				5	18
Metallurgy					3	1						1		1							0	6
Other sectors	2	1			6		3				4		1	1				1	1		13	33
Total	40	13	6	11	16	11	20	8	14	16	12	8	6	10	9	6	3	5	4	5	39	262

Source: Authors' elaboration.

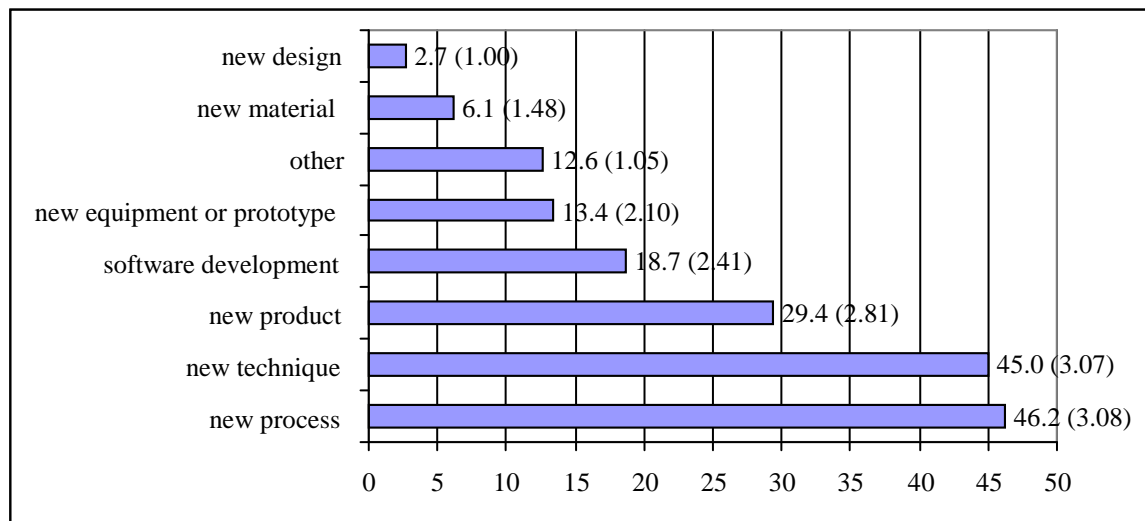
4.2. Technologies and transfer channels

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 regarding 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 the processes and the techniques to be distinct technologies and the similar results obtained were not due to their selecting both options 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 – Types of technology developed and transferred

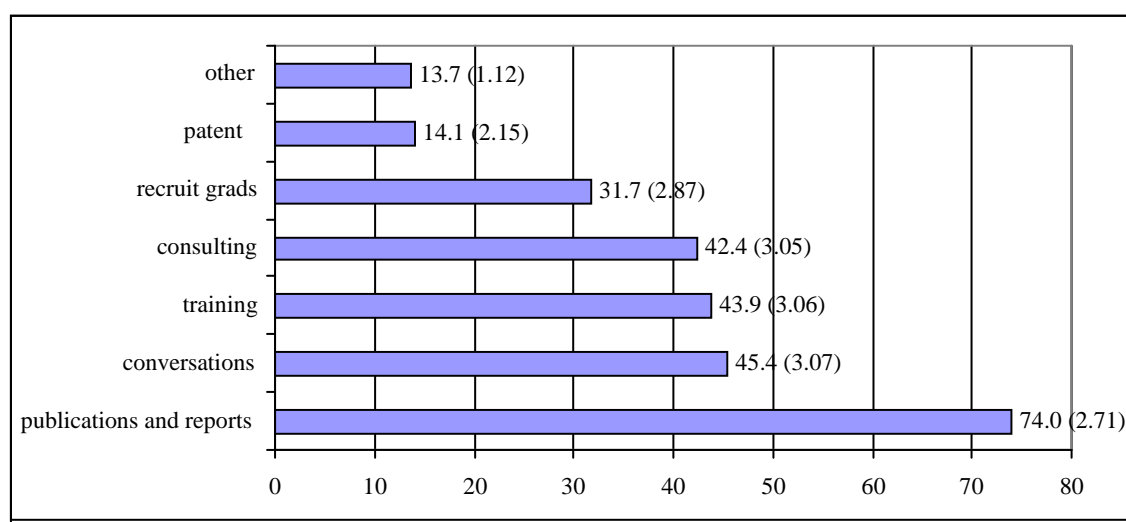


% of respondents indicating type of technology developed and transferred (N = 262; standard errors in parentheses).

Source: Author's elaboration.

The results in Figure 2 show that research groups used several channels to transfer technology, although the main channels were 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.

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 calculated¹⁰. Table 4 shows that different types of technologies are related to distinct channels. While the transfer of new processes present 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 for transferring products, materials, equipment and prototypes than transferring 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

¹⁰ Since the database is arranged in binary variables, it was calculated tetrachoric correlations.

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.

TABLE 4 – 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 the technology transfer. The interaction is generally extended to technology development.

The results presented in Table 5 show 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" which 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 5 – 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 the ranking of transfer channels by economic activity is noted.

4.4. When is a patent a relevant channel?

In section 2.2, it was presented that some critiques whose conclusion was 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 analyze these circumstances, 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 – and each group could have transferred more than one type to the firm –, 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 6. 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 channel¹¹. 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 one. These results are according to the argument presented in section 4.2.

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.

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 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.

¹¹ Model 2 is presented only for the sake of comparisons since publications and reports were the main channel of technology transfer reported. These results should be interpreted with caution since the dependent variable of this model (publications and reports) is what the group leaders stated in the questionnaire as been one of the main channels used to transfer the technology to the firm. To have a complete answer it would be necessary to ask the receptors firms whether they really absorbed the technology by reading the publications and reports.

Table 6 – 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)

	Model 1 Patent	Model 2 Publications and Reports
<i>Type of technology transferred</i>		
Product	0.180***	-0.042
Process	0.016	0.177***
Technique	-0.076*	0.114*
Design	-0.028	-0.351*
Equipment of prototype	0.179**	-0.040
Software	-0.044	0.063
Material	0.114	0.206**
<i>Research group's scientific field</i>		
Agricultural science	-0.178	-0.184
Biology	-0.061	-0.132
Health science	0.031	-0.586
Hard science	-0.051	-0.164
Engineering	-0.124	-0.225
<i>Technology's stage</i>		
Embryonic	-0.004	0.043
<i>Absorptive capacity</i>		
R&D lab	0.070*	0.141**
<i>Firm's economic activity</i>		
Manufacturing	0.052	-0.051
Agriculture	0.148*	-0.240**
Observations	257	257
Pseudo R2	0.194	0.128
Obs. P.	0.144	0.739
Pred. P.	0.972	0.773

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

5. CONCLUDING REMARKS

The 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 the 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 the technology transfer process features, not present in the CNPq Directory. The survey results suggest that patents are one of the less used technology transfer channels 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 by means of general guidance about technology, personal training, and technology adaptation to 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 processes 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 could be examples of products ready on 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 regarding 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 technologies like 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 the 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 in technology transfer mechanisms in almost all industries examined (except for the information and communication industries, which use 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 mechanisms.

The critiques about patent use to transfer technology were analyzed by a *probit* model. The results suggest that the use of patents is influenced by the technology type (when it is either 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 have embed a type of technology knowledge that requires a firm to have the capacity to assimilate technology.

Public policies aimed to promote the interaction between universities and industries should consider the different existing channels used to transfer technology. The Brazilian government, for example, took an important step by approving in 2004 the so called "Innovation Law", a set of incentives to foster university-industry interaction. Among the incentives is a license for civil servant researchers to open a firm, or to work in an existing one, to develop an innovation. This recognizes that some inventions need to be substantially improved to go into the market and the presence of the inventor during this development is crucial. Governments should also encourage firms to hire graduate students (using a fiscal stimulus, for example) from groups that transferred technologies in order to facilitate conversations and future interactions with universities, especially in developing countries, where firms have a weak absorptive capacity.

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