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Universities, organisational structure of the research activity and the spin-off formation: lessons from Brazilian case

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Author:

Thiago Renault (trenault@heliceconsultoria.com.br)

Co-Authors:

José Manoel Carvalho de Mello, Rodrigo da Silva Carvalho

Helice Consultoria (www.heliceconsultoria.com.br)
Rua Prof Luis Cantanhede 265/304 - Laranjeiras, Rio de Janeiro - RJ

UNIVERSITIES, ORGANIZATIONAL STRUCTURE OF THE RESEARCH ACTIVITY AND THE SPIN-OFF FORMATION: LESSONS FROM BRAZILIAN CASE¹

The relationship between universities and enterprises is an important issue in the innovation process; efforts have been made by policy makers to increase this relation in Brazil. The contributions that universities can make for the innovation systems are very heterogeneous, including indirect contributions, related with teach and research missions and direct contributions in the case of the technology commercialization and spin-off formation. When we analyse different profiles of research groups from engineering departments in Brazilian universities, with heterogeneous level of research quality and institutional structure, we realize that the organization of research activity influence directly the partnership between these research groups and enterprises. When we focus in the creation of new technologies that can go through market licensing or creating spin-offs to exploit them, the research groups with highest level of research activity seems to be more effective in this kind of activity. This paper presents data from High Education System in Brazil, the distribution of research activity in this system, its concentration and heterogeneous level of quality. Two in depth case studies about research groups from engineering field in two different universities are presented to illustrate the different models that can emerge in the university and industry relation when we have heterogeneous level of research activity.

Key-words: Universities; Spin-offs; Research; New Technologies;

1 - Introduction

There is an increasing interest from government, academics and enterprises in the wealth creation based in the results of the research activity supported by public funds. There are several mechanisms to promote the technology transfer / commercialization from universities through enterprises.

This phenomenon is contextualized in the increasing perception that the incentive of the innovation process in companies is a powerful tool to promote economic development of regions and countries (Kim & Nelson, 2000). Previous research in innovation process show that it involves a constellation of social actors from different institutional spheres. The interaction between these actors create innovation systems (Lundvall, 1988; Nelson, 1993; Edquist, 1997) that impact directly in the economic development process of the regions where these systems are enrolled (Storper, 1995; Saxenian, 1996; Kim & Nelson, 2000).

The studies focused in the interaction pattern between these actors show that there are actors from three institutional spheres, government, academy and enterprise, in addition, hybrid actors start to appear in the overlaps of these institutional spheres and actors from different spheres take different functions in the other spheres. These dynamic have been called by the emergent literature as Triple Helix of relations between government, enterprises and universities (Leydesdorff & Etzkowitz, 1998; Etzkowitz, 2000; Etzkowitz et al. 2005).

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Another important issue in the innovation field is the learn process necessary for the implementation and systematization of the innovation process (Lundvall, 1992). This process occurs during the trajectory of the actors evolved and is an accumulation of different experience in different times. The interaction with align objectives make the academic and enterprise environment more dynamics, the knowledge produced in this interaction go in both ways.

In the Brazilian case the interaction between different institutional spheres is in its early stage, especially academic and enterprise institutional spheres. This scenario was characterized as an immature innovation system (Albuquerque e Sicsú, 2000), where there is a passive learn process and a low propensity to convert knowledge in innovations (Viotti, 2002).

Most of the science and technology infra structure in Brazil is in the public universities, what puts this institutions in the centre of the innovation debate in the country. In recent years several policies focused in the increase of the universities and enterprises partnership were launched, the most important were a new finance system for S,T&I activities, the “Sector Finds” , approved in the end of the 90s and a new law that makes the relationship between public laboratories/researches and privet companies more flexible, the “Innovation Law”, approved in 2004.

2 - The relationship between universities and enterprises

The contributions of universities for the innovation systems are very heterogeneous; they can be divided in direct contributions and indirect contributions. The indirect contributions cover academic publications, conferences, technical meetings, human resources formation, technical training, and so on. These contributions are related directly with teach and research missions of the universities.

There are also the direct contributions that cover technology transfer / commercialization, trough the technology transfer offices, spin-off formation with incubator facilities and geographic proximity due to common objectives, in the case of Science and Technology Parks. These activities are aligning with the proactive promotion of the economic development, called in the emergent literature as Third Mission (Leydesdorff & Etzkowitz, 1998; Etzkowitz, 2000; Etzkowitz et al. 2005).

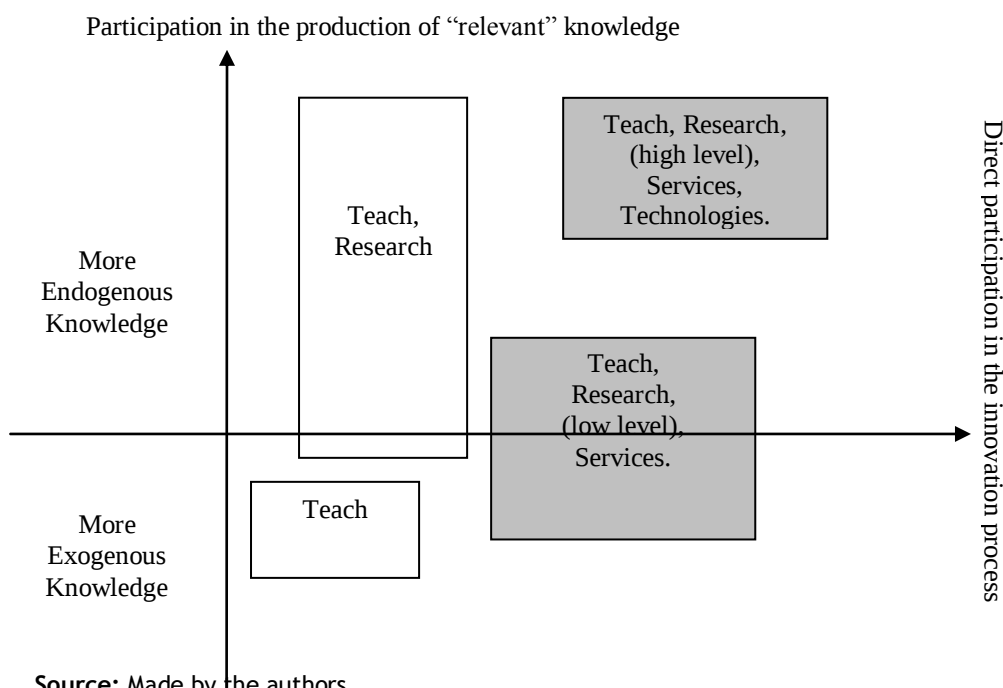
Among these mechanisms related to the third mission, the spin-off creation has been focused in several studies (Shane, 2004; Mustar et al, 2006) due to its tangible results in terms of wealth creation. It's a consensus between researches of this field that the existence of research activity, with high level of quality and relevance for the enterprise sector, is a pre condition for the university and enterprise partnership with technological development focus. The existence of a consolidate and systematic research activity, with high level of quality and relevance for the enterprise sector, makes the innovation system more dynamic and it's a pre condition for a successful program of spin-off creation or technology transfer by licensing (Mueler P., 2006; Landry, R. et al 2006; Rothaermel, F & Thursby, M. 2005; Langford, C. et al 2006; Bozeman, B. & Gaughan, M. 2007; Debackere, K. & Veugelers, R. 2005; Bower, J. 2003).

When we analyse different Brazilian cases of university - enterprise partnership, we find a heterogeneous level of quality and industrial relevance of the research activity, what impacts directly in the pattern of partnership that these research groups make with enterprises. In several of these groups the research activity is not systematic and most of the knowledge used in this kind of research activity is produced out side, in other research groups that make

the research in a systematic fashion that explore the knowledge frontier. Is not only the organizational structure of the research that impact in the university - enterprise partnership, the relevance for the enterprise sector of the knowledge that is produced is also very important for this analysis.

These research groups, despite of the different profile of activities when compare with those ones that have a systematic research activity, have important contributions for the innovation process, mainly in the technology diffusion, essential for countries that have a low rate of innovation in its enterprises, like Brazil. The figure below shows academic units with different positions in the innovation process.

Figure 1 - Participation of academic units in the innovation process



The research groups with low level of research activity tend to act in the university-enterprise partnership providing services like consulting, technological solutions with recombination of existent knowledge and human resources formation. In the other hand, academic units with high level of research activity, in addition of theses activities mentioned above, have the capacity to develop new technologies, and because of this, they have a bigger propensity to generate spin-offs to explore the market potential of these new technologies or license them for existent companies.

Academic units with different profiles make different contributions for the university enterprise relationship with technological development focus. The enterprises also have different levels of technological knowledge absorption, what demands appropriate mechanisms that can match what each actor can offer and what its expectations in this relationship. With this perspective we can observe many different operational models for this relationship.

In this sense, the paper analyse research groups from two Brazilian universities, placed in the same metropolitan region, where research groups form the engineering field, with different

research profiles, have different contribution for the innovation system of the region. The relationship of these research groups with enterprises is also very different and this difference is present in the interface mechanisms of each university, as the technology transfer office and the business incubator.

3 - The Brazilian Higher Education System and its relation with innovation system

For a better comprehension of why this study is relevant and the context where it's done, we should present some data from the Brazilian higher education and research systems, which are characterized by its big heterogeneity with different profiles of institutions. Universities have a small share, only 8%, in the total number of institutions. This is an important parameter for those who intend to promote policies to increase innovation activity based on the university-industry relationship in Brazil. As was presented in the previous section, the level of research activity and its relevance for industry are important issues that impact directly in the results of this relationship and require appropriate mechanisms that can match what each actor can provide to the other.

An overview picture of Brazil Higher Education Institutions can be figure out from INEP (2007) Educational Census. There are 2.165 Higher Education Institutions (HEIs), distributed along the following categories²:

HEIs type	Universities Number Totals	Others HEI Number Totals	Summing up Partial Totals
Federal	52	45	97
States	33	42	75
Municipals	5	54	59
Total Publics	90	141	231
Pro-profit	25	1,495	1,520
Non-profit	61	353	414
Total Privates	86	1,848	1,934
Total HEI	176	1,989	2,165

Table 1 - Higher Education Institutions in Brazil , 2006

Source: INEP (2007) Census

According to the Brazilian Ministry of Education (MEC), universities are institutions that provide teach, research and extension activities. Recently the government start a reform, according to the Reform of the Higher Education Law (2005), that is not approved yet, these institutions must have at least 12 courses in 3 different areas, graduation programs with at least 3 courses of MSc degree and 1 course of PhD degree, at least 50% of the professors with MSc or PhD degree and at least 33% full time professors.

This system had a rapid expansion in the last four decades, the total number of tertiary students expanded from 93,202 (1960) to 1,437,232 (1985), reaching 3,887,022 in 2003 and 4.5 million in 2007. In spite of this growth, the percentage of the age group 18-24 years of students enrolled in higher education didn't expanded since the 80s decade, remaining around 11% (INEP 2007). The number of institutions rise from 39 universities in 1964 for 176 in 2006 and the total number of higher education institutions rise from 900 in 1997 for 2,165 in 2006.

² Brazil has a GDP of around US\$ 1 trillion, a population of 190 million and 8,5 millions of Km².

During these years, the expansion was bigger in small institutions, 44% of the higher education institutions have less than 500 enrolled students. Most of them are private and for profit, nowadays around 90% of all HEIs in Brazil are private, in number of enrolled students it's 70%. The public institutions generally have a large number of enrolled students; most of them are universities and have research activities.

For policy makers, the heterogeneity and concentration of the higher education and research system should be an important parameter to foster innovation through the increase of university industry relationship in Brazil. Only around 10% of all the higher education institutions have research activity, and around these just a few (not more than 20) have extensive programs of research with more than 15 different PhD programs.

3.1 - Human Capital Formation and research

The Human capital formation is the main function of higher education institutions. In terms of contributions that these institutions can make for the innovation system, there are some strategic areas like engineering and technology that are very important for the innovation process. For a dynamic region based in technology companies, have a university with excellence in human capital formation is very important, these talents will help companies to be more competitive through innovation.

In Brazil most of the students enrolled in undergraduate programs are in human and social sciences, 69%, and only 11% are in engineering and technology field, 13% in biomedical sciences. In the graduation programs, the proportion of engineering and technology is the same, 11%, biomedical sciences is with 30% and human and social sciences with 30%. When we consider papers published in indexed journals, engineering is responsible for 10%, human and social sciences 1% and biomedical sciences 40%. So if Brazil wants to play in the international market as a technology producer, we must increase our number of engineering & technology students and the production of knowledge in this area.

In Brazil research activity, historically, was institutionalized in the graduation programs, in the universities. Nowadays there are 196 institutions that provide 1.819 graduation programs, 65% Universities, 26% faculties and 9% research institutes. There is a concentration of extensive programs of research in few universities, only 25 institutions have more than 10 PhD programs and 101 have only MSc programs.

This graduation system provides around 11.000 PhD and 35.000 PhD per year for Brazilian society. The evolution was intense in the last 20 years; in 1987 there were 868 PhD and 3.647 MSc. There are around 15.000 research groups that work in 268 institutions. Brazil has a share of 1,8% of world and 40% of Latin America scientific production measured by papers published in ISI indexed journals.

3.2 - Business Incubators, Technology Transfer Offices and Science & Technology Parks

As in Brazil most of the research competence is in the public universities, in the last 20 years many mechanisms arose in these institutions to promote the relationship between universities and enterprises. Generally those mechanisms include foundations that manage the

relationship between public universities and external actors³; business incubators that help new venture creation; technology transfer offices that manage technology property inside the public universities and make licensing contracts with companies; science and technology parks, where enterprises and universities stay near from each other due to common interests.

As we have a heterogeneous higher education system, where institutions have different profiles and act together in the same system of innovation, the mechanisms that arose in this institutions are also very heterogeneous in its operational model. Statistics don't show this heterogeneity, we only can analyse this phenomenon when we use in depth case studies.

The business incubator is a mechanism that was widely disseminated in Brazilian universities in the last twenty years. These business incubators have been launched with the aim to facilitate the transference of technologies that are produced in universities laboratories through the market. During the incubation process, groups of individuals that dominate technology and methodology competences with promising market applications are trained in management and market issues. During this period of incubation, the researches and the entrepreneurs are encouraged to act together in R&D activities.

The first business incubator was established in Brazil in 1986, in the University of São Carlos. Since then some 377 business incubators were established in Brazil, around 130 with technology orientation and linked directly to universities or research institutes. These incubators were responsible for 2,327 incubated enterprises, 1,678 graduated enterprises and 1,613 associated enterprises. The total number of employees in these enterprises is more than 30,000 people, the majority, higher qualified work force (ANPROTEC, 2006).

In Brazil the concept of business incubator is used in a broad way, not only related with high technology enterprises but also with middle, low and no technology enterprises. In addition, the concept is applied to other initiatives like popular cooperatives, cultural and social initiatives and so on. In this case the main function of the business incubator is teach groups of individuals how to behave like an organization.

With the consolidation of the technology incubation process in Brazilian universities, complementary activities start to appear in the more successful initiatives. Between these complementary activities we can see entrepreneurship courses, junior enterprises, business plan competitions, pre-incubation programs, and so on. Another trend in these more consolidated initiatives is provide services not only for the academic units in the universities but also for actors from different institutional spheres like government and existent enterprises. In some cases these initiatives act like regional innovation organizers (Renault & Carvalho, 2007).

Another mechanism that is present in Brazilian universities is the Technology Transfer Offices - TTOs. Like the incubators, the TTOs also have different profiles in different universities, the institutional culture, the market environment and the profile of the research activity are important parameters to analyse these differences. In 2003 there were around 25 TTOs in Brazilian universities, nowadays (2008) there are more than 100 TTOs affiliated to the

³ For example, when a company wants to make a project with a research group placed in an university (generally the public ones that have research), they use the university foundation as the contract manager for the project.

National Forum of University Technology Managers (FORTEC). This increase is related with a new “Innovation Law” that rule the relationship between public universities and private companies, making this relationship more flexible. According to this law, all public universities must have a Technological Innovation Nucleus, NIT in Portuguese, and this nucleus is responsible to manage the intellectual property of the knowledge that is produced in the universities laboratories and intermediate contracts with companies.

Brazil also has projects of science parks, with the success of some initiatives related to the university industry relationship; both actors start to have interest to have a geographical proximity, companies and research groups, with common projects can have gains with this proximity. The majority of the science parks in Brazil are in its very early stage, the Brazilian agency of innovation support 25 initiatives. In recent research in this 25 initiatives, Vedovello & Maculan (2006) had the following conclusions: (i) All the projects are in its very early stage; (ii) there isn't a standard model for the implementation of these parks; (iii) there is a lack of indicators that can help to evaluate the initiatives out puts; (iv) the science park's projects are not align to the local realities.

A Better comprehension of the different profiles that universities can assume in innovation systems, taking in account different profiles and levels of research activity, can help policy makers to combine more effective policies. The research activity in Brazilian higher education system is heavily concentrated. In a global picture of more than 2000 higher institutions, not more than 25 institutions have extensive PhD programs, with more than 10 PhD courses, around 200 higher education institutions have at least one graduation program, most of them with only one MSc course.

In this scenario, we can figure out the big heterogeneity in the way that these institutions collaborate for the innovation system in Brazil. In the next section we will present two case studies of Brazilian universities, both located in the same metropolitan area, with extensive research activity and partnerships with companies. In these institutions the historical trajectory and the profile and intensity of research activity is very different one from the other.

4 - Research activity and heterogeneous profiles of university industry relationship: two case studies in Brazilian universities

The Federal University of Rio de Janeiro - UFRJ, and Federal University Fluminense - UFF are located in Rio de Janeiro state, in the same metropolitan area. These universities have extensive research programs (MSc and PhD courses) with 40 different programs in the case of UFF and 84 programs in the case of UFRJ.

Our study was focused in research groups from the engineering field. The data was collected in official documents of Brazilian agency of innovation (FINEP), the Brazilian Coordination of Graduation Programs (CAPES) and documents from both universities. Additional data was collected trough in depth interviews with the research group leaders, business incubator and TTOs managers. The results show that these universities have different operational models to establish relationship with companies and that the research activity level and intensity is an important parameter for this relationship.

4.1 - UFRJ x UFF: Research and partnership with enterprises

The Coordination of Graduation Programs in Engineering - COPPE/UFRJ, was founded in 1963 with the mission to trainee higher qualified work force and do research activity to produce

new knowledge to support the modernization process of Brazilian industry. Since its early stage, COPPE/UFRJ was guided for two main principles: organization of research activity in a full time base and higher qualified human capital formation through the research activity.

The COPPE/UFRJ has 13 graduation programs in engineering field (Construction, chemistry, Electricity, Computer Sciences, Polymers, Metallurgy & Materials, Nuclear, Chemical and Biochemical Process, Mechanical, Biomedical, Transports, Production and Oceanic) three of them are evaluated with the best grade in the Brazilian Coordination of Graduation Programs (CAPES), grade 7. Other seven programs have grade 6, two with grade 5 and one with 4. This is the biggest research infra-structure in engineering in Latin America with 3,000 students enrolled in MSc and PhD courses, 300 professors/researchers and more than 100 laboratories. In addition, the institution has partnership and geographic proximity with the research institute of PETROBRAS (Brazilian oil company), called CENPES, the research institute of ELETROBRAS (Brazilian electricity company), CEPEL and a national institute of research in minerals, CETEM.

The university has a technology business incubator where 46 new technology based ventures were created, with products and services with high technology density. As we said in the previous section, when a university has strong research activity in technological fields, like engineering, there is a tendency to create new technologies with market potential. In this case, the business incubators and the TTOs have a big pipeline of technologies that can go to the market by licensing or creating a spin-off.

The UFRJ has a Technology Transfer Office that has 66 patents requirements in its pipeline. The UFRJ TTO also works in licensing these technologies, with 8 active licensing contracts. In the last 5 years the university managers started to build a technology park in the university campus but this initiative is in its early stage.

The UFF in the other hand has graduation programs in four areas of the engineering field (Construction, Metallurgy, Mechanic and Production) all of them created in the end of the 70s, with the human resources that were formed in COPPE/UFRJ. All the four graduation programs in engineering in this institution have grade four (grades vary from 7 to 2) in the evaluation of the Coordination of Graduation Programs (CAPES). There aren't research institutes of companies in this university and the professors/researchers are less than 80 with around 20 laboratories.

There is a business incubator in UFF but its outputs, when compared with COPPE/UFRJ, are not expressive. Both of the incubators were created in the 90s, COPPE/UFRJ in 1994 and UFF in 1998, but in UFF only 9 companies were created in the business incubator since the beginning. In addition, when we analyse the profile of these companies the technological density is not so strong like in UFRJ where the scientific base of the products and services created is much bigger. Another point is that in UFF from the 9 enterprises created in the incubator only 2 come from the university laboratories and both from fields where the university has strong research activity, Physics and Biochemistry, with graduation programs are evaluated with grade 6 by CAPES. The UFF also has a technology transfer office but until nowadays there is no patents given, only 7 requirements in the Brazilian National Institute of Industrial Property.

4.2 - UFRJ x UFF: case studies in research groups from engineering fields

We will present two case studies in each university that can illustrate the predominant profile of relationship between research groups from each institution and companies. As we showed,

COPPE/UFRJ has a stronger research base, what influence the operational model of its business incubator, TTO and technology park. In this university we analyse two case studies where research groups with strong research base create spin-offs to explore the market potential of its research results. In the case of UFF, where there is research but in a lower level, there are also partnerships with enterprises, but with a different profile. In this case what we see is more consulting services, projects of traineeship and technological solutions with the recombination of pre existent knowledge. In this second case the propensity to create spin-offs is lower because the research activity doesn't produce technological knowledge that can be explored for a new company.

The first case that we analysed in COPPE/UFRJ was the laboratory of membranes process, from the chemistry engineering department. This research group is composed by 3 senior researches with high academic productivity, recognized by the Brazilian research council (CNPq) with an academic productivity grant. The creation of this technology occurs during 30 years of research where many PhD and MSc students were graduated in close collaboration with laboratories from other countries. They developed a process to separate substances that can be used in many market applications like reutilization of water used in industry process, make water drinkable, food industry and so on. This technology has a big market potential.

During the development process the laboratory had partnerships with enterprises like PETROBRAS (Brazilian company of oil), Filtros Europa (water filter factory) and White Martins. Nowadays the researches decided to create a spin-off company to explore the market potential of the technology. They had facilities like government grants and venture capitalists interested in the technology.

Another case in this university is the Laboratory of Vibration Control, witch the coordinator is also a researcher with an academic productivity grant from the Brazilian research council. After many projects in partnership with companies he decides to create a spin-off company to explore commercially the results of his researches. This company provides solutions for the vibration problem in off shore oil platforms. The services of this company are very specialized and require a high rate of tacit knowledge.

In the case of UFF, successful experiences of partnership between research groups and companies are different. The Electricity Power Laboratory for example has many projects together of existing companies. Most of these projects are related with the more efficient utilization of electricity power resources where the laboratory provide to existent companies technology solutions that recombine pre existent technologies. The research activity in this laboratory isn't in the knowledge frontier; they basically keep up to date to the newest knowledge generated in their area.

The coordinator of this research group doesn't have an expressive academic production, most of his papers have a local circulation, he doesn't have international connections. In this case we don't see the spin-off formation process, once the research activity doesn't create new technologies, doesn't make sense to create spin-off to explore its outputs.

Another successful case of research group with close connections to enterprises in UFF is the Laboratory of Project and Quality Management; witch has more than 10 active projects with companies. The coordinator of this laboratory also presents a scientific production with a local circulation, without international connections. His studies are basically aimed in the revision of the latest knowledge produced in his field. This laboratory provides courses in company about project and quality management. Like the case before, no spin-off was

created to explore this opportunity; to give traineeship for companies is better to stay inside the university.

These two experiences that we analyse in UFF can illustrate differences in the operational model off UFF and COPPE/UFRJ in terms of partnerships between research groups and enterprises. In a general way we can say that COPPE/UFRJ has a profile more related to the generation of new technologies, with strong research base with a broad market potential. In the other hand, UFF also have relevant experiences of relationship between research groups and enterprises but in this case the activities are more related to the modernization process of pre existent companies, with a more localized impact. Both of the profiles are very important for the innovation system, one acting in the generation of new technologies with market potential and the other providing services for existent companies that help its modernization process.

5 - Conclusions

As was presented during this paper, there are several contributions that universities can give for the innovation system of a region. These contributions evolve the three academic missions, teach, research and promote economic development in a pro active fashion trough the technology licensing and spin-off formation.

Some data from Brazilian higher education and research system was presented, in this system the research activity is heavily concentrated in less than 5% of the institutions and there is a big heterogeneity in the operational model of each of them. The argument in this paper is that the profile of the research activity and its relevance impacts directly in the profile of the partnerships between research groups and enterprises.

In this sense we could see different profiles of partnerships between research groups and enterprises in both universities. In the case of COPPE/UFRJ, the predominant profile is the strong research activity base what permitted the creation of new technology with market potential. In this case the predominant pattern is the licensing of the technology trough the Technology Transfer office or the spin-off formation trough the incubation facilities.

In the other side we have the case of UFF, where the predominant pattern is the research activity in a lower level, with the aim to keep up to date to the new knowledge produced in their field. The outputs of this research activity generally only have a local impact and the pattern of partnership with enterprises in this case is consulting and training services based on existent technology/knowledge. These research groups act more in the dissemination of the up to date knowledge to existent companies. The propensity of spin-off creation is lower in this case, once the outputs of research activity don't include new technologies.

With this framework we can identify a much richer scenario for policy makers. The challenge is create policies that can combine generation of new technology with strong research base, bringing this technology to market with TTOs and incubation facilities and mach this movement with the research groups that act more in the modernization process of existent companies.

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