Received 29 June 2017
Accepted 2 October 2018

Research, development and transfer of environmentally sound technologies in Brazil

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Abstract

Purpose – Most research and development (R&D) activities in Brazil are performed by science and technology institutions (STIs). The purpose of this research was to determine whether environmentally sound technologies (ESTs) developed by these organizations were transferred to companies, either through cooperation during research or through mechanisms such as licensing agreements or spin-offs.

Design/methodology/approach – In total, 1,939 research groups and 702 patent registers, identified from the same set of words related to ESTs, using semantic search in open-access databases, covering a period from 2005 to 2014, were examined. The two data sets (patents and research groups) were overlaid, and it was possible to associate inventors' names with researchers' names.

Findings – The results showed that only six patents could be related to the 1,939 identified research groups. Of the six patents, only one was the object of a licensing agreement, and no spin-off was identified.

Practical implications – This study evidenced that it is necessary to expand the mechanisms of knowledge transfer, directed not only from STIs to companies but also in the opposite direction, given that companies recognize potential market opportunities.

The authors thank CNPq for the financial support, and the anonymous reviewers for their helpful and constructive comments that much contributed to improve the final version of the paper. Authors are solely responsible for any errors or statements.

Innovation & Management Review
Vol. 16 No. 1, 2019
pp. 2-16
Emerald Publishing Limited
2515-8961
DOI 10.1108/INMR-08-2018-0065

Originality/value – This study shows that improvements in the Brazilian National Innovation System are necessary, as ESTs research groups demonstrated a weak association with technologies transferred to companies, with only one case of technology transfer in the form of a licensing agreement.

Keywords Technology transfer, Spin-offs, Patent, Public research organizations, Science and technology institutions (STIs)

Paper type Research paper

1. Introduction

Highly industrialized countries achieved economic development by stimulating technological activities (Mazzucato, 2013). New technologies created through these incentives not only result in products and processes with higher perceived value in consumer markets but also increase national autonomy, thus reducing the need for external acquisition of essential technologies (Gnidchenko *et al.*, 2016).

The creation of green innovations (Dangelico and Pujari, 2010; Kunapatarawong and Martínez-Ros, 2016) can also add to the aforementioned benefits of technological development. This group of innovations includes environmentally sound technologies (ESTs), defined by Petruzelli *et al.* (2011), as technologies that enable managing pollution and related processes more efficiently, thus creating products, processes and services that are less polluting and consume less resources.

The United Nations Framework Convention on Climate Change (UNFCCC) has acknowledged the relevance of green technologies, and they have registered them in the IPC Green Inventory [World Intellectual Property Organization (WIPO), 2018].

Given the importance of these technologies in reducing negative externalities from production and consumption, each country should encourage their development. Technologies created by science and technology institutions (STIs) should be transferred to companies, for their effective application in new products and processes available in the market.

However, the transition of knowledge developed in STIs to companies does not occur without difficulties. Silva and Mazzali (2010) noted that the causes of divergence stem from cultural differences between the two types of institutions, in addition to the distinct goals they pursue. Companies must achieve financial targets, which drive them to work aiming at short-term results, in response to the highly competitive environment in which they operate. STIs (especially universities), in turn, seek medium- and long-term results, and focus on activities such as creation of new knowledge and training of human resources.

Other difficulties found in the relationship between companies and STIs mainly relate to the so-called "transactional difficulties" (Araujo *et al.*, 2015). They occur in the process of formalization and legitimization of partnerships and result from excessive bureaucracy, lack of consensus regarding the mechanisms for research funding and uncertainties about intellectual property (IP) management.

The challenges of the relationship between STIs and companies must be addressed, to attain joint results. These results are much necessary, mainly regarding green technologies or ESTs. This study aimed to find out if ESTs developed by Brazilian STIs were transferred to companies, either through cooperative research or through mechanisms such as licensing agreements or spin-offs.

2. Literature review

2.1. Management of innovation in STIs

In Brazil, technological innovation centers (NITs) were created as a result of the Innovation Act (Act 10,973 of December 2, 2004), which determined their establishment in public STIs, to ensure the enforcement of the policy that encourages the protection of creations, licensing and other forms of technology transfer (TT).

According to Torkomian (2009), many STIs already had similar structures under different names, such as innovation agencies, TT offices and IP centers. However, the Innovation Act introduced the mandatory implementation of NITs, whose format was also adopted by private R&D institutions.

For Santos and Torkomian (2013), effective results in the university–industry interaction could be achieved if NITs developed the following activities: to contact companies in search of partnership opportunities; to identify existing technologies in universities and offer them to companies; to meet corporate demands for problem solving; to protect IP resulting from research; to support the negotiation and elaboration of TT agreements; to support the creation of spin-offs; to carry out activities for supporting incubated companies and technological parks; and to promote regional development through specific actions for the community (cooperatives and social incubators, among others).

Although STIs implement their support activities to promote interaction with companies, the central issue that both organizations must consider is the allocation of resources for joint research and development (R&D), which will have a significant impact on the results of the innovation effort (Klingebiel and Rammer, 2014).

One of the main instruments used for the search of scientific and technological competencies is the Directory of Research Groups (DGP), of the National Council for Scientific and Technological Development (CNPq). Based on open data, with periodic validation by STIs that are part of the National Innovation System, this directory gathers information about human resources, research lines, scientific and technological production, research networks in which the group participates and the institutions (public or private, research or business) that are partners in joint projects. Hence, it is an important tool used by NITs' and companies' managers in planning and managing science, technology and innovation activities.

2.2 Mechanisms of technology transfer

Technology transfer consists of a set of stages necessary for the formal transfer of an invention made in STIs to companies (Stevens *et al.*, 2005). Such inventions must be formally protected with NITs' support, thus becoming an IP.

According to the National Institute of Industrial Property [INPI] (2013), IP derives from the human inventive or creative capacity, and it is a set of property rights regarding technological, scientific, artistic and literary capacity. According to Act 9,279 of May 14 (1996), industrial property refers to patents, trademarks, geographical indications and industrial designs.

Agrawal and Henderson (2001) showed that the most common forms of TT used in the interaction between STIs and companies are consulting, conferences, students' hiring, joint publications, research collaborations and patent licensing.

Bercovitz and Feldman (2006) propose a subdivision of categories, improving the arguments of Agrawal and Henderson (2001). They suggest that joint research is a form of TT based on knowledge. In turn, IP's forms of transfer are licensing and spin-offs. We examine these mechanisms in the next sections.

2.2.1 Licensing agreements. Licensing involves the transfer of a patent to one or more companies, to exploit the technology commercially for economic earnings. According to the Innovation Act, an STI can make licensing agreements regarding the right to use or exploit a creation internally developed.

When offering a new protected technology to companies, STIs must consider both the needs of the firms and of the society. Therefore, it will be possible to establish the most appropriate type of contract, considering exclusivity in patent's exploitation. Most contracts have an exclusivity clause to ensure advantage for the company that licensed the technology over its competitors (Carvalho and Gardim, 2009).

If the company that owns the exclusive right to exploit a protected technology does not launch a product or process in the market, within the term and conditions defined in the contract, it will automatically lose that right, and STIs may license it again (Act 10,973 of December 2, 2004).

2.2.2 Spin-offs. Spin-offs are new companies created to market a technology that resulted from scientific research. In this case, a researcher (or group of researchers) leaves the home organization (temporarily or permanently) with the developed technology, which will enable the newly created company to enter a competitive industry (Steffensen *et al.*, 1999).

Spin-offs can occur spontaneously or be planned. In the first case, business development starts when the researcher who created the invention finds out an application for that knowledge that can bring economic results (Oliveira, 2011). In turn, planned spin-offs result from the efforts of the researcher's organization, which supports the development of technology-based businesses through previously structured processes (Steffensen *et al.*, 1999).

Companies created from universities are called academic spin-offs (Ndonzuau *et al.*, 2002), and they are quite frequent in Brazil (Stal *et al.*, 2016), as most R&D activities are carried out by researchers in STIs. In fact, only 11.1 per cent of the country's PhDs work for companies, conducting R&D activities [Centro de Gestão e Estudos Estratégicos (CGEE), 2016].

In Section 3, we operationalize the theoretical framework, by defining boundaries, assumptions, characterization of variables and description of data sources and data treatment for the analysis.

3. Methodology

We used patent information and data on research groups to empirically examine ESTs developed by Brazilian STIs, and the mechanisms used in this process, with a focus on academic partnerships, knowledge transfer and IP transfer.

We used the same patent data sources previously used by Menezes *et al.* (2016), Mota *et al.* (2017) and Santos and Santos (2018). We got information on research groups from the studies by Rapini (2007), Silva and Pinheiro (2014) and Rapini *et al.* (2016).

The assumption of this study, based on Bercovitz and Feldman (2006), is that TT can occur through both through knowledge transfer – mainly as joint research – and IP transfer. This latter form will only take place if there is a patent that allows a licensing agreement or the creation of a spin-off. Thus, we analyzed invention patents (IPs) and utility models (UMs), as they receive a similar kind of protection from INPI, although they have different requirements for patent granting.

Data were collected in several stages. First, we got information about EST patents from INPI Patent Database, which is freely accessible at www.inpi.gov.br. We collected data about granted patents and patent applications, as both allow the accomplishment of licensing agreements and the creation of spin-offs.

The research covered the period from January 1, 2005, to May 1, 2014. Data collection occurred between May and October 2014, with an update between August and September 2015. The selection of EST patents was based on a semantic search, similar to the technique previously adopted by Petruzelli *et al.* (2011). Given the language differences between the reference paper and the database, some adjustments were necessary. Thus, the words used in the semantic search, in the fields that comprise the patent application (title, abstract and description of the invention), were *reutilization*, *reuse*, *pollution*, *pollutant*, *decontamination*, *toxic*, *recycling*, *recyclable*, *recycle* and *emissions*. We searched the compound words through the necessary command, as they were written (using quotation marks): "solid waste," "environment," "alternative energy," "energy efficiency," "renewable energy," "energy conservation" and "energy consumption reduction." We searched the chosen words in Portuguese.

We also used the AND operator, so that only patents that contained both the words *reduction* AND *raw material* would appear. The words *acid rain* and *disposal* were not used in the study, although foreseen in the original model, to limit the amount of data for analysis.

After the semantic search, we identified 702 single registers in the patent database. Data collected in these records were the following:

- registration number;
- date of filing application;
- title;
- holders;
- inventors; and
- patent status (granted, under analysis or rejected).

While patent holders may be physical or legal persons, only physical persons can be considered inventors. In this study, we adopted the assumption of the existence of researchers-inventors. This assumption allowed us to classify researchers linked to STIs' research groups who are simultaneously inventors in applications and in granted patents.

Thus, to determine if technologies' inventors were researchers with a professional link with STIs, we needed to check which of them were listed in CNPq's Directory of Research Groups (DGP). We accessed secondary data at the site www.lattes.cnpq.br/web/dgp, which is an open-access site. Data were collected between September and November 2014.

The procedure adopted used the module "parametrized query of the current database." Through semantic searches, the full name of the patent inventor was a search term in the fields "Name of the leader," "Name of the researcher" and "Name of the student." The "Exact Search" filter was used in the "Certified" or "Non-Upgraded" groups.

For the research groups' database, we also used the words mentioned in the patent search. Thus, each one consisted of a new search term, using the "Exact Search" filter, in "Certified" or "Non-Updated" groups, to be identified in the "Group name," "Name of research line" and "Keyword of the research line." After this search, we achieved 1,939 groups, from which we collected the following data:

- name of the group;
- keyword;
- institution of origin;
- date of creation;
- participation in research networks; and
- partnerships established.

The third stage of the study was the collection of primary data at STIs, in which we identified the researchers-inventors' professional link, to check if the technologies developed by the research groups that became patents were transferred to firms.

The six patent applications identified belong to public STIs, of which five are universities and one is a research institute certified as a unit of the Brazilian Company for Industrial Research and Innovation (EMBRAPII). There are two state universities and three federal. Hence, it was easy to get information, because all of them observe the Information Access Act (Act 12,527 of November 18, 2011).

We used a questionnaire with eight queries (see Appendix). The first question sought to validate the results identified in the collection of secondary data. The other questions were prepared using the conceptual proposal by Bercovitz and Feldman (2006).

Consultation to federal institutions' files was done through the Electronic System of the Citizen's Information Service (e-SIC), as well as to the State University of Campinas (Unicamp). We consulted the State University of Ponta Grossa (UEPG) through the Integrated Ombudsman Management System of the State of Paraná (SIGO). Data collection was carried out in October 2015, and all institutions provided the requested information.

4. Results

We identified 1,939 research groups related to EST R&D. In addition, we found 702 patent applications and granted patents related to these technologies, although only six had inventors from the research groups, as shown in Table I.

All applications were from southern and southeastern regions of Brazil. Southern organizations accounted for 62.2 per cent of patent applications and 70.4 per cent of patents granted in the country, and those from the southeastern regions were responsible for 26.7 per cent of patent applications and 25.6 per cent of patents granted. Thus, 96 per cent of patents granted came from two Brazilian regions only, and the remaining 4 per cent from organizations in the north, northeast and midwest.

Even originating from the most technologically developed regions (Souza, 2016), of the six applications that we analyzed only one enabled an IP transfer, as shown in Table II.

Although one of the patent applications had an academic partnership, there was no IP transfer. On the other hand, in a patent application that had the participation of a company since the research stage, which resulted in co-ownership, the developed technology was licensed. In the remaining patent applications, there was no evidence of academic partnership, knowledge transfer or intellectual property transfer.

The probability of transferring intellectual property should be higher in the four applications filed between 2006 and 2008. However, the only IP transfer occurred in 2011, probably due the type of knowledge transfer, based on co-ownership with a company.

The set of patents presented in Tables I and II seems to replicate attributes of the research groups identified in this research. In fact, emphasis on knowledge production through academic partnerships in research networks, prior to their transfer or development into technologies, is present in only 11 per cent of the analyzed research groups, as shown in Figure 1.

Research networks, according to DGP/CNPq (2015), aim to boost knowledge creation and the innovation process. Nevertheless, of the 213 groups that declared participation in research networks, only 64 took part in more than one network, which shows the reduced number of formal academic interactions based on common research objectives.

A larger number of research groups has scientific or technological cooperation with one or more partners, as shown in Figure 2.

Of the 1,939 groups analyzed, 751 established some type of scientific or technological cooperation, which represents 38.7 per cent of the total. Cooperation involved a wide range of organizations, including companies, research institutions, cooperatives, banks, city halls, non-profit institutions and public agencies, among others.

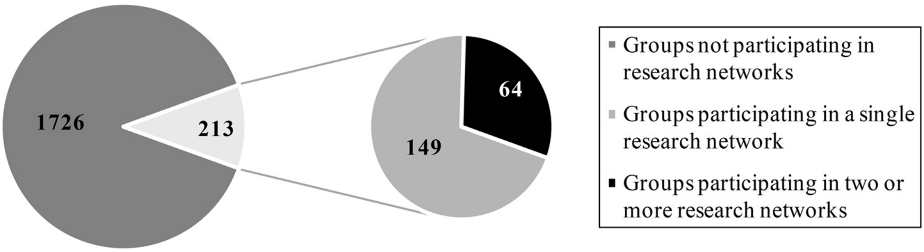
Table I. Patent applications linked to research groups

Application no. (Submission date)	Title	Holder(s)	Researcher(s)/Inventor(s) *	Research group (formation year)
IP 0602633-8 (07/04/2006)	Additive for diesel oil combustion optimizer and reducer of pollutants in the emissions of stationary and vehicular engines	National Institute of Technology (INT)	Álvaro José Barbosa Barreto Deise Mendes**	Energy (1982)
IP 0706115-3 (10/22/2007)	Recycling of multilayer packages	State University of Campinas (Unicamp)	Alexandre Kisner Celso Rodrigo Nicoleti Lauro Tatsuo Kubota** Martinho Rau	Electrochemical sensors (1994)
IP 0704070-9 (11/14/2007)	Process for recycling vulcanized elastomers, formulations of these elastomers and molded articles	Federal University of Rio de Janeiro (UFRJ)	Cristina Russi Guimarães Furtado Elen Beatriz Acordi Vasques Pacheco José Ribeiro de Albuquerque Neto Leila Lea Yuan Visconte**	Natural products in polymers (1992)
IP 0800654-7 (03/07/2008)	Process for treatment and reduction of pollutant load of vinasse and alternative economic destination of byproducts	Federal University of São Carlos (UFSCAR) Teaching Association of Ribeirão Preto (AERP)	Cristisna Filomena Pereira Rosa Paschoalato Katiuscia Carvalho Silva Marlei Barboza Pasotto Murilo Daniel de Mello Innocentini Reinaldo Pisani Júnior René de Oliveira Beleboni**	Biochemistry and pharmacology of biotechnological products (2006)
IP 1104168-4 (08/05/2011)	Separation process of LDPE/AL/LDPE layers for recycling of long-life carton packages through the use of a solution composed by a mixture of organic and inorganic acids	State University of Ponta Grossa (UEPG) Zero Resíduos S/A	Christisana Andrade Pessoa Jarem Raul Garcia Karen Wohnrath Fábio Santana dos Santos Rodolfo Thiago Ferreira**	Characterization and processing of polymers and polymeric mixtures (2007)
BR 102013001662-4 (01/23/2013)	Process for obtaining terephthalic acid by PET chemical recycling	Federal University of Espírito Santo (UFES)	Eloi Alves da Silva Filho** Gabriela Vanini	Group of conductive polymers, electroactives and recycled materials (2006)

Notes: *As patent is the necessary element for IP transfer, we disregarded links with other research groups that the inventor(s)/researcher(s) might have. This table shows the identified inventors/researchers and the oldest research group to which they belong; **Group Representative for patent issues.

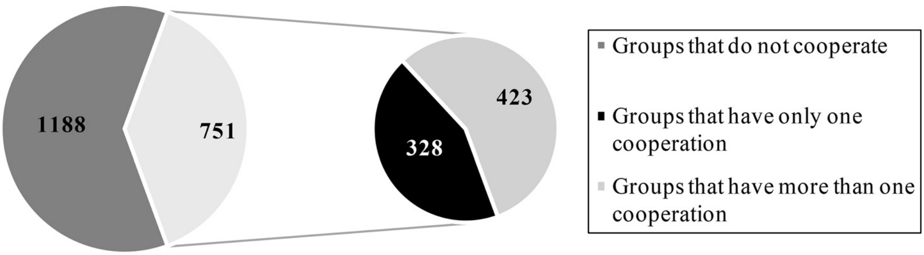
Order no.	Academic partnerships Co-ownership with other STIS?	Knowledge transfer Co-ownership with company?	Transfer of IP Licensing agreement?	Creation of spin-off?
IP 0602633-8 (07/04/2006)	No	No	No	No
IP 0706115-3 (10/22/2007)	No	No	No	No
IP 0704070-9 (11/14/2007)	No	No	No	No
IP 0800654-7 (03/07/2008)	Yes	No	No	No
IP 1104168-4 (08/05/2011)	No	Yes	Yes	No
BR 102013001662-4 (01/23/2013)	No	No	No	No

Table II. Analysis of patent information



Source: DGP/CNPq

Figure 1. Participation of groups in research networks



Source: DGP/CNPq

Figure 2. Scientific and/or technological cooperation declared by research groups

Of the 751 groups that established scientific or technological cooperation, 423 had more than one partner (56.3 per cent). Figure 3 shows the groups that cooperate, by organization types.

Most collaborations (57.3 per cent) occur between STIs. Probably this high percentage is due to the greater ease in working with similar organizations focused on research and/or training of human resources. However, it is important to highlight that a research group that establishes technological cooperation with a company, during the technology development stage seems to have a higher potential to bring the technology to the market, according to previously presented data. Cooperation with companies corresponded to 49.0 per cent of the total, and cooperatives were also included in this group. Other government entities, like city halls, and non-governmental organizations, such as unions, account for 22.3 per cent of the total cooperation of the groups.

An additional feature of the cooperation is that it is mainly done with national organizations. Partnerships with foreign organizations, especially those involving only STIs, account for just 12.3 per cent, as shown in Figure 4.

Even if we sum up the groups that declared belonging to research networks with the groups that stated to have scientific or technological cooperation, the result indicates that most of them do not work in cooperation with other organizations. A portion of 63.6 per cent of the research groups did not declare to have scientific or technological partnerships or even take part in formal research networks.

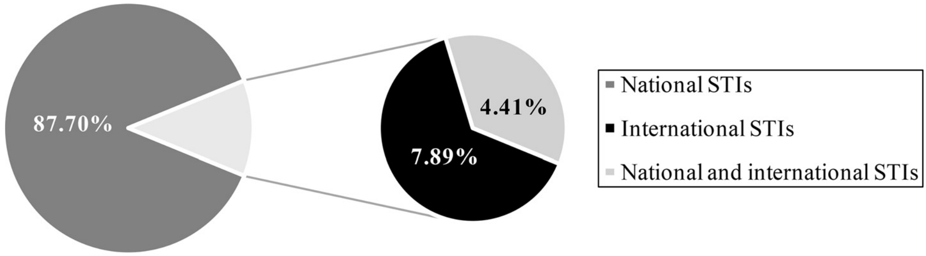
Of the 1,939 groups, 83 reported participation in research networks, but did not report scientific or technological cooperation. In turn, 621 groups reported cooperation but declared no participation in formal research networks. Only a small number of the groups (130 groups) stated that they participate in both research networks and scientific and/or technological cooperation.

5. Discussion

The most obvious result of this study is the identification of a small set, consisting of only six patent applications, which can be associated with groups related to EST R&D. In this group, we could identify technology transfer associated with just one of the applications.

Source: DGP/CNPq

Figure 3.
Categories of partners in scientific and/or technological cooperation declared by research groups



Source: DGP/CNPq

Figure 4.
Scientific and technological cooperation with foreign STIs

Regarding the small number of results identified, Thursby and Thursby (2001) observe that researchers often do not communicate their inventions because they do not believe they have marketing potential or because they do not want a low monetary gain. Other reasons are related to disagreement about IP protection policies, and many researchers prefer to disregard secrecy, necessary for the protection of technology, to eliminate the risk of having projects and publications postponed due to bureaucracy.

The difficulties in the protection stage are followed by difficulties in the TT stage. Although researchers communicate their inventions to the sectors responsible for their protection, there is a subsequent analysis of the technology to assess its potential for patenting and commercialization. That is, not all inventions communicated by inventors will be filed as patent applications by STIs. However, to select the most promising technologies, it is necessary to foster a culture of innovation (Rasmussen *et al.*, 2006).

Individual motivations may be a key issue to explain why academics engage with industry. D'Este and Perkmann (2011) observe that there are differences regarding the relationship channels. Research-related reasons drive joint research or contract research, but patenting and spin-off creation are motivated exclusively by the willingness to market a product.

Funding is a significant element that defines patent ownership in partnerships. In fact, Azagra-Caro (2014), using Eurostat patent data for the 27 European Union countries, demonstrates that, in general, dependence on public or private funding defines how STIs or companies create technology.

In Brazil, the most relevant incentives for innovation came from the Innovation Act (Act 10,973 of December 2, 2004). Enacted in 2005 through Decree 5,563 of October 11 (2005) it has gradually influenced the National System of Innovation. In fact, if we consider the set of six patents identified in the study, only two of them, filed after 2007, were academic or business partnerships, or transferred the developed technology.

The first partnership identified was academic, and it generated patent application IP 0800654-7, filed in 2008, between Federal University of São Carlos (UFSCar) and the Teaching Association of Ribeirão Preto (AERP). There was not a joint research project, but experiments were conducted in one institution and tests in the other, so that both institutions were responsible for the patent application.

There was a partnership with a company for the technology deposited in 2011 under patent application IP 1104168-4. The other patent applications show no partnerships with other research institutions or firms.

The absence of incentives to engage in a partnership, both academic and with a company, can explain this result. Because collaboration in innovation networks can stimulate patent applications (Paula *et al.*, 2017), there must be mechanisms to support technology transfer between organizations.

A new set of incentives from the Federal Government aims to encourage greater collaboration between STIs and companies. Act 13,243 of January 11 (2016) is the new institutional framework for innovation in Brazil, and it can stimulate more IP transfers, especially for products based on EST.

The transfer of intellectual property identified in this study derives from patent application IP 1104168-4, in which the company that licensed the technology exclusively is also a patent co-holder. Through this contract, a new business project was developed, the creation of a pilot plant, for introducing in the market a new process for recycling long life carton packages (LLCP).

LLCPs are composed of recyclable materials, usually duplex paper (75 per cent), aluminum (5 per cent) and low-density polyethylene (20 per cent). The process of recycling these materials is done in stages. Although paper is easily extracted in the first stage, the separation of the other materials goes through subsequent stages, with a high cost.

The technology developed provides the complete separation of low-density polyethylene and aluminum layers at a low cost and without harming the environment, thereby allowing the full reuse of these products by the polymer and metallurgical materials' industries.

The analysis of this TT shows that the patent owners identified a business opportunity related to the National Policy on Solid Waste (Act 12,305 of August 2, 2010), indicating that this is a green innovation.

Results show that technological innovation can be an important tool for the achievement of sustainable development. However, this study demonstrates that technological cooperation between companies and STIs is still rare, and the main consequence is that inventions will not reach the social or production environment as new products or processes.

Thus, TT mechanisms are essential, especially through licensing agreements and the creation of new ventures for commercialization of technology (Steffensen *et al.*, 1999).

6. Conclusions

The results achieved in this paper show a mismatch between EST development by STIs in Brazil, and the transfer of these technologies to companies, to be used in new products or processes.

The results showed that only six patents could be associated with the 1,939 identified research groups. Of the six patents, only one was the object of a licensing agreement, and no spin-off was identified.

The small number of TT agreements in the set of the examined research groups demands improvements in the Brazilian National Innovation System.

Given the results attained and considering the importance of green innovations, it is necessary to expand the mechanisms of knowledge transfer, directed not only from STIs to companies but also in the opposite direction. The available forms (participation in networks and technological collaborations) are used only by 36.4 per cent of the research groups studied. We emphasize that these groups belong to organizations that must have, by legal determination, structured Technological Innovation Centers able to facilitate interactions between researchers and companies.

A company's participation in a research project may increase the chance of transfer of the resulting IP. The development of technologies oriented to previously identified and well-defined needs and applications will bring more effective results and motivate those involved, to overcome the necessary steps for using them for social purposes or for commercialization.

Public and private managers need precise information to decide on the most appropriate forms of technological cooperation and innovation networking. Thus, it is essential that information registered in the research groups database (DGP/CNPq) be uniform, as it plays an important role in the decision-making process at different organizational levels. The suggested standardization would prevent a group from registering the research network with the name that appears in the approved project, while another group registers the network according to the notice or the funding body. Another benefit of standardization would be the unification of the institutions' names as partners of the groups – some use their abbreviation, others their company name or their fantasy name.

In addition to standardization, we suggest the creation of research groups' categories. In the current format, the group can only be in two categories: certified by the institution or not updated (excluded). The results of this study show that a more appropriate format would be based on maturity levels and achievements. The determination of the level of maturity is relevant, as the first patent application of the historical series analyzed in this study comes from a group created in 1982. The group achievements, regarding the description of graduates, completed collaborations and network projects, would be an important contribution to the record's accuracy, because in the present format, it seems to capture only the current situation of the group, disregarding details of activities performed in previous years.

This study has limitations. The results were achieved from the analysis of patents related to by research groups. Although patents are widely used as data sources for the analysis of new technologies' production, it is worth noting that not all technologies developed in the groups are patentable; therefore, patents are not a reliable picture of the research groups' technological production.

In terms of patents, the semantic keyword search may not provide a faithful picture of green innovations filed at INPI. Hence, we suggest that future studies make an evaluation using search engines, such as those based on International Patent Classification codes (IPC).

Regarding the research groups, even if they are certified by STIs, we should emphasize that the group coordinator is responsible for information on the group. Thus, there may be data limitations in this report, such as cases in which no scientific or technological cooperation was registered, but it may have actually happened in the research group.

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Appendix. Questionnaire

1) Was the technology related to the patent application ____________ (identified application number) registered at INPI developed by the institution's researchers? If so, were the researchers part of a research group registered at CNPq's Directory of Research Groups? Which one?

2) Was the technology developed in patent application ____________ (identified application number) registered at INPI done in partnership with other research institutions? If so, how did this partnership occur?

3) Was there a partnership with any company during the technology development process? What type of partnership?

4) Was there partnership after the development of technology? What type of partnership?

5) Was the technology referred to in patent application ____________ (identified application number) transferred to a company in order to develop a new product or process for the market?

6) If the answer to the previous question was positive, what type of technology transfer occurred? (Licensing, spin-off, or other contracts)

7) If the technology, referred to by the patent application, has not been transferred to a company yet, does it have the potential to reach the market in the future?

8) Was a new company (spin-off) created to exploit the technology developed by the inventors of patent application ____________ (identified order number)?

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Associate editor: Felipe Mendes Borini