

Benefits, results and barriers to interaction to industry: the perspective of academic research groups

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Abstract

The main aim of this paper is to analyse how individual perceptions of academic researchers about the benefits, results and barriers affect their interactions with firms. University has become a growing important source of knowledge for innovation and firms are trying to get closer to the university in order to appropriate of the knowledge generated by academic research. To evaluate the effect of the benefits, results and barriers, a comprehensive database from a survey to Brazilian research groups' leaders was used. Non-parametric IRT (Item Response Theory) technique was applied and clusters of responses were formed to each dimension. Then, these clusters were used to build an econometric model to evaluate the importance of the dimensions. Main findings show that intellectual benefits and academic results are important drivers to research groups to collaborate with industry and transactional barriers represent important obstacles to academic research groups to interact more with firms. These findings allow a better understanding of the main motivations and constrains faced by research groups in the collaboration with firms.

Key-words: university-industry linkages; knowledge and innovation; university; academic collaboration

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Introduction

Academic research plays an important role for the firms' innovation. It's widely accepted in the literature that university is a very important source of new scientific and technological knowledge and university-industry linkages are a vital channel for this collaboration. There is a growing literature that evaluates the main factors that affect university-industry interactions. Some of them, focused on the impact of interactions for innovation and the role of academic research (Klevatorick et al., 1995; Nelson, 1996; Cohen et al., 2002). Other studies have analysed the main factors that affect interactions and how individuals evaluate such relations and their potential benefits, results and barriers (Arza and Vasquez, 2010; D'Este and Perkmann, 2011; Tartari and Breschi, 2012; Tartari et al., 2012).

It must be recognised that university and industry operate within different institutional environment, with some important potentially conflicting norms and incentives (Dasgupta and David, 1994; Tartari et al., 2012). Academic researchers seek to generate new knowledge and publish their results in high-impact journals; scientists and engineers in firms are concerned to produce applied knowledge in valuable products and manufacturing processes. In this way, an important question that emerges from this problem is what drives research groups to interact to industrial partners.

Based on these assumptions, this paper aims to investigate how individual perceptions of academic researchers about the benefits, results and barriers affect their interactions with firms. To do that, it was used original and comprehensive data from a survey with academic research groups that have linkages with firms in Brazil. Data were organized by using nonparametric IRT (Item Response Theory) technique, which allows the formation of non-arbitrary clusters based on the pattern of responses of the questionnaire. By using these clusters, an estimated model that evaluates how benefits, results and barriers affect collaborations with industry was built.

Despite the recent growth of the literature about university-industry linkages, there are some missing points in the studies, such as how university initiate, build and maintain interactions with firms. The motivation to engage to collaborate with industry and the role of the main outcomes from the linkages are questions that must receive deeper analysis (Perkmann et al., 2013). In this way, this paper adds new contribution on the understanding of the main motivations and constrains faced by research groups in the collaboration with firm, by analysing the role of the benefits and results of the interactions with firms and the effect of the main barriers to establish collaboration. The analysis of the paper is based on the individual responses of the Brazilian research groups that interact with firms, which allow the understanding of their perceptions on the main factors that stimulate and constrain the collaboration with firms.

The paper is organised into 5 sections, in addition to this introduction. The first section presents the main conceptual remarks from the debate on university-industry linkages and the effects of the benefits, results and barriers for the interactions. Section two presents a brief description of data and section three presents the application of the nonparametric IRT methodology for the responses of the questionnaire. Section four presents the empirical model and discusses the effects of the benefits, results and barriers. Finally, section five brings final remarks and some policy implications.

1. Theoretical remarks on the effects of the benefits, results and barriers to university collaborate industry

Innovation is far from an isolated process within firms. Several studies have showed the importance of external agents that strengthen firms' in-house R&D expenditures, such as users, suppliers, and university. The increasing complexity of knowledge required for innovation forced firms to become closer to these external sources (Nelson, 1996; Mowery et al., 2004). Academic research, and the university, has become a growing important source of knowledge both for firms and for the whole society (Rosenberg and Nelson, 1994). Several authors, such as Klevorick et al. (1995) and Cohen et al. (2002), have showed that university has assumed an increasingly important role in fostering innovation in firms¹.

Besides this positive evaluation of the collaboration between universities and firms for the sharing of scientific knowledge, there are some serious concerns about some possible damages to the principles of open science (Merton, 1973). The market-orientation of university research, towards firms' innovative problem, may imply fewer publications, as well as changes in the research agenda of the university. Orientation problems can also emerge, since firms' innovative projects are usually linked to short-term problems driven by their operational needs (Tartari et al., 2012). It has long been recognized that there are different nature of the goals accepted as legitimate within the community of academic researchers and the community of firms R&D staff. The community of academic researchers is concerned with additions to the stock of public knowledge, whereas the community of firms' researchers is concerned with adding to the stream of rents that may be derived from possession of the rights to use private knowledge. However, in order to ensure a reasonably societal efficient allocation of resources in the production of new knowledge, society needs to have both communities firmly in place, and attend to maintaining a synergetic equilibrium between them (Dasgupta and David, 1994).

Based on this concern, there is a growing interest on the evaluation of the effects of the engagement of academic researchers with firms on the activities of the university (D'Este and Patel, 2007; Arza, 2010; Bishop et al., 2011; D'Este and Perkmann, 2011; Tartari et al., 2012; Perkmann et al., 2013; Tartari et al., 2014). Several studies have investigated the effect of the individual evaluation of the scientists of the expected benefits and costs on their collaboration with firms (Owen-Smith and Powell, 2001; Tartari and Breschi; 2012).

Regarding benefits, the engagement of academic researchers with industry can bring some important benefits. Many researchers engage with industry mainly to support their research activities. Collaboration with industry is mainly dominated by research-related motivations, including learning from industry and fund raising for research projects (D'Este and Perkmann, 2011). Relationships with firms are willing to approach academic researchers to industrial partners, since the interaction involves close collaboration among them. Close collaboration facilitates interactive learning which in turn indirectly benefits scientific production by generating new ideas and motivating new research projects, even with it maintains the distinct logic of both university and industry (Perkmann and Walsh, 2009). Intellectual benefits such as improved access to industrial partnerships and the possibility of working together with industrial researchers can provide to scientists the possibility to knowledge sharing, which can stimulate the development of new collaborative research projects (Garrett-Jones et al., 2010).

Two main benefits for universities from their interactions with firms are usually pointed out. First, intellectual benefits can emerge from joint research projects between university and

¹ The importance of the university has been supported by studies based on the analysis of the National Innovation Systems, which emphasise the role of the university as an important player in the national innovation system because they can affect the creation, development and diffusion of innovations (Nelson, 1996; Mowery et al., 2004; Mowery and Sampat, 2005).

firms with industrial applications and knowledge sharing, since linkages with firms may inspire new academic research projects and provide new insights for the research agenda (Meyer-Kramer and Schmoch, 1998; Arza, 2010). These benefits are particularly important in those scientific fields in which academic research and industrial application can advance simultaneously, in so-called "Pasteur Quadrant" (Stokes, 1997). Intellectual benefits are one of the most important motivations for researchers to collaborate with firms; even with sometimes commercial channels of interactions, such as spin-off, licensing and patenting, can reduce intellectual benefits (Arza and Vazquez, 2010).

The second main benefit are economic benefits, which are those benefits related to the achievement of extra funding to finance academic research (Arza, 2010) or involves the sharing of equipment, material or human resources (Tartari and Breschi, 2012). The access to financial and nonfinancial resources is other important factor encouraging academic researchers to increase their collaboration with firms. Moreover, the effect of getting access to financial and nonfinancial resources increases if the research group is collaborating to industrial partners (Tartari and Breschi, 2012).

Regarding results of the university-industry linkages, collaboration between university and industry can often generate important commercial results, since it can bring opportunities to develop, or co-develop, inventions that can be patented, licensed or it can generate opportunities for academic entrepreneurship, such as spin-offs (Perkmann et al., 2013).

Other important results from the collaboration with industry are the academic results. When academic researchers work together with industry on joint projects, the interaction with firm can usually provide new scientific discoveries. Joint research projects with industrial partners often results in academic publications, even with this is less true for different types of relationship, such as research contract and consulting, which consists in relationships with more applied purposes (Perkmann and Walsh, 2009). It is important to point out the importance of the academic results for the interactive research groups, especially when firms interact with high performance research groups. One of the main motivations of the research group on their interactions with firms is that they expect that there is also some academic result to be derived from the linkage, especially those relates to new scientific challenges (Perkmann et al., 2013).

Furthermore, it is important to mention that there are important barriers that affect the decision of researchers to interact with industry. Some of them are orientation (or mertonian) barriers, since they are related to the main motivations and concerns of academic researchers. One of the main characteristics of the community of scientific researchers is the possibility of chasing research freely and according to personal curiosity (Merton, 1973). For academic researchers, engagement with industry can pose potential dilemmas related to the different institutional logic prevailing in university and industry. One of them is the secrecy problem, which refers to the extent to which interaction with firms could be related to restrictions on the disclosures of research findings and on the diffusion of research results, with hazards to norms of open science (Tartari et al., 2012). In order to secure commercial appropriation of research results, academics might be require to delay, or even to forego, the publication of the results (Perkmann and Walsh, 2009; Brunell et al, 2010; Tartari and Breschi, 2012). In this way, academic freedom may be hampering if researchers are encourage to produce research results with commercial purposes and to move away from basic research (Mowery et al., 2004).

The loos of academic freedom and concerns related to the secrecy of the achieved results and restrictions for diffusion are factors that can hamper the collaboration between academic researchers and firms (Tartari and Bresch, 2012; Tartari et al., 2012). However, Tartari and Breschi (2012) had shown that the propensity to collaborate with industry partners is not significantly affected by the potential increase in secrecy or by publication delays. In this way,

problems related to secrecy or the diffusion of achieved results could not influence the decision to collaborate with industry.

Other important factor that can hamper university-industry linkages is the complementarity problem, related to the lack of complementarity between industry-related activities and academic research. Academic researchers might be hindered in their publication purposes by the fact that their projects with industry are neither novel nor sufficiently academically innovative to warrant publication in academic journals (Perkmann and Walsh, 2009; Tartari et al., 2012). Skewing problems could also arise from the collaboration with industry, since interaction could impose constraints on academic researchers' autonomy to establish their own research agenda (Tartari et al., 2012).

Other set of barriers for the collaboration with industry are transactional (or Williamson) barriers, related to factors that can create noteworthy transactional costs to collaboration to industry. Transactional costs often require academic researchers the development of new contractual relationships with their industry partners and the deal with university's technology transfer offices (TTO) and legal department (Tartari et al., 2012). The bureaucracy at the university should also discourage collaboration with firms (Audrestch et al., 2002). Even with the university senior management is committed to collaboration with the industry, operational levels may exacerbate the risk of interactions with firms and can create barriers to the collaborative contracts.

Some of the transaction barriers are related to capabilities barriers, since the lack of skills among university staff, especially in TTO, may hamper the engagement of academic researchers in university-industry joint projects (Owen-Smith and Powell, 2001; Tartari et al., 2012). At the university side, underfunded or understaffed TTO can produce long delays, awkward schedules, lax reporting and negligible responsiveness to the concerns of academic researchers in the collaboration process. At the industry side, the lack of skilled R&D and engineering staff may hinder linkages to academic researchers.

Besides the perceptions of individuals on the effects of the collaboration to industry, there are some characteristics of the research groups that can be driving factors of the interaction between university and firms. One of these factors is the quality of academic research performed by the research groups (Tornquist and Kallsen, 1994; Abramovsky et al., 2007; Mansfield and Lee, 1996; D'Este and Iammarino, 2010; Bishop et al., 2011; Laursen et al., 2011). The main argument is that higher performance universities, which accomplish high quality academic research, are generally more able to transfer knowledge from the university to firms because they are able to generate new knowledge with industrial applications (Tornquist and Kallsen, 1994). Academic excellence encourages cooperation, especially when technological problems of firms are closer to the state-of-the-art of scientific knowledge (Mansfield and Lee, 1996).

Other important factor is the size of the university department, since larger departments tend to be more able to interaction with industry (Mansfield and Lee, 1996; Scharfetter et al., 2001; D'Este and Patel, 2007; Perkmann et al., 2011). Scharfetter et al. (2001) pointed out that larger departments tend to have wider human, physical and financial resources for academic research and a greater stock of in-depth scientific capabilities and skills for interaction. An additional factor that affects university-industry linkages is the size of research teams, since research group with more technicians and researchers certainly has more accumulated capabilities, which arises from both previous research projects and the experience of interactions with firms (De Fuentes and Dutrénit, 2012).

The research group's scientific field also has an impact on its interactions with industry (Meyer-Krahmer and Schmoch, 1998; Bekker and Bodas-Freitas, 2008). Metcalfe (2003) reported that the nature of scientific fields and the manner of the accumulation of knowledge

varied across disciplines. For example, he found that engineering and applied technologies were disciplines that depend more on "trial and error" accumulation in practical contexts and are focused on problem solving. Therefore, research groups in these disciplines tend to interact with firms more often than groups in other basic sciences. Schartinger et al. (2001) also showed that research groups from applied technology fields interact with industry more than in other disciplines. Stokes' (1997) Quadrant of Pasteur also corroborates this argument because it shows the existence of differences in the application of knowledge among various scientific fields, which result in different patterns of interaction with firms and society.

University-industry linkages has been a growing subject of interest in Brazil (Suzigan et al., 2009; Rapini et al., 2009; Fernandes et al., 2010; Suzigan and Albuquerque, 2011; Chaves et al., 2012). In Brazil, universities have been exerting a greater role in fostering innovation in several industries, with notable impacts on the share of several Brazilian firms in international markets (Suzigan and Albuquerque, 2011). However, the role of university is particularly important to medium and medium-low technology industries, mainly because R&D expenditures of Brazilian firms are quite low, especially in high-tech industries (Albuquerque, 2007; Suzigan et al., 2009). Moreover, in Brazil academic research often acts as a substitute for firms' R&D expenditures, and sometimes that it also plays a complementary role to in-house R&D (Rapini et al., 2009). Regarding the profiles of firms that interacted with Brazilian universities, domestic firms with high shares of production in their industries engaged in more linkages than did foreign firms (Chaves et al., 2012).

Based on the recognised importance of university-industry linkages, this paper aims to analyse how perceptions of academic researchers about the benefits, results and barriers affect their interactions with firms. Original and comprehensive data from a survey with academic research groups that have interactions with firms in Brazil was used.

2. Data description

In order to exam how perceptions of academic research groups on benefits, results and barriers affect their interactions with firms, data from a survey with Brazilian research groups that interact with firms was used. Data was collected in spring 2008 from a questionnaire to the research groups' leaders from every knowledge fields and from the whole country, which had reported interactions with firms in the 2004 Census Directory of Research Groups of CNPq². The questionnaires were sent as electronic surveys to 2,151 research groups' leaders, and 1,005 valid responses were received.

The information collected by the questionnaire comprises the main characteristics of the research group, such as the numbers of interactions of the research groups, the quantities of researchers and technicians in the groups and their scientific fields; it also covered various aspects related to the interactions between research groups and firms, such as types of relationships, information channels and the perceptions of the research group leader using a Likert-scale, about benefits, results and barriers of their interactions with firms.

Besides main aspects related to the characteristics of research groups and their perception about their interactions, other factors were considered such as the quality of academic research, the size of the research group and the department to which it belongs.

² CNPq is the Brazilian Council for Scientific and Technological Development, which is an institution of the Brazilian Ministry of Science and Technology that is dedicated to the promotion and support of scientific and technological research.

To measure the quality of academic research, the grades the Brazilian governmental agency assigned to the postgraduate programs of the research groups were used³. Postgraduate programs and their research groups that produced higher-quality research, had greater impacts, and displayed better academic performances received higher grades than did groups associated with lower performance. The grade scale ranged from 1 to 7, and the grades 6 and 7 are assigned to centres that demonstrate worldwide excellence in a certain scientific field. In this study, the grades from the period of 2004-2006 were used. The program's postgraduate grade was the indicator chosen because it is comprehensive and comparable and it has been used to measure the quality of academic research in several studies on this topic (Abramovsky et al., 2007; D'Este and Iammarino, 2010; Laursen et al., 2011)⁴.

The size of the departments to which the research groups are linked was also evaluated. Some studies, such as Perkmann et al. (2011), have indicated that the size of the department affects the number of interactions a research group has with firms. To measure the sizes of departments, the number of full-time PhD researchers in the department was used⁵. Finally, the sizes of the research groups were obtained directly from surveys of the universities and were measured by the number of their members.

The final sample consisted of 612 complete observations of academic research groups. These research groups belong to 79 universities throughout Brazil, and they participated in all scientific fields. Together, they develop 2,771 interactions with firms from various industries.

Regarding to the evaluation of the research groups about the dimensions benefits, results and barriers of the interactions of firms, data was collected by using a Likert-scale according to its importance: unimportant, slightly, moderately or very important. The dimensions benefits and results could not be clearly separate. In this way, it is worthy to note that benefits can be achieved independently of the results, since an interaction can produce poor results but can benefit the research group, for example by labor training, by strength knowledge networks or by new ideas for research projects. In accordance to the questionnaire, it is assumed that results are related to the main aims of interactions, such as thesis, publications, new research projects and scientific discoveries. On the other hand, benefits are linked to the interaction and the gains related with it, such as additional funding for research, access to lab equipment and new ideas for research projects.

3. Nonparametric IRT

In order to assess how perceptions of the academic research about benefits, results and barriers affect their interactions with firms, scales from the pattern of responses were identified in order to define each of these three analyzed dimensions.

³ The grade is assigned by the Coordination for the Improvement of Higher Education Personnel (CAPES - Coordenação de Aperfeiçoamento de Pessoal de Nível Superior), which is an institution of the Brazilian Ministry of Education that is dedicated to regulating higher education in Brazil. Similar to several other countries, the evaluation is based on two main factors: the impact of the academic research as measured by publications in high impact journals and the training of young researchers.

⁴ Nevertheless, it is important to note that the use of this indicator applies only to research groups that are linked to postgraduate programs.

⁵ The data were obtained from *GeoCAPES*, the statistical geo-referenced database from CAPES for 2007. The size of the department was defined as the total number of researchers in departments associated with postgraduate programs of the same Higher Education Institution (HEI) in a CAPES Assessment Area. Interdisciplinary programs were excluded because it would have been impossible to associate them with specific scientific fields. HEIs were also used for specific units and university campuses that had separate departments and at least one postgraduate program.

The main aim of this procedure is to reduce the amount of items for each dimension, which helps to avoid multicollinearity problems at the econometric model. It also allows the estimated model to consider more adequately parameters and to provide appropriate estimation for the interpretation of the coefficients. To do that, a nonparametric Item Response Theory (IRT) technique was used. This technique allows the identification of scales (cluster of items) from the pattern of responses that an individual produces through questionnaires, by generating *ex post* clusters, which avoid arbitrariness in the selection of groups of variables⁶.

The application of nonparametric IRT to data on the dimensions of benefits, results and barriers allows the selection of groups of items that form a coherent scale, since the clustered items show adequate level of scalability (H-index), with a significance level of 5%⁷. The results for each dimension are presented in Tables 1-3, which show the clustered items and its H-index. Tables also show the number of respondents and the share of answers "moderately important" and "very important" for each category.

Application of IRT for the items of the dimension of benefits allows the identification of two clusters (Table 1). First group are the **intellectual benefits**, which includes academic and tacit benefits such as reputation and networks. The second group comprises the **economic benefits**, by aggregating items related to material or financial obtained from interaction with firms. The importance of intellectual benefits, measured by the share of answers "important", is higher than economic benefits, which can indicate that research groups tend to realize as more important the intellectual benefits arising from the interaction.

Table 1 – IRT to the dimension "benefits"

Cluster	Item	Moderately important	Very important	Total	%
Intellectual Benefits	Ideas to new collaborative projects	175	327	502	82.0
	New ideas to research projects	138	398	536	87.6
	Interchange of information or knowledge	171	333	504	82.4
	New network relationships	157	283	440	71.9
	Reputation	159	271	430	70.3
Economic Benefits	Joint use of equipment labs	171	161	332	54.2
	Supply of inputs for research	169	260	429	70.1
	Financial resources	128	302	430	70.3

Source: own elaboration.

Clustered items for the dimension results (Table 2) show that two clusters are related to academic purposes, **knowledge results** and **academic results**⁸. The third cluster is the **commercial results**, which comprises items linked to industrial applications of the results of

⁶ In the nonparametric IRT analysis, 'mokken' package from R statistical software was used. Other techniques such as Cluster Analysis and Structural Equation Modeling (SEM) could also be used. However, these techniques present some problems, for example, when there is a non-linear relation between the items. The non-linearity of the data, even with the use of appropriate correlations measures, can result in a mismatch between the model and the data (Ackerman et al., 2003).

⁷ Result for the scaling index is also showed in Tables 1-3. The H index is considered strong if it is ≥ 0.5 , with the lower limit on 0.3 (Mokken, 1971). Results show that all indexes were higher than the lower limit and most of the items presents H-index higher than 0.5. So, no items were discarded.

⁸ The application of IRT to the scale academic results considers the inclusion of "software" as an academic result.

academic research. It is possible to note that results linked to knowledge and to academic activities were considered more important by the research groups, which may indicate a steepening of the researchers to the intellectual results of the interactions with firms.

Table 2 – IRT to the dimension “results”

Cluster	Item	Moderately important	Very important	Total	%
Knowledge Results	New scientific discoveries	142	233	375	61.3
	New research projects	168	354	522	85.3
Academic Results	Training	111	411	522	85.3
	Theses e dissertations	112	413	525	85.8
	Publications	140	361	501	81.9
	Software	84	103	187	30.6
Commercial Results	New products and devices	137	220	357	58.3
	New manufacturing process	127	148	275	44.9
	Improvement in products	112	181	293	47.9
	Improvement in manufacturing process	110	188	298	48.7
	Patents	95	173	268	43.8
	Design	72	52	124	20.3
	Academic entrepreneurship and <i>spin-offs</i>	83	70	153	25.0

Source: own elaboration.

Finally, in the dimension barriers, three clustered items were found (Table 3). **Capabilities barriers** involves difficulties of research groups and firms linked to the lack of professionals, and capabilities, that can bridge the interest of both firms and university. **Orientation barriers** encompass differences in priorities and deadlines between firms and university, in the same line with the different orientation pointed out by Merton (1973). The third cluster is **transactional barriers**, which comprises a set of factors regarding the formalization and the legitimation of the interaction between firms and university, what Tartari et al. (2012) called “williamson barriers”.

Table 3 – IRT to the dimension “barriers”

Cluster	Item	Moderately important	Very important	Total	%
Capabilities Barriers	Lack of knowledge about universities’ activities	165	207	372	60.8
	Lack of knowledge on the needs of firms	182	182	364	59.5
	Lack of professionals to dialogue with academic researchers	141	153	294	48.0
	Lack of professionals to dialogue with firms	177	144	321	52.5
	Problems on trust	112	166	278	45.4
Orientation Barriers	Differences on priorities	177	171	348	56.9
	Differences on research deadlines	159	85	244	39.9
Transactional Barriers	Bureaucracy in the firm	180	107	287	46.9
	Bureaucracy in the university	193	282	475	77.6
	Costs	197	191	388	63.4
	Intellectual Property Rights	139	112	251	41.0
	Geographical Distance	123	49	172	28.1

Source: own elaboration.

The definition of the main clusters for each of the dimensions that affect collaboration of research groups with firms allows a comparison to the literature about the benefits, results and barriers for university-industry linkages (Table 4). As could be seen, there are many authors that analyse the main dimensions that affect the decision of academic researchers to collaborate with industry.

Table 4 - Theoretical background and the IRT clusters

Intellectual Benefits	Intellectual Benefits (Arza & Vasquez, 2010) Resources (Tartari & Breschi, 2012) Learning (D'este & Perkmann, 2011) References for public project and knowledge Exchange (Meyer-Krahmer & Schmoch, 1998)
Economic Benefits	Access to in-kind resources and funding (D'este & Perkmann, 2011) Resources (Tartari & Breschi, 2012) Additional facilities and Additional funds, Flexibility of industrial funds (Meyer-Krahmer & Schmoch, 1998) Tagible Benefits (Arza & Vasquez, 2010)
Knowledge Results	New research projects (Perkmann, 2013)
Academic Results	Publications (Perkmann & Walsh, 2009)
Commercial Results	Commercialization (D'este & Perkmann, 2010; Perkmann et al., 2013)
Capabilities Barriers	Skills of university (or TTOs) staff (Owen-Smith and Powell, 2001) Managerial problems (Meyer-Kramer and Smoch, 1998)
Orientation Barriers	Freedom and Secrecy (Tartari & Breschi, 2012; Tartari et al., 2012) Complementarity (Perkmann e Walsh, 2009) Subject skewing (Tartari et al., 2012) Restrictions to publications and short-term orientation (Meyer-Kramer & Smoch, 1998)
Transactional Barriers	Technology Transfer Problems (Owen-Smith and Powell, 2001) Williamson Barriers (Tartari et al., 2012) Bureaucracy (Audrescht et al., 2002)

Source: own elaboration.

After the definition of the clusters of the responses from research groups leaders, an estimated model was built to exam the effects of each dimension in the interactions of research groups with firms.

4. Model and Results

An estimated model was built using the clusters formed by the nonparametric IRT for each dimension affecting interactions with industry. The main advantages of the use of this technique are that the introduction in the estimated model of the clusters generated by the nonparametric IRT can avoid multicollinearity problems. The model relates the number of interactions of each research group with the identified clusters of the dimensions, benefits, results and barriers; the main driving factors of the decision of research groups to collaborate with firms, such as the quality of academic research, the extent of the department and the size of research group; and some controls. The variables and their proxies are presented in Table 5.

$$Inter = Benefits + Results + Barriers + Quali_{dept} + Size_{dept} + Size_{group} + Controls$$

Table 5 – Variables description

Variable	Description	Source
Inter	Number of interactions of the research group	<i>Survey.</i>
Benefits	Dummies for each cluster; 1 if the median of the responses for that item is higher than or equal to 3	Own elaboration based on IRT; data from Survey.
Results	Dummies for each cluster; 1 if the median of the responses for that item is higher than or equal to 3	
Barriers	Dummies for each cluster; 1 if the median of the responses for that item is higher than or equal to 3	
Quali _{dept}	Average grade of the post graduate programs in the field of assessment in which the research group is linked	CAPES, 2007.
Size _{dept}	Number of researchers in the department related to the research group	CAPES, 2006.
Size _{group}	Total members of the research group	<i>Survey.</i>
Finan	Share of research funds received by firms (%)	<i>Survey, 2008</i>
PRI	Dummy for Public Research Institutes	<i>Survey, 2008</i>
SSE	South-Southeast region dummy	-
Manuf	Regional Share of employment in manufacturing Industry	<i>RAIS, 2008</i>
Area	Dummies for the scientific field	<i>Survey.</i>

Source: own elaboration.

Regarding the main driving factors, quality of academic research can affect interactions with firms. High performance research groups are stimulated to collaborate with firms, since they can provide solution to more complex innovation problems, especially when industrial technological efforts are closer to state-of-art scientific knowledge (Mansfield & Lee, 1996). In addition, better performance research groups are better able to provide technological solutions with industrial application (Tornquist and Kallsen, 1994). The size of department is other important driving factor for research groups to collaborate to industry (Mansfield and

Lee, 1996; Perkmann et al., 2011). Larger departments have wider human, physical and financial resources for academic research and greater capabilities to interact with industry (Schartinger et al., 2001). In the same way, research groups with more technicians and researchers are more able to attend industry's needs (De Fuentes and Dutrénit, 2012).

In was added to the estimated model dummy variables to control scientific fields, since it expected different patterns regarding the number of interactions according to different scientific fields. This assumption is based on the different roles of the scientific disciplines in supporting industry innovation, since some areas, such as Engineering, tend to generate more applied knowledge than Natural Sciences (Meyer-Krahmer and Schmoch, 1998; Metcalfe, 2003; Bekker and Freitas, 2008).

In addition, other characteristics of the research group that can affect the number of interactions were also controlled. The pattern of finance of the research projects was also controlled by adding a variable for the share of funding of the research group that came from private firms (*Finan*). A dummy to control for differences of research groups linked to Public Research Institutes (*PRI*) was added because Public Research Institutes can play a distinctive role in supporting the creation of technological capabilities in developing countries (Mazzoleni and Nelson, 2007). Two supplementary controls were added for regional characteristics. The first is a dummy for the South and Southeast regions (*SSE*) because the unequal regional distribution of R&D expenditures among Brazilian regions, that shows that firms in the South and Southeast regions have much higher technological activity. The second is the share of the manufacturing industry in the total employment of the firm's region, which is used as a way to control the characteristics of the local industrial structure (*Manuf*).

Results of the coefficients of the negative binomial regression are presented in Table 6.

Table 6 - Coefficients estimation– Negative Binomial Regression

		BASELINE MODEL	BENEFITS	RESULTS	BARRIERS	FULL MODEL
		(1)	(2)	(3)	(4)	(5)
Benefits	Intellectual		0.61728*** (0.13416)			0.47744*** (0.14091)
	Economic		-0.03823 (0.10136)			0.03149 (0.10590)
Results	Knowledge			0.04873 (0.10610)		-0.01874 (0.10940)
	Academic			0.49066*** (0.0994)		0.41974*** (0.10184)
	Commercial			-0.17712 (0.09507)		-0.07949 (0.09996)
Barriers	Capabilities				-0.07088 (0.09190)	-0.07070 (0.08999)
	Orientation				0.13282 (0.09962)	0.06176 (0.09787)
	Transactional				-0.29574*** (0.09207)	-0.37461*** (0.09486)
Department Quality	0.10488* (0.04318)	0.10853* (0.04290)	0.11096** (0.04320)	0.10985* (0.04328)	0.10916* (0.04272)	
Department Size	0.00103* (0.00045)	0.00113* (0.00045)	0.00095* (0.00045)	0.00106* (0.00045)	0.001087* (0.00044)	
Group Size	0.00984*** (0.0019)	0.00914*** (0.00173)	0.00849*** (0.00156)	0.00987*** (0.00195)	0.00817*** (0.00154)	
Finan	0.25248* (0.1224)	0.22676 (0.12598)	0.2159 (0.12030)	0.24101* (0.12242)	0.14911 (0.12440)	
PRI	0.85476*** (0.25709)	1.147*** (0.26351)	0.8322*** (0.25437)	0.83702*** (0.25504)	0.95843*** (0.25637)	
SSE	0.24599*** (0.11774)	0.21300 (0.11761)	0.2003 (0.11663)	0.21268 (0.11764)	0.16673 (0.11586)	
Manuf	-0.80376 (0.49919)	-0.73237 (0.49668)	-0.71490 (0.5008)	-0.5455 (0.5001)	-0.45736 (0.49722)	
Dummies for knowledge areas	Yes	Yes	Yes	Yes	Yes	
Constant	0.06126 (0.22913)	-0.4063 (0.2469)	-0.1495 (0.25037)	0.1384 (0.2390)	-0.30943 (0.26133)	
Number of Observations	612	612	612	612	612	
LR chi2	290.54	312.82	317.41	302.55	346.88	
Prob>chi2	0.0000	0.0000	0.0000	0.0000	0.0000	
Log likelihood	-1444.20	-1433.06	-1430.77	-1438.20	-1416.03	
Pseudo R2	0.0914	0.0984	0.0998	0.0952	0.1091	

*** p < 0.1%; ** p < 1%; * p < 5%; Standard Error in parentheses

Source: own elaboration.

The independent variable is the number of interactions the research group reported they have with firms (*Inter*). Five main estimations were done. Model (1) is the baseline model, and contains only driving factors and controls. Models (2), (3) and (4) comprise the main dimension of the perceptions of academic researchers separately. Finally, in model (5), full model was tested. The signs are consistent to the previous specification, and it is possible to observe a slight increase in R². As a robustness check, the comparison between previous models and the full model show the quality of the estimators, since among main results, both controls and separately analysed dimensions present no change in the significance of the coefficients.

Regarding the main results, intellectual benefits and academic results present positive and significant coefficients, whereas transactional barriers present negative and significant coefficients.

Regarding benefits, intellectual benefits positively affect research groups' interactions with firms. In this way, it is possible to conclude that factors such as ideas to new collaborative projects, new ideas to research projects, knowledge sharing, new networks relations and reputation positively affect the decision of research groups to collaborate with industry. This finding confirms previous research (Perkmann and Walsh, 2009; Garrett-Jones et al., 2010; Arza and Vazquez, 2010; D'Este and Perkmann, 2011) that shows the importance of intellectual benefits for the research groups. It is possible to ensure that collaboration with industry has an important effect on the development of new research projects at the university. This reveals that collaboration with industry is often very fruitful for research groups, since through these linkages academic researchers are able to generate new insights and ideas for the development of new academic research projects. This means that interaction with industry is able to bring new research questions to the university. Furthermore, interaction with industry is also able to bring new ideas for new cooperative projects with industry. This reveals an important feature of the collaboration projects of research groups with firms, since these relationships are established from a maturation process between both agents and often result from a long-term relationship.

As regards to economic benefits, coefficients are not significant. This result shows that no relation can be found between the number of interactions and the economic benefits, such as joint use of equipment labs, inputs for research and financial resources. This finding differs from other studies, such as Tartari and Breschi (2012), which shows that obtaining resources is one of the main motivators of the collaboration with firms. However, this could mean that academic researchers give more importance for intellectual benefits that arise from collaboration with firms than economic ones, which means that intellectual benefits often overcome financial assistance related to interactions to firms (Fernandes et al., 2010).

Concerning results, academic results also positively affect the decision of research groups to collaborate with industry. This finding shows that researchers consider important academic results that emerge from collaboration with firms, such as training of researchers, theses and dissertations, publications and software, tend to interact more with industrial partners. This is evidence that collaboration with industry can generate relevant academic results, and that university-industry linkages cannot deviate university from its main mission to generate new knowledge. Publications in journals and theses and dissertations are the primary way of disclosure of results from academic research, which means that collaboration with industrial partners can generate new knowledge that will become academic product.

On the other hand, knowledge results and commercial results present no significant coefficients. This means that academic researchers that interact more with firms tend to consider academic results more important than knowledge results, such as new scientific discoveries and new research projects, and commercial results, such as new products, patents or academic entrepreneurship. However, findings show that interaction with firms can provide new publications, thesis and dissertations, in a clear demonstration that knowledge sharing between university and industry can provide new scientific knowledge, and so, publication in academic journals. D'Este and Perkmann (2011) also found positive effect of the motivations for learning in interactions of academic groups, which means that the search for academic results are important motivators for researcher groups to perform more interactions with companies.

Finally, results also show that transactional barriers have a negative effect on the number of interactions of research groups. This result suggests that research groups that have more

collaboration with industrial partners presents lower complaining on transactional barriers, such as bureaucracy both at university and in the firm, costs of the contracts, intellectual property rights and geographical distance. This means that research groups that collaborate more with firms can develop capabilities to manage the contracts and to deal with university bodies. However, this could also suggest that there is a task for the university's TTO in order to stimulate and the simplify operation to formalize collaboration between university and firms.

In addition, orientation barriers do not present significant coefficient, as well as capabilities barriers. This could indicate that, among Brazilian research groups that interact with industry there cannot be found orientation (or mertonian) problems, related to the different institutional logic prevailing in university and firms. This means that research groups interacting with firms are able to establish collaborative projects with industrial partners and it does not hinder the university's mission of generating new knowledge and its publication in high impact journals. This finding is convergent to Tartari and Breschi (2012), which have shown that the potential increase in secrecy and publication delays does not affect the propensity of academic researchers to collaborate with industry.

In relation to the main driving factors of the interaction of research groups with firms, quality of academic research presents positive and significant coefficient. This means that better-performing research groups interact more with firms, which shows that more collaborative research between universities and industry can be found among research groups with higher quality academic research. The size of the department also has a positive effect on the number of interactions of research groups, which means that research groups linked to larger departments were better able to interact with firms. Concerning the size of the research group, the larger the research groups are, the more they tend to interact with firms. Larger research groups are better able to handle broader and, in several cases, more diversified, academic skills, which improves their ability to interact with firms.

Regarding the main controls, the dummy for Public Research Institutes also presents positive and significant coefficients, which shows the important role played by these institutions in the building of new capabilities in developing countries (Mazzoleni and Nelson, 2007). Moreover, dummies for scientific fields also present significant coefficients, which show different patterns of interaction with industry among research groups' scientific fields.

5. Final remarks and policy implications

The main aim of this paper was to analyse how perceptions of academic researchers about the benefits, results and barriers affect their interactions with firms. The main assumption of the paper is that university has become a growing source of information and knowledge for firms' innovation, which result in an increase of the importance of university-industry linkages. In this way, an important question regarding this subject is what drives academic research to interact with industrial partners. In this way, by analysing benefits and results of the interactions with firms and the effect of the main barriers to engagement with industry, this paper adds new contribution on the understanding of the main motivations and constrains faced by research groups in the collaboration with firm.

Main findings of the paper show three main points. First, intellectual benefits from the collaboration with industrial partners, such as ideas to new cooperative project, new ideas to research projects, information and knowledge sharing, new network relations, and reputation, positively affect interactions of research groups with firms. Second, academic results, such as publications, thesis and dissertation, training of researchers, and software, are also drivers of the interactions between research groups and firms. Third, and on the other hand, transactional barriers, such as bureaucracy in university and in firms, costs, intellectual

property rights and geographical distance, play an important role to discourage researchers to interact more with industrial partners.

These findings were found by using of the nonparametric IRT technique, which allows the formation of non-arbitrary clusters of the perceptions of the research groups about the benefits, results and barriers to collaborate with firms. These clusters were used in the econometric model, which allowed the estimation of a model that sought to assess how these dimensions affect their interactions to firms, even controlling other driving factors, such as the quality of academic research, the size of the group and the scientific field.

Main findings can add new questions on the literature about university-industry linkages. Results show that interactions with firms can also be a driver for intellectual benefits of the research groups that collaborate with industrial partners, since interactions with firms can also provide intellectual benefits for academic researchers. Results show that ideas to new scientific projects and the exchange of information and knowledge are important benefits related to the collaboration with firms. This conclusion is strengthened by other finding that shows that orientation barriers were not significant, which means that cannot be found orientation problems among Brazilian research groups that interacts with firms. Academic results are also important drivers for research groups in their collaboration with firms. This finding show that collaboration with industrial partner can also provide academic results, such as publications, theses and dissertation, which also shows that linkages with industry can strengthen academic activities and provide inputs for academic disclosure.

Finally, findings can also provide policy implications. First, related to the importance of intellectual benefits and academic results, it is clear that policy measures toward to stimulate university-industry linkages can not only not hinder academic activity, but also can strengthen the capacity of research groups to generate academic outcomes such as publications, theses and dissertations. Second, since transactional barriers have a negative effect to the number of interactions of research groups, policy measures should try to simplify procedures and increase transparency on the contracts with firms. This is a task also to university TTO, since it can be an important channel to stimulate cooperation with industrial partners.

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