TYPES OF UNIVERSITY-INDUSTRY INTERACTION: a new approach to bridge the gap between universities and industries

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ABSTRACT

University-industry (U-I) interaction promotes a debate that is hinged on the National System of Innovation dynamics. Thus, by taking into account the different patterns of U-I interactions in developed and developing countries, the literature has sought to categorize them, but hasn't paid attention to the interactions that may contribute to leverage the different knowledge gaps between universities and industries. So, this study aims to assess the types of interaction that narrow or bridge those knowledge gaps. To achieve that, a new typology is proposed, which seeks to contemplate several common elements often dealt with in the literature in a piecemeal fashion. These elements are viewed as a continuum, in which it is possible to perceive the interactions targeted at practical and short-term application on the one hand, and interactions oriented towards long-term joint research on the other, leading to an increasing level of knowledge needed for innovation. In the new typology model proposed the interactions are classified into *training-oriented*, *diffusion-oriented*, *funding-oriented*, *development-oriented, and research-oriented*, in which the latter two differ from the others, and this difference lies in the quality of interaction and in the possibility of competitive upgrade of the industries engaged in these interactions. The Brazilian 2010 Census data available from the CNPq Research Group Directory was used to test the model, which refers to 6,792 U-I interactions. In this context, analyzing the five types proposed, the most frequent among all interactions were the development-oriented (39%), diffusion-oriented (23%), and research-oriented (16%). It is likely that U-I interactions have improved in terms of quality in an attempt to attain a joint higher technological development; however, this finding does not neglect the existence of "points of interaction" in Brazil.

Keywords: University-industry interaction, interaction typology, innovation, developing countries, Brazil.

1 INTRODUCTION

Based on the assumption that the national context may have a strong influence and may stimulate, facilitate, delay or impede firms' innovative activities (FREEMAN; SOETE, 2008), the present paper aims to assess the relationships between universities and industries in the context of the Brazilian National System of Innovation (NSI). NSI is understood as a group of private and public institutions that, by way of interactions, produces and, consequently, propagates new technologies on the market, contributing to the wealth of regions, thus interconnecting science and technology – the core element of this system (FREEMAN, 1987, 1995; NELSON; ROSENBERG, 1993).

Thus, university-industry (U-I) interaction, concerning the development of knowledge, inventions, and innovations, promotes a debate that is hinged on the NSI dynamics. In developed countries, there exists a positive feedback system between universities and industries, which generates a flow of information and knowledge that moves in both directions, and in this case, basic research is a source of suggestions for new projects and also a way to assist the completion of ongoing organizational projects (COHEN; NELSON; WALSH, 2002). In the specific context of developing countries, firms often do not have enough internal capabilities to develop innovative activities, and their interaction with universities is one of the possible mechanisms whereby existing restrictions on assets can be overcome (ZAWISLAK; DALMARCO, 2011). However, in Latin America, the interactions between universities and industries are still confined to consulting activities, despite the fact that there is a small demand for sophisticated technological knowledge, which is eventually met by importing it from other countries (AROCENA; SUTZ, 2000; ARZA, 2010).

Thus, by taking into account the differences between the patterns of interactions in developed and developing countries, it is possible to note the literature has sought to categorize the different types of interactions, utilizing organizational resource, duration of the agreements and their degree of formality (BONACCORSI; PICCALUGA, 1994), the outcome of the interaction (SANTORO, 2000), the reasons that lead universities and industries to interact (ARZA, 2010), among others, as the major variables for the classification of the typology.

However, it is observed that there is no consensus among authors, whatsoever, about the definitions of U-I interaction types. Perkmann and Walsh (2007) explain that, while some authors refer to the channel by which information is transferred between university and industry, others look into the process, i.e., how the interaction happens. Besides, it is verified whether the proposed typologies make very little headway in identifying the types of interactions that allow bridging the existing knowledge gaps between these actors, considering that such gaps lie mainly in the distinct objectives of universities and industries, as the former focus on academic activities whereas the latter put in a great deal of effort into solving technical problems. Also, if firms want to upgrade in terms of innovation, they can not just rely on universities to provide the solutions to their problems, but they need to have some prior fundamental knowledge over the process or the product. This prior knowledge will be assessed during the interaction with the university, and will be complementary to the one provided by the university.

Therefore, given the differences between universities' and industries' knowledge and needs, what is the typology that best suits the different goals of the available interactions? In an attempt to answer this question, the paper aims to assess the types of interaction that narrow or bridge the gaps between universities and industries. Such knowledge gaps would be overcome once the industry relies on the university to solve current product and process development problems, in which the knowledge of both is mandatory to the success of the results.

Hence, once a typology representing the objectives of each interaction is obtained, it will be possible to show universities and industries the most appropriate type of interaction for each purpose, trying to counterbalance the level of knowledge between both actors. The new typology proposed here seeks to contemplate the several common elements described in the literature which could be adopted to characterize and fill the knowledge gap, as well as to meet the needs of universities and industries. These elements, addressed in a piecemeal manner in the literature, are viewed as a continuum, in which it is possible to perceive the interactions targeted at practical and short-term application on the one hand, and interactions oriented towards long-term joint research on the other, leading to an increasing level of knowledge, which is needed for innovation. To achieve this, a new typology is introduced, which classifies interactions into five types: training-oriented, diffusion-oriented, funding-oriented, development-oriented and research-oriented.

Finally, the interactions between research groups and industries in Brazil were categorized and analyzed to verify whether the proposed typology includes the features of the types of university-industry interactions in a given context, thereby identifying the interaction types that fill the knowledge gap between universities and industries. The data used in the present paper were obtained from the 2010 Census from the CNPq Research Group Directory, considered a secondary source of information.

Aside from this introduction, the paper is organized into five sections. Section 2 contains the review of the literature on the importance of university-industry interaction and on interaction types. Section 3 introduces a new approach to interaction types. Section 4 describes the methods used. Section 5 presents and interprets the results. Finally, an overview of the study and the final remarks conclude the paper.

2 UNIVERSITY-INDUSTRY INTERACTION

In the technological economics literature, mainly in regard to national systems of innovation (NSI), scientific and technological output is highlighted because of its crucial role. The NSI consists of a network of economic, social, political, and organizational institutions that promote the development, dissemination, and utilization of innovations. (EDQUIST, 1997). So, the key aspect of this network is concerned with coherent interactions between the actors, aimed at the development of innovations and, consequently, at economic growth (PÓVOA, 2008).

Notably, there are two widely known models which aim is to assess the interactions that make up the NSIs. Firstly, Sabato's Triangle attempts to explain how the government, industries, and science interact with one another, given a unidirectional flow of information (SABATO; BOTANA, 1975). The Triple Helix model, on the other hand, is an interactive approach that contemplates the interactions which occur among the actors mentioned above, underlining that, while industries and science interact, the government sets the policy framework (ETZKOWITZ, 2003).

With the advent of modern technology, a complex relationship has been assumed between science and technology, highlighting the interaction between academic research and industrial innovation (ROSENBERG; NELSON, 1994; ROSENBERG, 2000). Rosenberg (1982) asserts that technology provides questions and problems to be addressed and solved by scientific research and also furnishes a body of empirical knowledge to be sorted out and analyzed by scientists. The existence of a positive feedback system is then verified, which may be construed as a bi-directional information and knowledge flow.

In view of a growing wave of interactions between science financed by the public sector and the U.S. industry, Mowery and Sampat (2005) investigated the main results of academic research for industrial innovation, such as networks of scientific and technological capabilities, the prototypes of new products and processes, technological and scientific information, human capital, equipment, and provision of necessary tools. Their findings refer to the concept of entrepreneurial university and provide this NSI actor with a function that goes far beyond the traditional role ascribed to universities, which encompassed the supply of college education and production of scientific knowledge (MEYER-KRAHMER; SCHMOCH, 1998; COHEN; NELSON; WALSH, 2002; MOWERY; SAMPAT, 2005; MAZZOLENI; NELSON, 2007).

Other studies, carried out by Klevorick et al. (1995) and Cohen, Nelson and Walsh (2002), sought to look into the factors that influence the contributions of academic research to industries. They concluded that contributions are made through different mechanisms, which vary across industrial sectors according to the relevance science bears for each sector and according to the absorptive capability of participants, recalling that public research takes on added importance in large industries (MEYER-KRAHMER; SCHMOCH, 1998; COHEN; NELSON; WALSH, 2002). Moreover, Giuliani and Arza (2009) propose, in their conceptual model, that U-I interaction is conditional upon two major factors, namely the internal knowledge base held by industries and the scientific quality of research areas on the university side. It is reasonable to assume that universities act as external sources of knowledge at the firm level, and that they can make their assets more dynamic, allowing them to innovate.

It is then possible to perceive the relevance of the relationship between universities and industries for economic, industrial, and technological development of countries, as universities are general sources of knowledge, in addition to sources of specialized knowledge of industrial technologies, which allow for industrial innovation and strengthen NSIs (SUZIGAN; RAPINI; ALBUQUERQUE, 2011). Because the interaction between universities and industries is a fundamental factor for the application of scientific knowledge in the production sector, which stimulates and leverages innovation processes in firms, notwithstanding its incipience in developing countries, it is paramount that the topic is addressed in studies, offering a better insight into such interaction.

Therefore, it is believed that the differences in the NSIs of each country, as well as sectoral features and the absorptive capability of industries that interact with universities, do not allow every interaction between the two to be alike. The types of interaction can be evaluated by different sets of variables, as outlined in the upcoming section, which describe the types of U-I interaction investigated in the literature by way of a systematic review of papers on the topic.

2.1 Types of university-industry interaction

University-industry interaction depends on different factors, among which special attention should be given to: NSI characteristics in each country, the importance of innovation to each sector of the economy, the size and absorptive capability of industries that interact with universities, the objectives of academic research at universities, among others. So, distinct types of interaction can be observed, which can be categorized using different variables. In what follows, the types assessed by a few authors are described, but only one of them was devised with the aim of specifically analyzing the Latin American context.

Databases were mapped to identify studies on U-I interaction. Chart 1 summarizes these studies and also those mentioned previously. It should be underscored that, despite the vast literature on U-I interaction, there are few studies on interaction types, as most papers address the motivations, the mechanisms, the impacts, and technology transfer involved in this interaction.

Chart 1: Previous studies on types of U-I interactions

Author	Variables used in the classification of interaction types	Types of interactions proposed
Bonaccorsi and Piccaluga (1994)	These authors propose six types of cooperation, classified according to the organizational resource on the university side, taking into consideration the duration of the agreements and their degree of formality.	The six types of interaction proposed were: informal personal relationships, without participation of the university; formal personal relationships, agreements between universities and industries; participation of an intermediary institution; formal agreements with clearly defined goals; formal agreements without clearly defined goals (“umbrella-type”); and the creation of structures for the interaction.
Meyer-Krahmer and Schmoch (1998)	The authors propose 11 types of U-I interaction based on a literature review, highlighting the works by Allesch et al. (1988) and Cohen et al. (1994), in addition to interviews with experts at universities.	The following types of interaction were proposed: collaborative research, informal contracts, education of personnel, doctoral theses, contract research, conferences, consultancy work, seminars for industry, scientist exchange, publications, and committees.
Cunha and Fracasso (1999)	The authors used the following attributes: vision, strategy, management, focus of research, relationship, and indicator of success.	The authors proposed the following types of interaction: classic model, market model, and partnership model.
Santoro (2000)	The author utilized the interaction outcome as main variable in the classification.	The following types were proposed: research support, cooperative research, knowledge transfer, and technology transfer.
Schartinger et al. (2002)	The authors take into account the differences in interaction between economic sectors and scientific disciplines.	Nine types of interaction were proposed: collaborative research, joint scientific publications, contract research and consulting, mobility of researchers from universities to industries, financing of university research assistants by industries, joint supervision of PhD and Master’s theses, training of industry members at universities, lectures at universities held by industry members and technology-oriented new industry formation by university researchers.
D’Este and Patel (2007)	The authors use frequency of interaction, individual, group, and university characteristics, range of interactions in the academic community, and different interaction categories on the part of the researcher as variables.	The types of interaction are grouped into five categories: meetings and conferences, consultancy and contract research, creation of physical facilities, training, and joint research.
Perkmann and Walsh (2007)	The degree of finalization of the research is used as variable. Finalization refers to how technical, social or economic the research objectives are, instead of having knowledge as an end in itself. In the case of research partnership, finalization is low, but in consultancy work, it is high.	Two main types of relationship-based forms of university-industry links were proposed: research partnerships (generate outputs of high academic relevance, includes collaborative research activities and university-industry research centers), and research services (provided by academic research, less exploitable for academic publications, includes contract research and some academic consulting).

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Author	Variables used in the classification of interaction types	Types of interactions proposed
Bekkers and Freitas (2008)	The authors use the sector/disciplines variable to determine whether sectoral activities explain U-I interaction.	The authors propose 23 channels of interaction divided into six groups: scientific output, informal contacts and students; labor mobility; collaborative and contract research; contacts via alumni or professional organizations; specific organized activities; patents and licensing.
Zanin et al. (2008)	The authors use the source of the flow of relationship as variable.	The following types of interaction were proposed: from research groups to the production sector or from the production sector to research groups.
Arza (2010)	The author classifies the types of interaction by comparing the reasons that lead universities and industries to interact.	The four types of interactions were: traditional, services, commercial, and bi-directional. This classification refers specifically to the context of Latin American countries.
Cosh and Hughes (2010)	The authors used several interaction indices (frequency, type, source of interaction, funding) to assess the difference in interactions between two countries.	The authors propose 12 types of university-industry interactions: informal contacts; recruitment at first degree, or master's level; publications; conferences; testing and standards; recruitment at the post-doctoral level; problem-solving/consulting by university staff; joint research and development projects; internships; exclusive licensing of university-held patents; innovation-related expenditure with university-related activities; non-exclusive licensing of university-held patents.
Puffal (2011)	The author proposes a classification based on the CNPq types of interaction, which were grouped using factor analysis.	Types of interaction proposed: interaction with use of technical information; interaction with use of resources available from the university or research institute; and interaction with use of patent information.
Torres et al. (2011)	The authors used the purpose of the interaction as variable.	The types of interactions were: information, human resources, research services and products, and firm setup.

Source: Data compiled by the authors.

3 A NEW TYPOLOGY MODEL

In light of the literature review shown above, it is observed that there is no consensus whatsoever about the definitions of U-I interaction. Among the reviewed authors, different types of variables are analyzed in order to categorize the existing types of interaction. Perkmann and Walsh (2007) explain that, while some authors refer to the channel by which information is transferred between university and industry, others look into the process, i.e., how the interaction happens. Therefore, the present paper proposes a new typology model that bears resemblance to the second definition used by Perkmann and Walsh (2007), although it makes some progress by attempting to identify the types of interaction that can bridge the existing knowledge gap between universities and industries.

In regard to the typologies presented in the literature, most of them fail by focusing on the channel whereby information and knowledge are transferred; moreover, they are circumscribed by the fact that they reflect only the reality of developed countries. In turn, the typology proposed by Arza (2010), which refers specifically to Latin American countries, needs to be looked at in further detail, as it is focuses on too broad reasons for interaction, not allowing to identify which interactions could actually reduce the knowledge gap that exists between universities and industries. Furthermore, it is not possible to identify what type of interaction an industry should have with an university when it needs to develop a product or a process in a short time period, in which the knowledge provided by both is paramount to the success of the project. In this interaction both actors must participate actively.

The typology proposed by Arza (2010) only considers the industry as being proactive in the bi-directional and the commercial interaction. However, those interactions don't reflect the situation faced, since the bi-directional one considers long term interactions, while the commercial interaction reflects the intent, by the university, to commercialize the results of academic research (which clearly doesn't apply to this case). The commercial interaction proposed by author (2010) relates mainly to incubators and technology licensing. Also, the typology demonstrates that the interaction of services or the traditional type are not appropriate, since the industry adopts a passive attitude towards interaction, bringing no benefits as far as innovative activities are concerned. In addition, regarding traditional interaction, there is no distinction between providing qualification in human resources and offering other types of knowledge transfers, such as conferences and publications, which have different impacts on the industry.

Accordingly, it is important to develop a typology that identifies and considers these peculiarities and types of interaction that could help to even out the level of knowledge between universities and industries. This typology would make a contribution by allowing industries in developing countries to improve the quality of their commercially available products, processes, and services. Also, the better understanding of the importance of long-term research would undeniably foster innovative activities. This would allow tackling the questions often raised by business entities that universities don't understand industries' needs, that their discourse is far beyond what is really needed, when, in fact, industries do not make an effort to get acquainted with the activities universities have undertaken. Nonetheless, by having a typology that reflects the goals of each interaction, it is possible to show universities and industries the most appropriate type of interaction for each objective, reducing the knowledge gap between them.

Therefore, the review of the literature on typologies made it possible to identify several common elements that could be adopted to characterize and fill the existing knowledge gap between universities and industries. These elements, handled in a fragmentary way in the literature are regarded as a continuum, with interactions targeted at practical and short-term applications on the one hand, and interactions aimed at long-term joint research on the other, increasing the level of knowledge needed for innovation.

The typology model proposed then includes five types of interaction, which are analyzed according to the duration of interaction, to the direction of information flow, to the level of knowledge involved, to the degree of formality, to the complexity of interaction, and to the absorptive capability of the actors. The five types of interaction are:

i. *training-oriented:* consists of human resources training, which occurs mainly through interchanges between universities and industries. This type of relationship does not necessarily imply long-term interactions, so, usually, participants do not need to have high absorptive capability in order to interact. Furthermore, the level of complexity of the interaction is low and information flow can occur from university to industry or the other way around;

ii. *diffusion-oriented:* consists of public technological knowledge and currently available solutions, without a high level of complexity. Level of knowledge is low, and participants do not need to have high absorptive capability. An example of this type of interaction is the access to academic papers, in which knowledge is readily available and can be easily acquired. Another example, a little bit more complex, is technology transfer between universities and industries by the acquisition of patents by the latter. This case fits into this sort of interaction if and only if the industry is not involved in the development of the patent, but only purchases the technology that has been developed by the university;

iii. *funding-oriented:* consists of the services supplied by universities and industries, for instance, technical consulting activities and utilization of frameworks made available by the partner, including laboratories and materials for tests. Both short-term and long-term interactions are possible, depending on the implicit goals of the interaction. In addition, information flow is too low, as it does not necessarily imply active participation of the parties, being seen as a typical service delivery kind of business. In some contexts, consulting services may also indicate a funding-oriented interaction, for example, when an industry hires services from a university and uses its laboratories indirectly for tests;

iv. *development-oriented:* consists of interactions targeted at joint technological development. So, in this type of interaction, participants are active, even when results are used in the short run only. In this type of relationship, knowledge and information flow in both directions, i.e., from universities to industries and vice versa. The absorptive capability of participants must be high so that both can engage in research activities. An example would be that of an industry that appeals for help to a technology center in order to develop a new product, whose technology and knowledge it does not master or is not readily available. However, the outcome of this interaction is known *ex ante* by the industry; this outcome could be a product developed with the technology provided by the partner. This research partner (university or technological center) plays the role of an R&D department for a given time period. Bearing this in mind, this type of interaction can be considered to be the first one in the attempt to bridge the knowledge gap between industries and universities;

v. *research-oriented:* this type of interaction is the most complex one, since all participants must be active in scientific and technological research. First, it implies bi-directional flows of knowledge and information between universities and industries. The absorptive capability of participants must be high so that they can acquire, appropriate, transform and explore the knowledge they have access to. The main assumption about this type of interaction is that it occurs in the long run, and that results might not yield benefits in the short run. An example is joint research ventures aimed at innovation. In this interaction, the industry's R&D activity is transiently replaced because of a specific and transitory deficiency, being supplied by its interaction with the university or research center. The outcomes obtained from this type of interaction allow for the industry's competitive upgrading, shifting it away from the mere performance of operating routines, as shown on the previous interaction models (except for the development-oriented interaction which, as mentioned earlier, represents the first step of the industry towards gaining competitive edge). Unfortunately, this interaction model is often restricted to few sectors, which are on the state of the art of their specific knowledge. In the Brazilian context, this interaction model is seen in the agri-food sector, as highlighted by Zawislak and Dalmarco (2011), in which EMBRAPA (Brazilian Agricultural Research Corporation) plays an essential role. This type of interaction is therefore desirable in the U-I interaction context.

In order to check whether the proposed typology reflects the characteristics of the types of interaction between universities and industries in a given context, and to identify whether the development-oriented and research-oriented types actually reflect the features of sectors with the narrowest knowledge gap between the actors, a database used to investigate university-industry interactions was employed. Brazil, a Latin American country with so many idiosyncrasies and that differs from developed countries with respect to the investigated issue, was then chosen.

It was verified that the Brazilian NSI can be regarded as complete, but it is poorly dynamic and interactive, widening the knowledge gap between universities and industries. Hence, the pattern of interaction between universities and industries in Brazil is restricted to "points of interaction" or "spots of interaction," in which instances of success are disperse and localized, with conspicuous inequalities in technological, scientific, and innovative activities at the regional level (ALBUQUERQUE, 2003; RAPINI, 2007; SUZIGAN; ALBUQUERQUE, 2011). Among the reasons for and benefits of U-I interaction, demonstrated by research groups and industries in Brazil, the following are noteworthy: human resources training (SEGATTO-MENDES; SBRAGIA, 2002; RAPINI et al., 2009), testing and use of existing resources by universities and research institutes (FERNANDES et al., 2010), procurement of research funding sources (SHIMA; SCATOLIN, 2011), access to new technologies, knowledge, and ideas (SHIMA; SCATOLIN, 2011; PORTO et al., 2011) and technology transfer to innovation activities (FERNANDES et al., 2010). Rapini (2007) complements this finding by saying that interactions in developing countries are restricted to consultancy work and to routine services, thus limiting high-level research activities as well as joint experimental development.

Finally, in line with these strands of literature, Dalmarco (2012) points out that, in Brazil, the interactions between universities and industries are basically targeted at solving technical problems, whereas research activities aim to meet industries' needs. In addition, most industries that interact with universities belong with the agriculture and livestock sectors, which can be explained by the technological standard of the Brazilian agribusiness, generating competitive edge for the sector and allowing them to outplay their international competitors (ZAWISLAK; DALMARCO, 2011). Thus, while low-tech sectors are trying to interact with scientific research, the high-tech ones are characterized by an informal relationship with universities.

4 METHOD

The present study has a descriptive design and explores quantitative data provided by a secondary source of information. The analyzed data were obtained from the 2010 Census, conducted every two years, available from the CNPq Research Group Directory. These are the most recent census data available at the time the analysis was performed.

The information was specifically retrieved from the 2010 Census table model, accessed online. The table model allows assessing the research scenario in Brazil, and comprises seven units of analysis: groups, lines of research, researchers, students, technical staff, interaction with the production sector and with scientific, technological, and artistic output.

Moreover, a customized database was requested from CNPq's Statistics and Information Service (AEI), as it contains more in-depth information about the interaction of research groups with industries, including, for instance, the location of the industry and the activity it undertakes, based on the Brazilian National Classification of Economic Activities (CNAE). Such request was necessary given the objectives of the study and the analyses proposed in the subsequent section. Had the customized database not been provided, it would not have been possible to perform the analyses.

Regarding the analyses, some procedures were performed to sift through the data and choose those that did matter. First, relationships and interactions with Public Administration were excluded from the database, as well as those interactions with nonprofit organizations, and with natural persons, and kept only those established with corporate entities. Other filtering procedures were employed, which are shown in detail in the discussion of the results and are specific to the objective of each analysis.

Finally, the data available from the database refer to information recorded by research group leaders. In the question about the types of interaction developed with industries, group leaders may list up to three types of relationship established with a given industry. Chart 2 shows the classification of the types of U-I interaction proposed by the CNPq Research Group Directory, following the types of interaction presented earlier.

Chart 2: Types of Interaction

Type of interaction	Types of University-Industry Interaction according to the CNPq Research Group Directory
Training-oriented	Training of research group personnel by the research partner, including on-site courses and training
	Training of research partners by the research group, including on-site courses and training
Diffusion-oriented	Technology transfer from the group to the research partner
	Technology transfer from the research partner to the group
	Development of non-routine software for the research group by the research partner
	Development of software by the group for the research partner
Funding-oriented	Supply, by the group, of input materials for the research partner's activities without any linkage to a specific mutual interest project
	Supply, by the partner, of input materials for the research activities of the group without any linkage to a specific mutual interest project
	Technical consultancy services not covered by any of the previous categories
Development-oriented	Non-routine engineering activities, including development of prototype or pilot plant for the partner
	Non-routine engineering activities, including development/manufacture of equipment for the research group
	Scientific research with possible immediate use of results
Research-oriented	Scientific research without possible immediate use of results

Source: Data compiled by the authors, based on U-I interaction types of the CNPq Research Group Directory.

5 RESULTS AND DISCUSSION

The present section is aimed at introducing and discussing the information collected from the 2010 Census carried out by the CNPq Research Group Directory and from the custom-built database provided by AEI. Firstly, the sample analyzed is described. After that, the knowledge areas of research groups according to the type of interaction proposed are presented. The same is done later in an attempt to relate Brazilian regions, industry size, and sectors of economic activity to the types of interaction proposed in the model. Finally, all analyses seek to draw upon what was presented in the literature review, in order to identify similarities and dissimilarities.

That being said, for the discussion of the results, only those data relative to interactions established with corporate entities were assessed. Additionally, it was decided not to use the interactions classified as *not specified* or as *other predominant types of interactions that did not fall into any of the previous categories*. These methodological choices were based on the fact that these two categories did not fit any type of interaction proposed in the model introduced previously.

Hence, the results refer to 6,792 interactions established with corporate entities. After filtering data from the database, we perceived that these interactions are established by 3,268 firms with different corporate taxpayer identification numbers. Nonetheless, the number of firms with different trade names is even smaller, totaling 2,984. Thus, each firm may have more than one type of interaction with a given research group and also interact with several research groups. Therefore, the density of interactions per firm amounts to approximately 2.27, which is conducive to the idea that interactions are concentrated in industries that are capable of interacting with universities and acquiring knowledge from this interaction. This scenario involves a small number of industries (less than 0.02%), given that the Brazilian Institute of Geography and Statistics (IBGE) estimates that there existed more than 11 million industries and private businesses in Brazil in 2012 (See Table 1).

Table 1: Description of the analyzed sample

Sample	Number of industries
Interactions by corporate entities	6,792
Interactions by corporate entities with different taxpayer identification numbers	3,268
Interactions by corporate entities with different trade names	2,984

Source: Data compiled by the authors, based on CNPq Research Group Directory.

From the knowledge areas that most interact with industries (Table 2), we may infer that the development-oriented interaction predominates in all areas, except for Linguistics, Languages, and Arts, with a total of 21 interactions, being, therefore, of little relevance to the discussion. In the other areas, the diffusion-oriented type is the second most common type of interaction, whereas in Biological Sciences and in Applied Social Sciences, the second most important type of interaction is research-oriented one. In absolute figures, the fields of engineering account for 36.6% of the interactions and Agricultural Sciences for 22.9%. The latter stands out as the area that places Brazil among the higher-ranked countries in the agribusiness scenario, which guarantees it's competitiveness in the international scenario.

Table 2: Types of interaction according to area of knowledge

Areas of knowledge	Training-oriented	Diffusion-oriented	Funding-oriented	Development-oriented	Research-oriented	Total
Agricultural Sciences	123	376	199	637	222	1,557
Applied Social Sciences	58	58	58	104	70	348
Biological Sciences	28	103	79	228	133	571
Exact and Earth Sciences	50	319	138	374	158	1,039
Fields of Engineering	168	564	342	1052	363	2,489
Health Sciences	38	97	135	208	124	602
Human Sciences	17	37	35	58	18	165
Linguistics, Languages and Arts	4	6	5	1	5	21
TOTAL	486	1,560	991	2,662	1,093	6,792

Source: Data compiled by the authors, based on CNPq Research Group Directory.

In Table 3, we show the types of interaction across Brazilian regions, relativizing industry size, thus presenting a quite interesting overview. Of the total interactions per region, the southeastern region contains 3,332 interactions (49.05%), followed by the southern region, with 1,841 interactions (27.1%). The northeast is the third region with the highest number of interactions – 924 (13.6%), followed, respectively, by the midwestern region with 453 interaction (6.67%) and by the northern region, with 242 interactions (3.56%). Of the five types proposed, the development-oriented interaction was the one that prevailed (39%) in all Brazilian regions, followed by the diffusion-oriented one (23%). The third most frequent type of interaction was the research-oriented one (16%), followed by funding-oriented type (15%). Lastly, is the training-oriented type (7%).

The development-oriented type, which represents the overwhelming majority of interactions according to the Census data, is aimed at joint technological development for both participants, and happens initially to bridge a gap detected by one of the participants. A total of 2,662 interactions of this type were observed all over Brazil in the analyzed period, and most of them were established by large industries, even though there is not considerable difference in the number of interactions developed by small and medium-sized industries. The southeastern region accounted for 50% of that total, followed by the southern region (27%), while the remaining 23% is distributed among the other regions.

The second most frequent type of interaction was the diffusion-oriented one, with 1,560 interactions all over Brazil. This interaction aims to obtain readily available solutions, without a high level of knowledge, thus being in line with Dalmarco (2012), who points out that the main objective of such interaction is to solve technical problems. Industries that use this type of interaction are chiefly the small and large ones, but in the southern and southeastern regions (accountable for 74% of the total interactions), it has a higher frequency among small industries, which is perfectly understandable since small industries tend to purchase technologies that are readily available on the market. In other words, there are remarkable differences between the interactions established by the southeastern and southern regions from those established by industries in the midwestern, northeastern, and northern regions.

The research-oriented type, the third most frequent (1,093 interactions), is particularly relevant for the development of technological and scientific knowledge, contributing to industries' long-term innovation strategies and to intellectual knowledge on the university side. As observed in Table 3, this type of interaction is more frequent in large industries, without stark differences between small and medium-sized ones. Nevertheless, the southeastern and southern regions are accountable for 74% of research-oriented interactions in Brazil. The southern region, for example, shows a negligible difference in the number of interactions established by large and small industries: 101 interactions involving large industries and 91 involving small ones, a difference of only 10 interactions. In this region, Rio Grande do Sul is the state with the highest number of interactions: large industries established 39 interactions and small industries established 37 interactions, most of them related to activities in the manufacturing industry.

The funding-oriented type is one of the least frequent, totaling 991 interactions (15%) across Brazil, being more remarkable in the southeastern region (51%), followed by the southern region (27%). This type of interaction has quite peculiar characteristics, though: medium-sized industries (along with large ones in the southeastern and midwestern industries) account for the largest number of interactions, except for the northeastern region, where small industries establish the highest number of such interactions. However, unlike the findings of Arocena and Sutz (2000) and Arza (2010) for Latin America, interactions between Brazilian universities and industries are not restricted to consultancy services, as this type of activity is classified as funding-oriented, the fourth most frequent type of interaction.

Finally, the training-oriented type is the least frequent of all: 486 interactions (7%). Again, the regions with the highest number of interactions are the southeast and south, with 51% and 23%, respectively, in this case. In the southeastern, southern, and midwestern regions, small and large industries are the ones that often develop these interactions, while the other regions do not show remarkable differences between industry sizes. It is important to remember that, in this type of interaction no knowledge is produced, it is just transferred, and participants do not need to have high absorptive capability.

Table 3 demonstrates marked regional inequalities in technology, science, and innovation, as revealed by Albuquerque (2003). Whilst the southern and southeastern regions account for approximately 76% of development-oriented and research-oriented interactions (regarded as the most important for generation of knowledge and development of innovation strategies by industries), the other regions account only for the remaining 24%. On the other hand, when industry size is analyzed, there were no stark differences between large and small industries, a finding that runs counter to that of Cohen, Nelson and Walsh (2002), as those authors state that public research is more relevant to large industries. Consequently, these interactions are the most relevant to the development and generation of technological and scientific knowledge, requiring that the industries involved in the interaction have attained a minimum threshold of internal capabilities so that they can absorb and integrate external knowledge, as underlined by Arza (2010).

By performing a horizontal analysis of the quality of interactions on a per-region basis, the midwestern region stands out, with 59% of development-oriented and research-oriented interactions. The southeast is the second region with better quality interactions (56.4%), followed by the south and northeast (54%). Finally, the northern region, where most interactions are established with the overriding aim of knowledge diffusion rather than knowledge output, accounts for 50.8% of qualified interactions.

This regional analysis is interesting because it demonstrates that, even when a region has a smaller number of interactions, these interactions can be of better quality (as is the case of the midwestern region) comparatively to a region that interacts more, such as the northeast. By looking at the scenario outlined above, it is observed that, albeit moderate, regional rates indicate larger interaction targeted at research for knowledge output, in which industries and universities engage for an indefinite time period, compared to that interaction whose sole purpose is to make use of already existing technologies developed by universities, thereby not contributing to making industries and the region adopt innovation strategies. This scenario can also indicate that industries are giving closer attention to interactive activities that do not only yield immediate productive benefits, but also provide knowledge for laying the foundations for innovation strategies, whereby they will be able to gain competitive edge. Perhaps this hypothesis can be more strongly supported by the large number of research-oriented interactions established by small industries in the southern region: maybe these small industries are starting to recognize the importance of knowledge and innovation for their competitiveness.

Table 3: Types of interaction according to the regions and size of the industries

Region	Training-oriented	Diffusion-oriented	Funding-oriented	Development-oriented	Research-oriented	Total
Midwestern	26	102	59	185	81	453
Up to 19	11	41	15	48	15	130
20 to 49	1	7	9	17	6	40
50 to 99	2	6	5	13	3	29
100 to 499	0	6	9	18	12	45
500 or more	12	42	21	89	45	209
Northeastern	75	238	117	328	166	924
Up to 19	22	74	45	87	47	275
20 to 49	8	28	11	21	17	85
50 to 99	5	21	10	27	9	72
100 to 499	7	29	18	56	27	137
500 or more	33	86	33	137	66	355
Northern	23	65	31	88	35	242
Up to 19	9	22	7	22	14	74
20 to 49	0	1	3	4	0	8
50 to 99	1	1	1	2	0	5
100 to 499	5	8	11	14	4	42
500 or more	8	33	9	46	17	113
Southeastern	250	691	512	1,339	540	3,332
Up to 19	90	272	149	393	155	1,059
20 to 49	23	56	47	136	37	299
50 to 99	14	51	42	83	40	230
100 to 499	28	104	94	227	91	544
500 or more	95	208	180	500	217	1,200
Southern	112	464	272	722	271	1,841
Up to 19	44	165	86	216	91	602
20 to 49	7	46	28	69	16	166
50 to 99	2	31	32	41	24	130
100 to 499	20	70	47	112	39	288
500 or more	39	152	79	284	101	655
TOTAL	**486**	**1,560**	**991**	**2,662**	**1,093**	**6,792**
%	7	23	15	39	16	100

Source: Data compiled by the authors, based on CNPq Research Group Directory.

Based on the assumption that there exist differences across industrial sectors according to the importance science has for each sector (MEYER-KRAHMER; SCHMOCH, 1998), it was sought to investigate how different sectors[1] behave towards U-I interaction. To do that, the classification proposed earlier was adopted, as shown in Table 4.

Previous studies on U-I interaction in Latin America suggest that the predominant relationship in this context is related to a low demand for sophisticated technological knowledge, and when such knowledge is needed, industries seek it in other countries (ARZA, 2010). In view of the data shown in Table 4, the statement does not appear to fit properly into the reality of Brazilian interactions, given that technical consultancy services, whose information often flows in one direction, i.e., from universities to industries, are included primarily in the funding-oriented and diffusion-oriented categories, interactions that are not

[1] Industries were classified according to the sectors outlined in the Brazilian National Classification of Economic Activities (CNAE), which is also used by CNPQ Research Group Directory.

predominant in the analyzed sectors. These data are not supported by Rapini (2007) either, who suggests that interactions in developing countries are limited to consultancy and routine services, restraining high-level research and to joint experimental development. In this respect, the differences from the classification described in previous studies indicate that the proposed typology may then be the most suitable to assess university-industry interactions, showing that development-oriented and research-oriented types tend to bridge the knowledge gap between these actors. On the other hand, a strong development-oriented interaction is observed in Brazil, which tends to solve direct problems at the industry level and to carry out short-term research, suggesting that the industry's R&D department could be replaced by a research institute. This is supported in the literature, in which universities are seen as technical problem solvers, whose research activities meet the needs of industries (DALMARCO, 2012).

By comparing the data with those obtained for higher-ranked sectors, we noticed that five macrosectors account for approximately 70% of the interactions with universities, namely: manufacturing industry (42.7%), professional, scientific, and technical activities (8.6%), electricity and gas (7.7%), extraction industries (5,8%), and agriculture, livestock, forestry and aquaculture (4.8%). Besides, there are two sectors which do not interact with universities (international organizations and other extraterritorial institutions, and household services), and sectors with rare interactions, such as arts, culture, sports and leisure, real estate, and other services. In addition, the active pharmaceutical ingredients and pharmaceuticals sector had the largest number of interactions per industry, with 2.46 interactions per CNPJ (corporate taxpayer identification number), followed by the chemicals sector, with 2 interactions per CNPJ. Both sectors belong to the manufacturing industry, whereas those industries from the agriculture, livestock, forestry and aquaculture sectors exhibited 1.97 interactions per CNPJ. Moreover, in the manufacturing industry, medium-high-tech industrial sectors (e.g., manufacture of chemicals) and high-tech sectors (e.g., active pharmaceutical ingredients and pharmaceuticals) have a considerable number of development-oriented and research-oriented interactions, which is in line with the sector characteristics described by the OECD (2011). However, this conclusion contrasts with the findings of Zawislak and Dalmarco (2011), who conclude that the interactions of these sectors in Brazil would be informal.

In the same group of manufacturing industries, attention should be paid to the manufacture of food products, a sector that belongs with low-tech industries, thus partially confirming the results of previous studies that suggest that low-tech industries are the ones that interact more often with universities in Brazil, on account of the technological standard of Brazilian agribusiness (ZAWISLAK; DALMARCO, 2011). Nevertheless, while the sector is regarded as low-tech, development-oriented interaction prevails (37%), followed by diffusion-oriented interactions (22%). Diffusion-oriented interaction is characteristic of low-tech sectors, in which a larger number of solutions are available (e.g., patents). Conversely, owing to the highest rate of development-oriented interactions, a change in sector characteristics is likely underway because of the closer interaction with universities prompted by research, which requires a more active participation of industries.

Interestingly, in the information and communications sector, diffusion-oriented interaction turned out to be the most frequent (44%), followed by the development-oriented (25%) and research-oriented (15%) types. The characteristics of this sector concerning university-industry interactions contrast with those observed for all other sectors, as development-oriented interaction was the most frequent in all cases, followed by the diffusion-oriented one. This finding raises some questions: what are the characteristics of this sector that make it different from the other sectors in terms of university-industry interactions? What is the technological standard of this sector in Brazil and in other countries?

Also, short-term interactions, which are more frequent in Latin America, can also be observed in Brazil, with predominance of short-term joint development relationships represented by the development-oriented interaction, despite the fact that this type of interaction already represents some upgrade compared to the other types. From a different perspective, however, research-oriented interaction, desirable in the U-I interaction context, which is characterized by scientific output towards the frontier of knowledge, occupies the third position. Since this was not a longitudinal study, it is not possible to conclude that some progress has been made towards a more complex type of interaction. Interestingly enough, less complex interactions, such as the training-oriented and funding-oriented types, show less absolute importance than the development-oriented and research-oriented types, which are linked to a higher standard of technological development, as suggested by the classifications.

Finally, it is inferred that the results obtained from the analyses do not corroborate the reasons and benefits evidenced by the literature regarding U-I interaction in Brazil. According to the reviewed literature, interactions between universities and industries are linked to human resources training (SEGATTO-MENDES; SBRAGIA, 2002; RAPINI et al., 2009), testing and use of existing resources by universities and research institutes (FERNANDES et al., 2010), and to the procurement of research funding sources (SHIMA; SCATOLIN, 2011); nonetheless, the data reveal that training-oriented and funding-oriented interactions are the least frequent and, therefore, the literature data could be questioned. On the other hand, development-oriented and research-oriented interactions, characterized by access to new technologies, knowledge, and information (SHIMA; SCATOLIN, 2011; PORTO et al., 2011) and technology transfer to innovation activities (FERNANDES et al., 2010) account for 55.3% of all interactions, raising the possibility of a change in the U-I interaction pattern in terms of the type of relationship, but not disregarding the existence of “points of interaction” or “spots of interaction” (RAPINI, 2007; SUZIGAN; ALBUQUERQUE, 2011).

Table 4: Types of interaction according to the sectors of economic activities

Brazilian National Classification of Economic Activities (CNAE)	Training-oriented	Diffusion-oriented	Funding-oriented	Development-oriented	Research-oriented	Total
Agriculture, Livestock , Forestry, Fishing, and Aquaculture	34	94	32	115	49	324
Arts, Culture, Sports, and Leisure	4	0	0	1	1	6
Construction	17	23	23	44	17	124
Education	7	3	7	25	18	60
Electricity and Gas	29	143	27	253	70	522
Extraction Industries	14	35	24	49	32	154
Financing, Insurance, and Related Services	14	37	24	54	20	149
Household Services	0	0	0	0	0	0
Housing and Food	1	5	4	9	3	22
Human Health and Social Services	29	32	32	54	39	186
Information and Communications	29	175	31	100	59	394
International Organizations and Other Extraterritorial Institutions	0	0	0	0	0	0
Management Activities and Additional Services	2	5	6	7	2	22
Manufacture of Active Pharmaceutical Ingredients and Pharmaceuticals	4	51	39	108	44	246
Manufacture of Chemicals	17	91	73	199	84	464
Manufacture of Food Products	29	94	68	155	75	421
Manufacturing Industry	152	590	470	1,225	463	2,900
Other Services	1	3	3	3	4	14
Professional, Scientific, and Technical Activities	34	109	80	231	127	581
Public Administration, Safety and Social Security	3	4	3	9	7	26
Real Estate	0	2	3	2	2	9
Trade; Repair of Motor Vehicles and Motorcycles	12	34	15	46	17	124
Transportation, Storage, and Post Office Services	12	18	15	45	10	100
Water, Sewage, Waste Management Activities, and Decontamination	13	32	16	47	15	123
Not specified	79	216	176	343	138	952
TOTAL	486	1,560	991	2,662	1,093	6,792

Source: Data compiled by the authors, based on CNPq Research Group Directory.

6 FINAL REMARKS

The present paper aimed to assess the types of interactions that reduce or fill the gaps between universities and industries. So, a new typology was proposed to contemplate several common elements described in the literature that could be adopted to characterize and bridge the knowledge gap between universities and industries and meet their needs, taking into account the limitations of the other typologies reviewed herein. The main variables used for the classification were the following: duration of agreements, direction of information flow, the level of knowledge of universities and industries, the degree of formality and complexity of the interaction, and the absorptive capability of both actors. These variables set the tone for the proposed classification of the five types of interaction.

That being said, the new classification approach was introduced, according to which interactions were categorized into: *training-oriented (1), diffusion-oriented (2), funding-oriented (3), development-oriented (4)* and *research-oriented (5).* In this regard, the first three types of interaction proposed consist, respectively, of the interchange of people between universities and industries (1), the technological knowledge in the public domain and the currently available solutions that can be transferred between the actors (2), and the technical consultancy activities and use of the partner’s available infrastructure, which constitutes a typically commercial relationship (3). The other two types refer to joint technological development activities (4) and to interactions targeted at long-term research (5). It may then be concluded that only types 4 and 5 differ from the others, and this difference lies in the quality of interaction and in the possibility of competitive upgrade of the industries engaged in these interactions, which can be considered to be the ones that reduce the knowledge gap between universities and industries and that meet their needs.

Some significant conclusions could be drawn for Brazil, country to which the typology was applied. First, firms were found to have 6,792 interactions with universities, but these interactions were restricted to 2,984 firms, which accounts for less than 0.02% of private industries in Brazil. Second, regarding the classification of interactions proposed in this study, the development-oriented type was the most frequent (39%) in all Brazilian regions, followed by the diffusion-oriented type (23%). The research-oriented type comes in the third position, accounting for 16% of the interactions, followed by the funding-oriented type (15%), and lastly by the training-oriented type (7%). This scenario indicates that industries have given more attention to interactive activities that provide not only immediate production benefits, but also knowledge to build the foundations for innovation strategies, enabling them to gain competitive edge. Perhaps, this hypothesis could be strongly supported by the large number of development-oriented and research-oriented interactions, to the detriment of training-oriented and funding-oriented interactions, which include the main reasons and benefits of U-I interaction in Brazil, as corroborated by the literature. It might then be inferred that interactions between universities and industries have sought more qualification and a joint higher technological development, bringing about a change in the interaction pattern regarding the types of relationships. However, these conclusions and reflections do not disregard the existence of “points of interaction” or “spots of interaction” in Brazil, as the analyzed interactions still occur at the regional and sectoral levels.

As a suggestion for future studies, the proposed typology could be applied to other contexts, allowing the validity of the model to be tested, regardless of national discrepancies. This suggestion arose from the limitations of this study, that is, from the fact that a country-specific database was utilized.

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