Innovative performance of Brazilian public higher educational institutions

Analysis of the remuneration of research groups and companies

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Abstract

Purpose – The purpose of this paper is to identify the compensation between research groups and companies that contribute the most for the innovative performance of Brazilian public higher educational institutions (PHEI), using as database the 2010's tabular plan from CNPq's Directory of Research Groups.

Design/methodology/approach – Descriptive and multivariate statistical techniques such as spearman correlation, cluster analysis, ANOVA and discriminant analysis were used.

Findings – Compensations that contribute the most for the updating of the PHEI are identified as transfer of financial resources from the partner to the group; providing grants for the group; transfer of material supplies to partner's activities; temporary physical transfer of human resources from the group to the activities conducted by the partner; other forms of compensation that do not fit in the previous categories; and partnering with transfers of resources of any kind going in any direction.

Research limitations/implications – As a limitation, it is pointed out the discontinuity of the tabular plan, which presents 2010 as the last available data.

Practical implications – The results can contribute to programs and policies to encourage innovation within universities.

Originality/value – It may be inferred that the stimulus to specific compensations may expand the quantitative idea of interaction points between the university and companies, linking qualitative aspects, which leads to an understanding that such interactions may, in fact, contribute directly to the activity of generating and spreading knowledge and innovation.

Keywords Innovation, CNPq, Public higher educational institutions, Relationship with companies, Research groups

Paper type Research paper

Introduction

Societal knowledge is impacted by a transition from the industrial society, where changes were broad, profound and fast, being considered the core for economic development. In this scenario, for nations and companies, the activities of science and technology and of R&D emerge as essential to innovative performance, turning innovation into a crucial variable, closely related to interaction processes between organizations and other agents (Mota, 1999).

In this context, researches developed in universities play an important role as a source of basic and applied knowledge. Hence, universities are no longer "ivory towers" and become referenced as strategic tools for development and economic change (Mowery & Sampat, 2005).

The university model that combines education and research dates back to the beginning of the XIX century. Historically, universities were no longer just higher educational institutions and became instructions with social functions on both education and research. As of this development, universities started to be perceived as a proficuous place for integration and differentiation of the functions that compose the knowledge basis, combining academic learning to experimental theories and practice (Etzkowitz & Leydesdorff, 1995). Therefore, their roles have been renewed and reinvented as to consider societal demands, acting rapidly and contributing to economic and social development (Kruss, Adeoti, & Nabudere, 2015).

Interactions between universities and companies (U-C) accordingly rise, strengthening the innovative performance of a nation (Mowery & Sampat, 2005). Therefore, this field of study broadly emerges, capable of being enriched by the literature of the triple helix.

In the middle of the 1990s, Henry Etzkovitz coined the concept of triple helix. It describes the importance of the government-university-industry relationship as one of the main foundations to create a sustainable system of innovation that, aligned to the reality of the economy of knowledge era, stimulates the "rise of incubator centers, innovation centers, offices for technology transfer, new laws and development mechanisms" (Valente, 2010, p.6), technology parks, research institutions, among others (Etzkowitz, 2009).

Regarding the actors "universities" and "companies", the broadening of their interactions results in innovative advances, that direct the national context to a better attitude towards the competitive global scenario (Rapini & Righi, 2007). This generates bilateral processes of technology and knowledge transmission (Meyer-Krahmer & Schmoch, 1998), promotes articulation between the scientific and technological infrastructure and the institution (Pavitt, 1998), besides resulting in a development mechanism to obtain and/or provide resources to generate and develop innovation (Rapini, de Oliveira, & Silva, 2016).

Literature brings important considerations on motivation and benefits resulting from the interaction universities and companies (Nieminen & Kaukonen, 2001; Mowery & Sampat, 2005; Perkmann & Walsh, 2009; Aguiar-Díaz, Díaz-Diaz, Ballesteros-Rodríguez, & De Sáa-Pérez, 2016). Arza (2010) states that the interaction may result in intellectual or economic benefits, represented by several forms and intensities. Hence, according to Araujo *et al.* (2015), the results of the interaction may be referred to knowledge, academic factors and innovation.

As another form of U-C interaction, remunerations are still little explored in literature, especially according to the perspective of the relationship between research groups and companies (Rapini *et al.*, 2016). Therefore, according to the National Council for Scientific and Technological Development (*Conselho Nacional de Desenvolvimento Científico e Tecnológico* - CNPq) (2017), remunerations do not only address aspects of financial transactions, but also different retribution ways that agents may establish according to their established agreements and objectives.

In face of this context, considering the importance of U-C interactions regarding funding for projects developed in research groups, the aim of this article is to identify the remunerations that contribute most to innovative performance in Brazilian public higher educational institutions (*Instituições Públicas de Ensino Superior* – PHEI). Employing, to this end, data from the Directory of Research Groups (*Diretório dos Grupos de Pesquisa* - DGP) of CNPq. This research reflects the central question of this research:

Q1. Which remunerations contribute most to the innovative performance of PHEI?

This study develops the theme, emphasizing information available on the 2010 Census from DGP, which covers a broader range of federal public educational institutions in the country. Nonetheless, the employment of 2010 data is justified by this being the last publication of the Tabular Plan.

Developing the theme, this article consists of a theoretical background followed by the research method, results and discussions and, finally, data analysis, considering, from the perspective of remunerations, the relationship between research groups and companies and the innovative performance.

Theoretical background
University-company interaction
To comprehend the interaction between universities and companies (U-C) it is important to refer to the triple helix concept. According to Etzkowitz, Webster, Gebhardt, and Terra (2000), such definition approaches a new institutional setting where agents compose a network. In this model, the focus is towards the interaction between university, industry and government; besides addressing the creation of hybrid arrangements in which innovation is central, where the government does not play the main role and the university is also the engine of innovation (Etzkowitz, de Mello, & Almeida, 2005). Hence, all parties have a commitment to enable the value system inserted in relationships to improve communication by inserting a reflexive tone, given that these are pervaded by multiple interests and particularities. Such diversity in the communication fields sponsors creativity, resulting in an intensively knowledge-based society (Leydesdorff & Etzkowitz, 1998).

Knowledge has increasingly become crucial for innovation. Therefore, the involved actors in a triple helix possess characteristics and roles within the science context. The university plays the role of stimulator of knowledge-based development through students and researchers' skills within the science and technology field. The government stands as the maintainer of interaction stability, provider of incentives and benefits, supporter for establishing research environments, besides providing financial, legal and juridical support. As for the company, it is considered the source of goods and services productions, which is also involved with knowledge, supporting and promoting it, either by means of people training or by opening new enterprises, or by moving towards both research and market (Bin, 2008; Etzkowitz, 2009).

Rapini *et al.* (2016) points out that U-C interactions emerged in the end of the 1970s, during the collapse of the import substitution policy, which resulted in the need to promote the national scientific development. Therefore, these relationships became beneficial to both sides, given that, from the perspective of companies, relationships with universities aim at obtaining access to new knowledge and technology, reducing costs and sharing R&D risks, enhancing efforts that reflect innovative performance in the market, direct and indirectly seizing governmental resources available to research, besides organizational, people, product and process development.

In the academic perspective, collaborating with companies reflects on opportunities to obtain, create and apply knowledge, to enhance the knowledge production structure and to expand partnerships. Moreover, opportunities to develop improved researches, to identify new demands for future projects, to assert its role in society, as well as bringing sources of necessary resources to develop their research projects (Nieminen & Kaukonen, 2001; Mowery & Sampat, 2005; Perkmann & Walsh, 2009; Arza, 2010; Araujo *et al.*, 2015; Aguiar-Díaz *et al.*, 2016).

Regarding interactions with the government, the recent focus lies on governmental policies that intend to promote access to knowledge and technology to companies and to reduce intrinsic costs and risks in the innovation process developed in universities (Rapini *et al.*, 2016).

Solely considering the perspective of U-C interactions of the Triple helix, CNPq has instated the DGP, in an effort to describe the limit and the general profile of scientific-technologic activities in Brazil, by means of Educational Institutions (*Instituições de Ensino -* EIs). DGP is a tool that provides an inventory of scientific and technologic research groups in the country (CNPq, 2017). Among the range of information, U-C interactions stand out by means of a survey of relationships between Educational Institutions (research groups) and companies. Hence, the aim of this survey is to analyze the degree of involvement of research groups with the productive sector, private or public. To this end, such relationships are categorized according to the types of existing relations and to the generic remuneration setting (CNPq, 2017).

Regarding the interaction between these actors, 14 habitual types of relationships have been inventoried, those being bilateral, i.e. with interactions from research groups to companies and from companies to research groups. Concerning remuneration (the focus variable of this article), the aim of the inventory was to identify how compensations occur in these relations, not focusing on figures. Therefore, there are 10 available categories of the most traditional remuneration forms (CNPq, 2017). The authors Tartari and Breschi (2012) are aligned with this study's efforts, stating that there is a positive influence of the possibility to gain access to resources (financial, material and intellectual) to the existence of interactions.

Research groups: the perspective of universities
Nowadays, society is strongly based on knowledge. Science has presented itself as the main axis of development. Meanwhile, universities perform a fundamental role on scientific knowledge, through the specialized training of people (Rosenberg & Nelson, 1994), development of scientific research, both basic and applied (Nelson, 1990; Rosenberg, 1992), specific development such as spin-offs (Etzkowitz & Leydesdorff, 2000), technology transfer and promotion of academic entrepreneurship (Haase, Araújo, & Dias, 2005), among the other forms of interaction. Such scenario highlights the university position as an engine for economic progress and innovation (Aguiar-Díaz *et al.*, 2016).

Research groups are inserted in this context of a scientific knowledge that promotes economic and technological development, consisting of basic science units in the university. These groups are defined as social entities, in which members execute interdependent tasks and have complementary skills (Guzzo & Dickson, 1996), work towards a common objective (Wang & Hicks, 2014; Qian, 2016) to research and develop science and technology (Quian, 2016) through shared use of material and financial resources (Aguiar-Díaz *et al.*, 2016). The main characteristic of research groups is the existing collaboration among researchers that, in many cases, is not explicit in authorship, but represented as a contribution in projects (Wang & Hicks, 2014).

Due to working in projects, research groups represent a favorable environment to obtain and disseminate intellectual skills, providing their participants with knowledge in research planning, literature analysis, and review, knowledge on collection methods and data analysis, besides scientific text writing. Hence, the groups are seen as complementary to courses offered by universities (Odelius *et al.*, 2011), given that they provide researchers with the opportunity to develop methodological and intellectual competence (Feldman, Divoll, & Rogan-Klyve, 2013).

Given the importance of research groups as benefic to the development of practical and reflexive skills, several studies were performed to depict their contributions to participants (Feldman *et al.*, 2013). Moreover, to understand how collaboration happens in this environment (Harvey, Pettigrew, & Ferlie, 2002) and to verify the support from these groups to innovation development (Souza & Castro, 2016; Antunes, Souza, & Antonialli, 2017). In the work of Feldman *et al.* (2013), an exploratory study was performed, allowing the authors to conclude that participation in research groups promotes relationships where mentoring no longer belongs exclusively to professors. However, it is still noticed that their participation and disposal constitute fundamental parts. Odelius *et al.* (2011) argues that this context enables researchers to not only develop technical and theoretical skills, but also improve social skills during the process of learning how to work coordinately and cooperatively.

According to Harvey *et al.* (2002), existing collaboration in groups results from collective processes characterized by communication, influence and negotiation. Hence, management refers also to examining internal and external competencies to align skill development, resources allocation and competencies to the dynamic environment of science. Therefore, the authors argue that some elements are necessary to an effective group setting, such as: a strong leadership towards an articulated strategic direction; a connection between theory and practice; the constitution of diversified basic and complementary competencies; the existence of well selected and motivated talents; the adoption of a flexible and entrepreneurial attitude; theme arrangement; the presence of positive internal interorganizational relationships; and an effective institutional and external network.

Lastly, to Haan, Leeuw, and Remery (1994), the research groups play an important role in science by distributing research funds; enabling access to publication media; attracting graduate students; developing complementary heterogeneity; helping establish a contact network; revealing emerging concepts, as well as elaborating and disseminating them.

Literature review: the connection with innovative performance of public higher educational institutions

Quandt, Bezerra, and Ferraresi (2015) state that, to deal with innovation, it is necessary to see it as a result of resources, behavior and collectively deployed activities, as to allow for new products, processes and systems to be developed. Yet, it must be taken into consideration that innovation is inserted in a context and is subject to the influence of complex and dynamic factors. Accordingly, to promote innovation it is necessary that strategies and policies approach all characteristics and factors that are grounds for the ability to innovate.

This complexity of the innovative activity generates difficulties on how to identify its determiners and consequently, on how to measure it. Literature shows as used parameters: research and development (R&D), technology, patents, new products and other factors related to the production process, organizational and process improvements. Such factors determine the innovative performance (Hagedoorn & Cloodt, 2003; Fernandes, Lourenço, & Silva, 2014; Quandt *et al.*, 2015).

Innovative performance, as a result, refers to innovative efforts of the organization towards product, process and organizational structure improvement (Gunday, Ulusoy, Kilic, & Alpkan, 2011; Quandt et al., 2015). According to Quandt et al. (2015), the innovative performance is related to dimensions that provide conditions and enable innovation: strategy, leadership, culture, organizational structure, processes, people, relationships, technological infrastructure, measurement and learning. Among those, there is a high focus on the importance of relationships with external agents.

The Oslo Manual (OECD/Eurostat, 2018) points out that innovation is also seen by the perspective of knowledge flow and, for this reason, there are interactive processes of knowledge creation and transfer, both internal and external. Hence, the innovative performance in PHEI relates to creating an incentive, sharing and applying knowledge.

Moving on to the literature review on relationships between research groups and companies on this scope, the work of Souza and Castro (2016) points out that one of the biggest contributions of research groups refers to the innovative performance provided to the educational institutes they are part of. Based on a quantitative research, the authors verified that the innovative performance of PHEI is associated to the number of PhDs and to the relationship between research groups and companies.

Complementing this result, Antunes et al. (2017) analyzed the most significant relationships to the innovative performance of public educational institutions. The authors concluded that the most important relationships on a better innovative performance are based on technology transfer from the group to the partner, as well as on software development by the partner to groups; unusual engineering activities and development/ manufacturing of equipment to the group; and scientific research with immediate use of results.

Additionally, there is the study of Rapini et al. (2016), treating the relationships between research groups and companies. They have performed an exploratory research which aimed at identifying the existing forms of remuneration between these two bodies. According to their results, the prevailing relationship type between research groups and companies is the "transfer of financial resources and materials between parties". Besides this, other remunerations are also seen as relevant, such as those related to scholarships and personnel transfer, as well as returns on generation and exchange of knowledge resulting from interaction. Hence, the authors emphasize that the "motivation to engage in cooperative activities between U-C is based on access to complementary resources, sharing knowledge and abilities, as well as risks of research activities" (Rapini et al., 2016, p. 241).

Research method

To respond to the aim of the research, a quantitative exploratory-descriptive research was developed, based on data made available by the Tabular Plan of the DGPs (Diretório dos Grupos de Pesquisa - DGP) from Brazil (CNPq, 2017). The DGP in Brazil consists of an inventory that comprehends updated information on active scientific and technologic research groups in the country. Data stored there refers to researchers, students and technicians from each team; to active lines of research; to specific knowledge; to information on scientific, technologic and artistic production; besides references on established partnerships between the groups and other institutions, such as organizations in the production sector (cnpq, 2019).

Data made available by the directory help understand the situation of the Brazilian scientific-technologic activity, making this directory a valuable source of information to the development of researches (CNPq, 2019). It is important to emphasize that the directory kept by CNPq is the only one to gather information related to research groups and their

relationships with organizations in the secondary sector. Consequently, such base was chosen for the registry collection employed in the present study.

Initially, to provide a numeric overview of research groups, the Statistical Summary from DGP was employed. This tool presents a low set of selected tables and charts containing information that summarize the data base content and provide a rather clear picture of the installed research capacity in the country (CNPq, 2017). Considering the period from 2010 to 2016, the collected data were:

- total of groups;
- groups by region, federal unit and major area;
- amount if researchers;
- scientific production;
- technical production subdivided in software, technology production and processes or techniques;
- groups with relationships;
- groups per major area and with relationship;
- types of relationships; and
- types of remuneration.

To develop this study, the subsequent step was to survey information relevant to the types of remuneration of groups, mainly on innovative performance of PHEI. The tool "Tabular Plan" from CNPq was used as an information source.

The Tabular Plan establishes the research profile in Brazil quantitatively through tables whose construction and visualization settings are dynamically performed by the user (CNPq, 2017). In accordance with data available on the Statistic Summary and on the Tabular Plan, the last statistic reference available on the Tabular Plan of DGP (2010) was chosen. The 2010 census considers a broad set of information generated by research groups registration in the CNPq directory, the base of Lattes curriculum and the collection system of the Coordination for the Improvement of Higher Education Personnel (*Coordenação de Aperfeiçoamento de Pessoal de Nível Superior* - CAPES), diverging from the most current census - of 2016. Based on the Tabular Plan, the following data was employed to develop the research:

- educational institutions;
- total of groups by educational institution;
- technical production by educational institution; and
- types of remuneration ("Rem".) by educational institution (10 types, shown on Table VII).

To define the research sample, the Tabular Plan presented 304 registered institutions, both public and private. Accordingly, the registry "Cadastro e-Mec" of Institutions and Courses of Higher Education was used, to select only PHEIs. Consequently, from 304 educational institutions obtained from the Tabular Plan, only 118 (39 per cent) composed the sample used in the research (PHEI). Furthermore, information on administrative category (Federal, State and City) and academic organization (university, institute, faculty, center or foundation) of these institutions were added to the research.

Based on the sample design and data base construction, it was possible to work under the perspective of several multivariate statistical techniques, through the statistical software Statistical Package for the Social Sciences (SPSS).

Firstly, so that collected data reliability be verified, the Cronbach's Alpha Coefficient was used. Reliability reflects the consistency of a variable or groups of variables related to what they intend to measure. One of the most used measures to diagnose reliability is the full scale of Cronbach's Alpha, whose values range from 0 to 1.0, being the value of 0.60 indicated as the inferior limit of acceptancy (Hair, Black, Babin, Anderson, & Tatham, 2005).

Subsequently, to develop a correlation analysis and evaluate the relation degree between the study variables, a Kolmogorov-Smirnov's normality test was necessary, given that such test is appropriate for more than 30 samples (Mendes & Pala, 2003). Based on this evaluation, the 10 remunerations present p values below the 1 per cent level of relevance, demonstrating that these variables present non-normal distribution. Consequently, the non-parametric correlation is indicated, i.e. Spearman's Correlation (Mukaka, 2012). According to Bauer (2007), this kind of correlation must be used as an alternative to substitute Pearson's coefficient, when quantitative variables have combined distributions differing from the normal bivariate distribution.

Afterward, a Cluster Analysis with Ward's Hierarchical model was performed, based on Maroco (2010) and Malhotra (2011). According to Maroco (2010), the analysis of groups or clusters consists of an exploratory technique of multivariate analysis that enables combining subjects or variables in homogeneous groups regarding one or more common characteristics. A cluster or group reflects a group of similar objects by means of a generic title capable of reflecting all elements lying within it (Kowalski, 1997). The objects in each group tend to be similar to each other, yet, different from objects in other groups (Malhotra, 2011). In Ward's method, according to Malhotra (2011), the aim is to minimize the square of the Euclidian distance to the averages of the clusters.

An ANOVA test was then performed to deepen data obtained by the Cluster Analysis. The analysis of variance, ANOVA, is used to compare averages of two or more populations from where random and independent samples were extracted (Maroco, 2010). In this case, ANOVA was employed to evaluate if clusters significantly differ from each other based on accordance averages.

Subsequently, to identify which were the remunerations that contribute most to innovative performance, a Discriminant Analysis was performed considering the four extracted clusters as dependents variables and the 10 types of remuneration as independents variables to show, among these, the most relevant ones. According to Gimenes and Uribe-Opazo (2003), this analysis enables finding existing relations between a qualitative dependent variable and a group of independent quantitative variables with explanatory power. Therefore, the Stepwise Method was employed, as it is the most commonly employed method and estimates discriminant functions from which independent variables sequentially enter according to the discriminatory power that they add to the accuracy relevance in the group (Hair *et al.*, 2005).

Results and discussion
This topic is divided in two sections: overview of research groups in Brazil and remuneration of research groups with innovative performance.

Overview of research groups in Brazil
Based on data presented on the Statistics Summary of DGP, a comparative overview was developed between the last issued Statistics Summary (2016) and the Statistics Summary of 2010. The year of 2010 was selected for being the same year of the last statistical reference of the Tabular Plan available and used in this study.

A growth of 37 per cent was identified in the number of research groups in 2016 compared to 2010. This information indicates an increase of more than ten thousand research groups in national territory, as shown in Table I. It also is possible to highlight the North, Northeast and Central West regions as those with higher indexes of growth in the number of research groups, being 66.22, 52.91 and 47.53 per cent, respectively. Regarding Southeast and South regions, they present a lower growth, 24.32 and 39.22 per cent, respectively. However, in absolute numbers, the Southeast region stands out in terms of quantity of research groups in Brazil (16.009 research groups).

One of the possible causes for this growth may be related to the increase in the number of Graduate Programs in the country. In 2010, there were 2,840 registered programs in CAPES. As of 2016, this number rose to 4,177 programs, which represents an increase of 47.07 per cent (*Coordenação de Aperfeiçoamento de Pessoal de Nível Superior*, 2019).

An individual analysis of the states shows that the state of Amapá, North region, presented a 291 per cent increase in the number of research groups (from 43 research groups in 2010 to 168 groups in 2016). Then Maranhão, Northeast region, had the second biggest increase, of 113 per cent (from 232 research groups in 2010 to 493 groups in 2016). However, even though growth indexes are high, South and Southeast region states, such as São Paulo, Rio de Janeiro, Rio Grande do Sul, Minas Gerais and Paraná still present the highest quantity of research groups in the country, with 7,447, 4,360, 3,601, 3.477 and 3,174 respectively.

Regarding the number of researchers, in Table II, there has been an increase of 54.83 per cent. The other (technicians) category stands out, with an increase of 363.11 per cent. Researchers, PhDs, specialists, graduate students and undergraduate students present an increase of de 59.24 per cent 47.34, 41.58 and 36.77 per cent respectively.

Regions	2010		2016		(2016-2010)	
	Groups	Relative (%)	Groups	Relative (%)	Increase of Groups	Increase (%)
Central West	1,965	7.10	2,899	7.71	934	47.53
Northeast	5,044	18.30	7,713	20.50	2,669	52.91
North	1,433	5.20	2,382	6.30	949	66.22
Southeast	12,877	46.80	16,009	42.50	3,132	24.32
South	6,204	22.51	8,637	22.90	2,433	39.22
Total	27,523	100	37,640	100	10,117	36.76

Source: DGPs - CNPq (2017)

Table I.
Increase in research groups in Brazil

Types of Researchers	2010		2016		(2016-2010)	
	No. of Researchers	Relative (%)	Number of Researchers	Relative (%)	Increase in Researchers	Increase (%)
Doctorate Degree	81,726	63.41	130,140	65.21	48,414	59.24
Masters	34,832	27.02	49,316	24.71	14,184	41.58
Specialization	6,639	5.15	9,782	4.90	3,143	47.34
Graduate	4,917	3.81	6,725	3.37	1,808	36.77
Other	778	0.61	3,603	1.81	2,825	363.11
Total	128,892	100	199,566	100	70,674	54.83

Source: DGPs - CNPq (2017)

Table II.
Number of researchers

By increasing the number of programs there has also been an increase on enrolled students, going from 224,316, in 2010 to 347,035, in 2016 (*Coordenação de Aperfeiçoamento de Pessoal de Nível Superior*, 2019). This total increase is reflected in the addition of entering researchers in the research groups. It should be noticed that, according to the research of Souza and Castro (2016), the quantity of PhDs influence the innovative performance of PHEI.

Scientific production in 2016, has also registered a low increase (7 per cent) in comparison to 2010. In this category are complete nationally distributed articles, complete internationally distributed articles, complete studies published in annals, books, book chapters and dissertations.

The major area of applied social sciences was the most noticeable one on scientific production, with a 21.9 per cent increase, followed by Health Sciences and Human Sciences, with 8.14 and 7.74 per cent, respectively. The major areas of Agricultural Sciences and Computer and Engineering had the worst rates (0.14 and −0.16 per cent, respectively), as the last has been falling in the past six years.

Regarding technical production, which according to the Statistical Summary involves software production, technological products and processes with and without patent/ registry/catalogue, has decreased in the past years (−3 per cent rate), Table III. Nonetheless, on relating technology production to the major areas, it can be observed that Applied Social Sciences, Biological Sciences and Health Sciences have grown 36.93 per cent, 16.85 per cent and 15.67 per cent. As of the other areas such as Linguistics, Languages and Arts (−25.94 per cent), Human Sciences (−25.68 per cent), Agricultural Sciences (−25.32 per cent), Computer and Engineering (−8.46 per cent) and Exact and Earth Sciences (−4.52) have experienced a decrease in technology production.

Consequently, this overview shows that the increase on the areas of Applied Social, Biological and Health Sciences, was not enough to revert the general decrease on technical production. However, when analyzing solely the major area of Applied Social Sciences, it is possible to question the data of the own Statistics Summary, given that this area does not

	2010		2016		(2016-2010)	
Major area	Productions	Relative (%)	Productions	Relative (%)	Increase of Productions	Increase (%)
Exact and Earth Sciences	3,135	12.95	2,993	12.78	−142	−4.52
Agricultural Sciences	3,298	13.63	2,463	10.52	−835	−25.32
Biological Sciences	2,968	12.26	3,468	14.81	500	16.85
Health Sciences	3,255	13.45	3,765	16.08	510	15.67
Human Sciences	2,562	10.59	1,904	8.13	−658	−25.68
Computer and Engineering	6,698	27.68	6,131	26.18	−567	−8.46
Linguistics, Languages and Arts	794	3.28	588	2.51	−206	−25.94
Applied Social Sciences	1,492	6.16	2,043	8.72	551	36.93
Other*	0	0	63	0.27	63	–
Total	24,202	100	23,418	100	−784	−3.24

Notes: *According to the CNPq Knowledge Classification Table, this classification category includes the fields of Hospital Administration, Rural Management, Military Careers, Religious Careers, Sciences, Biomedicine, Actuarial Sciences, Social Sciences, Decoration, Fashion Design, Project Design, Diplomacy, Surveying Engineering, Cartographic Engineering, Armaments Engineering, Mechatronics Engineering, Textile Engineering, Social Studies, Natural History, Industrial Chemistry, International Relations, Public Relations and Executive Secretariat
Source: DGPs - CNPq (2017)

Table III.
Technical production

present a great productive *locus* for software and technology products and processes. Therefore, it is understood that, technical production possibly encompasses other interpretations by group leaders on the variables of technical production, besides those described on the Statistics Summary, such as software production, technologic products and processes with or without patents/registry/catalogues. Consequently, other studies should be performed, especially a qualitative approach, to understand the interpretation of group leaders in the area of Applied Social Sciences on the variables of technical production. Moreover, it is also suggested that, as further research, testing the hypothesis that could justify the decrease on the major areas of Linguistics, Languages and Arts, Human Sciences, Agricultural Sciences, Exact and Earth Sciences and Computer and Engineering. Therefore, the drawn conclusion may be that these major areas have decreased due to low public and private incentive to them.

Regarding the major areas, the number of research groups per area has risen by around 36.76 per cent, Table IV. The area of Applied Social Sciences had the biggest growth, of 55.99 per cent in research groups, followed by Human Sciences with 50.19 per cent and Linguistics, Languages and Arts with 44.61 per cent. The areas with the lowest growth were Biological Sciences, with 18.02 per cent and Exact and Earth Sciences com 21.98 per cent.

Regarding relationships between research groups and companies, the Statistics Summary of 2016 presented one of the biggest growths. An increase of 261.69 per cent in relationships between research groups and companies has been identified per major areas, Table V. The area of Linguistics, Languages and Arts stands out, with an increase of 1,230.23 per cent and Human Sciences with 762.98 per cent. The major area of Agricultural Sciences registered a lower growth of 120.93 per cent. A similar analysis was performed by (2007), who identified upon consulting the 2002 Census a concentration of relationships in the areas of Computer and Engineering, with 43.8 per cent of the total and Agricultural Sciences, with 19.5 per cent.

Major area	2010		2016		(2016-2010) Increase of	
	Groups	Relative (%)	Groups	Relative (%)	Groups	Increase (%)
Exact and Earth Sciences	2,934	10.66	3,579	9.51	645	21.98
Agricultural Sciences	2,699	9.80	3,355	8.91	656	24.31
Biological Sciences	3,108	11.29	3,668	9.74	560	18.02
Health Sciences	4,573	16.62	5,877	15.61	1,304	28.52
Human Sciences	5,387	19.57	8,091	21.50	2,704	50.19
Computer and Engineering	3,548	12.89	4,965	13.19	1,417	39.94
Linguistics, Languages and Arts	1,836	6.77	2,655	7.05	819	44.61
Applied Social Sciences	3,438	12.49	5,363	14.25	1,925	55.99
Other[*]	0	0	87	0.24	87	–
Total	27,523	100	37,640	100	10,117	36.76

Notes: [*]According to the CNPq Knowledge Classification Table, this classification category includes the fields of Hospital Administration, Rural Management, Military Careers, Religious Careers, Sciences, Biomedicine, Actuarial Sciences, Social Sciences, Decoration, Fashion Design, Project Design, Diplomacy, Surveying Engineering, Cartographic Engineering, Armaments Engineering, Mechatronics Engineering, Textile Engineering, Social Studies, Natural History, Industrial Chemistry, International Relations, Public Relations and Executive Secretariat
Source: DGPs - CNPq (2017)

Table IV.
Research groups per
area

Major area	2010		2016		(2016-2010)	
	Relationship no.	Relative (%)	Relationship no.	Relative (%)	Increase of Relationship	Increase (%)
Human Sciences	235	6.70	2,028	15.99	1,793	762.98
Health Sciences	430	12.26	2,045	16.15	1,615	375.58
Applied Social Sciences	328	9.36	1,360	10.72	1,032	314.63
Computer and Engineering	1,068	30.46	2,049	16.16	981	91.85
Biological Sciences	352	10.04	1,721	13.57	1,369	388.92
Exact and Earth Sciences	343	9.78	1,339	10.56	996	290.38
Agricultural Sciences	707	20.17	1,562	12.34	855	120.93
Linguistics, Languages and Arts	43	1.23	572	4.51	529	1,230.23
Other[*]	0	0.0	5	0.0	5	–
Total	3,506	100	12,681	100	9,175	261.69

Notes: [*]According to the CNPq Knowledge Classification Table, this classification category includes the fields of Hospital Administration, Rural Management, Military Careers, Religious Careers, Sciences, Biomedicine, Actuarial Sciences, Social Sciences, Decoration, Fashion Design, Project Design, Diplomacy, Surveying Engineering, Cartographic Engineering, Armaments Engineering, Mechatronics Engineering, Textile Engineering, Social Studies, Natural History, Industrial Chemistry, International Relations, Public Relations and Executive Secretariat
Source: DGPs - CNPq (2017)

Table V.
Relationship between research groups and companies per major area

The current data still indicate the importance of these two areas (Computer and Engineering and Agricultural Sciences), especially of Computer and Engineering. It is still in the main position, with 16.16 per cent of the total of established relationships with companies; but also shows a growth in the participation of other areas, such as Health Sciences, which has 16.13 per cent of relationships and Human Sciences, with 15.99 per cent. In 2002, the direction of relationships was to tend to industry and contribute to agricultural development (Rapini & Righi, 2007), important areas to the national economy. Currently, it can be noticed that less prestigious fields in 2002, such as Linguistics, Languages and Arts have presented substantial participation growth. It means a diversification on focus and activities developed in companies along with universities.

Given that the major areas have positive increases, it is possible to affirm that during the past six years there have been better relationships between research groups and companies. However, central West, North and Northeast regions were the most benefited by these relationships, as they have presented an increase of 340.33 per cent, 339.31 per cent and 307.69 per cent, respectively, in relationships between research groups and companies (Table VI). The South and Southeast regions have obtained lower growth, with 201.59 and 259.13 per cent, respectively.

Regarding the types of remuneration, the gross amounts as to occurrence in research groups in 2016 are shown on Table VII:

In brief, it was verified that from 2010 to 2016 there has been a significant increase, especially regarding research groups. This reflects on the increased growth on the number of bound technicians and PhDs, scientific production, relationship and remuneration between research groups and companies. The regions of North, Northeast and Central West stand out, as well as the areas of Applied Social Sciences and Human Sciences, as the highest indexes of growth. On the other hand, the South and Southeast regions presented the lowest growth indexes. Additionally, some traditional major areas such as Agriculture, Health, Exact and Earth Sciences and Biology have been declining. It should also be noticed

the low technical productivity of research groups, reflecting on negative indexes of innovative performance, especially when considering some traditional areas such as Computer and Engineering.

Remuneration of research groups with companies and innovative performance
After verifying the overview on research groups in Brazil, the aim was to analyze remunerations of research groups from PHEI and companies, answering the following question:

Q2. Which remunerations contribute most to the innovative performance of PHEI?

Initially, with the data obtained from the last statistical reference of the Tabular Plan (year 2010), available on the DGPs in Brazil, an analysis of Cronbach's Alpha Coefficient was performed, to verify the reliability of the work data. The obtained amount was 0.899, which according to literature (Hair *et al.*, 2005) stands above the minimum value to be considered ideal (0.600), representing high reliability of data.

	2010		2016		(2016-2010)	
Regions	Relationship no.	Relative (%)	Relationship no.	Relative (%)	Increase of Relationship	Increase (%)
Central West	243	6.93	1,070	8.44	827	340.33
Southeast	1,534	43.75	5,509	43.45	3,975	259.13
South	945	26.95	2,851	22.48	1,906	201.69
Northeast	611	17.43	2,491	19.64	1,880	307.69
North	173	4.94	760	5.99	587	339.31
Total	3,506	100	12,681	100	9,175	261.69

Source: DGPs - CNPq (2017)

Table VI.
Relationship between research groups and companies per region

Types of Remuneration in 2016	No. of Remuneration
Rem.1 – Transfer of financial resources from the partner to the group	4.650
Rem.2 – Transfer of financialz resources from the group to the partner	3.466
Rem.3 – Scholarships provided to the group by the partner	5.529
Rem.4 – Partnership without transfer of resources of any kind involving exclusively risk relationship	7.891
Rem.5 – Transfer of materials to the group's research activities	5.734
Rem.6 – Transfer of material resources for the partner activities	3.879
Rem.7 – Transfer of temporary human resources from the partners to the group's research activities	5.263
Rem.8 – Transfer of temporary human resources from the group to the partner's activities	4.553
Rem.9 – Partnership with resources transfer of any kind on a dual path	5.155
Rem.10 – Other forms of remuneration that do not fit in any of the previous	7.556

Source: DGPs - CNPq (2017)

Table VII.
Main remuneration types between research groups and companies

Following statistical techniques, Spearman's Correlation was used, to verify the degree of relation between 10 types of remuneration and innovative performance (technical production). As obtained results (Figure 1), there are positive strong (from 0.7 to 0.9) and moderate (from 0.5 to 0.7) correlations, as indicated by Mukaka (2012), significant at 1 per cent. It is highlighted that the 10 types of remuneration have a positive association to the innovative performance of PHEI and, consequently, it was decided to keep the variable 6, which presented a positive correlation below 0.6, as it is understood that this variable may be important in the study.

After identifying the relevant associations between types of remuneration and innovation (technical production), a cluster analysis was performed, to verify groups formed by remunerations obtained from research groups and companies. The cluster analysis is justified by Souza and Castro (2016), who identified that innovative performance of IPE is directly related to the quantity of relationships/remunerations. Consequently, it is important to identify which institutions present a higher quantity of remunerations and, subsequently, performing a Discriminant Analysis enables identifying the main remunerations, which contribute most to the innovative performance of PHEI. As a result, fours clusters were formed: Cluster 1 with 86 PHEI (73 per cent of total); Cluster 2 with 23 PHEI (19 per cent); Cluster 3 with 6 PHEI (5 per cent); and Cluster 4 with 3 PHEI (3 per cent).

To further explore the profile of these clusters, an ANOVA test was performed. Hence, the clusters were related to administrative categories, academic organizations, quantity of research groups, technical production and mean quantity of remunerations per IPE. As a null hypothesis, it has been established that there are no differences among the clusters. As a result, it was verified that the variables quantity of groups, technical production and quantity of relationships were significant at 5 per cent, according to the assumptions of Hair et al. (2005). Therefore, Table VIII was developed.

Based on the cluster analysis, it was possible to determine that the dominant profile on cluster 1 is represented by institutions with a low quantity of research groups, technical production and low quantity of remunerations per institution. Therefore, Cluster 1 named Low Mean Remuneration between Research Groups and Companies.

On the profile of cluster 2, a high quantity of groups prevail, yet with a low technical production and moderate quantity of remunerations per institution. Cluster 2 is named Moderate Mean Remuneration between Research Groups and Companies.
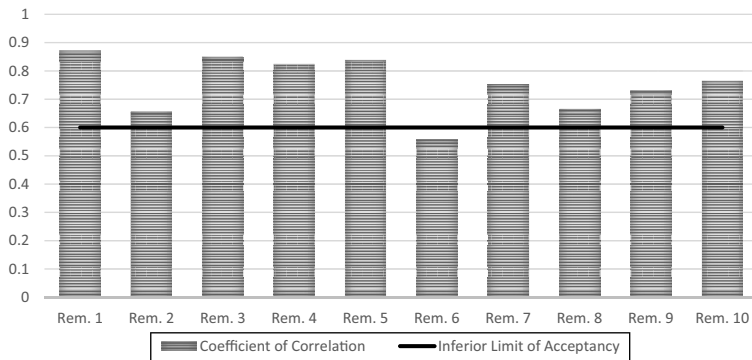
Figure 1.
Coefficient of correlation between types of remuneration and innovative performanceSource: Developed by the authors

Source: Developed by the authors

No. of IPES	Cluster 1 86	Cluster 2 23	Cluster 3 6	Cluster 4 3
Quantity of Groups (*)	Low quantity of groups[a]	High quantity of groups[b]	High quantity of groups[b]	High quantity of groups[b]
Technical Production (*)	Low technical production[c]	Low technical production[c]	High technical production[d]	High technical production[d]
Average quantity of Remuneration per institution (Total of 10 types of remuneration)	Low quantity of Remuneratio[e]	Moderate quantity of Remuneration[f]	High quantity of Remuneration[g]	Extremely high quantity of Remuneration[h]

Notes: [*]The values were classified based on cluster analysis; [a]below 247 research groups; [b]over 247 research groups; [c]below 446 technical productions per IPE; [d]over 446 technical productions per IPE; [e]average calculation of 21 remunerations per institution; [f]average calculation of 113 remunerations per institution; [g]average calculation of 337 remunerations per institution; [h]Average calculation of 542 remunerations per institution
Source: Developed by the authors

Cluster 3 solely presents institutions with a high quantity of groups and technical production and high quantity of remuneration per institution. Cluster 3 is named High Mean Remuneration between research Groups and Companies.

Finally, cluster 4 presents federal and state public institutions, solely composed by universities with a high quantity of groups and technical production and extremely high quantity of remuneration per institution. Cluster 4 is named Extremely High Mean Remuneration between Research Groups and Companies.

According to the results, the high technical production solely occurs among groups whose mean remuneration is considered high or extremely high. These groups englobe a small part of Brazilian PHEI, as a total of 9 institutions have been identified, distributed between clusters 3 (6 PHEI) and 4 (3 PHEI). It was also verified that many institutions of high education in the country, according to Clusters 1 (86 PHEI) and 2 (23 PHEI), present a low innovative performance, evidenced by the low level of technical production. The level of remuneration in these groups is considered low and moderate, respectively.

The nine institutions present on Clusters 1 and 2, which present the highest indexes of technical production and mean remuneration, are the same pointed by Antunes *et al.* (2017) as detainers of a higher level of relationships with. Hence, it may be inferred that operating in partnership with private organizations may reflect on innovative performance, as already highlighted by Souza and Castro (2016).

Table IX presents the studied PHEI classified in accordance to the results of the cluster analysis.

To identify the types of remuneration that interfere most on clusters differentiation and, consequently, that most impact on innovative performance, a Discriminant Analysis was performed. Therefore, the four obtained clusters were defined as dependent variable and as independent variable the 10 types of remuneration. Furthermore, as a null hypothesis, it has been established that there are no differences among the clusters (Low, Moderate, High and Extremely High Mean Remunerations per Institution).

Through the Discriminant Analysis, the obtained results point to a rejection of the null hypothesis by the Wilks Lambda test with a significance level of 1 per cent, which indicates that there are differences among the clusters. It may be understood that the remunerations that most discriminate clusters, according to the Stepwise Method are: Remuneration 1

Clusters	Institutions
Cluster 1 – Low Mean Remuneration between Research Groups and Companies	UFAC; IFAL; UFAL; UNCISAL; UNIFAP; IFAM; UEA; UFAM; IFBA; UEFS; UESB; UESC; UFBR; IFCE; UECE; URGA; UVA-CE; IFB; IFG; IFGoiano; UEG; UEMA; UFMA; IFMT; UNEMAT; UEMS; UFGO; UFMS; UEMG; IFSEMG; IFTM; UEMG; UFJF; UFSJ; UFTM; UFVJM; UNIFALMG; UNIFEI; UEM; UENP; UEPG; UNESPAR; UNICENTRO; UEPB; UFPB; IFPA; UEPA; UFOPA; UFRA; IFSertõesPE; IFPE; UFRPE; UNIVASF; UPE; IFPI; UESPI; UFPI; UERN; UFERSA; FURG; IFFarropilha; IFRS; UNIPAMPA; CEFET/RJ; IFRJ; IME; UENF; UFRRJ; UNIRIO; IFRO; UNIR; UFRR; IFCatarinense; IFSC; UNOESC; IFS; UFS; FAMERP; ITA; UNITAU; UFT; e UNITINS; UFF; UFMT; UDESC
Cluster 2 – Moderate Mean Remuneration between Research Groups and Companies	UFBA; UNEB; UFC; UNB; UFG; CEFET/MG; UFLA; UFOP; UFU; UNIFEI; UEL; UNIOESTE; UTFPR; UFCG; UFPA; UFRN; UFPEL; UFSM; UERJ; FURB; UFSCAR; UNICAMP; e UNIFESP
Cluster 3 – High Mean Remuneration between research Groups and Companies	UFMG; UFV; UFPR; UFPE; UFRGS; UFRJ
Cluster 4 – Extremely High Mean Remuneration between Research Groups and Companies	UFSC; UNESP; e USP

Note: IPES were classified according to Federative Units
Source: Developed by the authors

(Financial resources transfer from the partner to the group); Remuneration 3 (Scholarships provided to the group by the partner); Remuneration 6 (Material resources transfer for the partner activities); Remuneration 8 (Temporary physical transfer of human resources from the group to the partner activities); Remuneration 10 (Other forms of remuneration that do not fit in any of the previous); and Remuneration 9 (Partnership with resources transfer of any kind on a dual path), respectively.

The discriminant function presented a coefficient of canonic correlation to the first discriminant function of 0.970; to the second discriminant function of 0.646; and to the third discriminant function of 0.319. In brief, this indicates a high association degree between the function with the analyzed clusters. Finally, the results also show that 92.4 per cent of PHEI were correctly classified in the cluster, which indicates a high coherence percentage of the classification.

These results are in accordance to the research of Rapini *et al.* (2016). The authors categorized the types of remuneration in four blocks according to similar characteristics and consequently obtaining the category of financial and material resources; knowledge exchange; others; and risk. The research results indicate that 56.7 per cent of the total quantity of remunerations is in the category of financial and material resources. It is relevant to notice that these results converge with remunerations 1, 6 and 9. Specially given that Remuneration 1 (Financial resources transfer from the partner to the group) has represented in both researches the most important remuneration. The second category, exchange of knowledge, obtained 19.5 per cent of the total quantity of remunerations, encompassing both remunerations 3 and 8. Remuneration 3 is also highlighted (scholarships provided to the group by the partner) for obtaining the highest percentage (12.5 per cent) in this block (knowledge exchange), confirming the order of importance for the described

remunerations. Lastly, the category "Others" represented 13.1 per cent of the total quantity of remunerations and within this category solely lies the relationship described as 10. Regarding the risks category, the present study has not discriminated a remuneration in this category (Rapini *et al.*, 2016).

The results also comply with the statements of Sbragia, Marques, and Faria (2017) regarding factors that influence the establishment of partnerships between universities and companies. According to the authors, cooperation with private organizations allows the PHEI to have access to resources to fund researches; enables knowledge exchange, brings it closer to the industrial context and keeps it updated regarding the sector needs; besides providing researchers with opportunities to establish consulting contracts.

In brief, the results from this research show that, besides motivation based on resources, some types of remuneration (the discriminated ones) contribute to a higher innovative performance of PHEI. This reinforces the idea exposed by Etzkowitz *et al.* (2005) that universities, within the Triple Helix approach, are innovation engines.

Conclusion

To achieve the aims of this research, by means of multivariate statistical techniques, cluster and discriminant analysis were performed based on data made available on by the DGPs, aiming at verifying which are the most important remunerations to innovative performance to PHEI. As a result, it was possible to extract four clusters, as follows: cluster 1 with 86 institutions with Low Mean Remunerations between Research Groups and Companies; cluster 2 with 23 institutions with Moderate Mean Remunerations; cluster 3 with 6 institutions with High Mean Remunerations; and in the last cluster, only 3 institutions were obtained with Extremely High Mean Remunerations between Research Groups and Companies. Therefore, based on the Discriminant Analysis, it is understood that the remunerations that most influence the innovative performance of PHEI are remunerations 1, 3, 6, 8, 10 and 9, respectively.

These results reinforce the idea that, by stimulating some specific types of remuneration, it is possible to obtain an increase in the innovative potential of the PHEI. Besides, by associating these findings to the results obtained by Antunes *et al.* (2017), specific alternatives to develop the innovative potential of PHEI emerge. Such alternatives combine relationships and forms of remuneration. Such perspective moves toward the considerations of Schaeffer, Ruffoni, and Puffal (2015) on the need to go beyond the ideas of "interaction points" between U-C. From this point of view, it is not suitable to solely value quantitative expansion on the number of relationships between research groups and companies; the quality of interactions must be valued and focused so that they can indeed directly contribute to the activity of knowledge and innovation generation and distribution.

On the other hand, results must be rather cautiously evaluated, as there are different work fields of research groups. This issue converges with the arguments of Rapini *et al.* (2016) on the existence of statistical differences in the forms of remuneration established between the groups of companies and the productive sector. Mainly regarding the scientific excellence of groups, the fields of knowledge, the types of established relationships and the sectorial classification of companies according to the level of technologic intensity. Moreover, Souza and Castro (2016) also point out the variable "Quantity of PhDs" as another influencing aspect on innovative performance of PHEI.

As a practical contribution to PHEI, it is seen that, tracing a relationship between the results of this research and those pointed out by Antunes *et al.* (2017) regarding relationships that most contribute to innovative performance, it may be stated that PHEI must determine innovative ways based on technology development and transfer, as well as

on developing practice-oriented researches. As of this indication, considering the structural realities, PHEI may evaluate their strategic guidelines.

Accordingly, the establishment of new relationships must be based on technology transfer from the group to the partner; software development by the partner to groups; unusual engineering activities and development/manufacturing of equipment to the group; and scientific research with immediate use of results. Such relationships, considered a dual path of possible supporting, must be mainly based on remunerations that involve, by the company, scholarships provision and financial investments and, by the group, material resources, and human capital provision.

Regarding the limitations of the present study, the first one could be the period of the Tabular Plan data used in the analysis (up to 2010). Through a contact with CNPq, it was possible to understand that the absence of this data update was not casual. However, due to the great contribution and relevance of the collected data and especially given the results obtained by this study, the importance of continuing the Tabular Plan is reinforced, as to the comprehension of the development and continuity of researches in Brazil – such as this present work. Therefore, it is suggested to CNPq to reconsider the decision of discontinuing the Tabular Plan as, updated or not, the provided data have attended to a need of data, which is not covered by other censuses, adding great value to the study. A second limitation is regarding the lack of further details on the types of remuneration provided by DGP, which impairs a deeper comprehension of interactions. As the last limitation, it is emphasized the lack of complementary basis that could subsidize the obtained results.

Therefore, an in loco quantitative research is an appropriate future agenda so that research group managers describe the reality of the interactions, highlighting difficulties, needs, opportunities and other practical matters of interactions, as well as describing how remunerations occur with companies and how they are established and managed. Hence, it is possible to contribute, even more, to the literature on triple helix. Given that, considering real contexts, relevant aspects of helices will be investigated, emphasized and described, providing a foundation to new discussions.

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