Theme: Triple Helix and innovation for development
Subtheme: 2.4 – The rise of science and innovation in world regions (Latin America): change and diversity.

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The impact of the bilateral relationship firm-university on firm's ability to innovate: empirical evidence from Brazilian firms.

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Abstract

This study attempts to discuss how do the motivations and characteristics of interaction between Brazilian firms and universities impact on Brazilian firms' ability to innovate. From an original data base with information from 325 Brazilian firms that have interaction with universities, we employed regression logistic technique to test the effect of independent and control variables on each dependent variable. The results indicated that the interaction determinants *firm size*, *R&D intensity* and *industry* have an association with technological performance, whereas public funding did not show any significant relationship. The result also indicates that the reasons for firms to interact with universities don't show any relation with the technological performance.

Keywords: Triple helix, innovation, motivation, Brazilian firms.

1. Introduction

Since the seminal contribution of Schumpeter (1982), the innovative activity has been shown in literature as a central component to the technical progress and an important way of economical development of firms, regions and countries. Innovation can be understood as a collective and institutionalized process in which science and technology have a fundamental role in the promotion of technical changes of products and processes, as well as in the organizational forms.

The interaction between the scientific production and the technological production plays an important role in the country's national systems of innovation. In developed countries, it is possible to identify the existence of circuits of positive retro alimentation between these two dimensions in which there are information and knowledge flows on both directions. Universities and Research Institutes produce knowledge which is transferred to the firms of the productive sector, while the storage of technological knowledge produces important questions to the scientific elaboration and to the orientation of the human resources qualification.

Due to its economical and social history, Brazil has a little dynamic National System of Innovation in terms of interactions established between the universities and

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firms. According to the previous studies (Mazzoleni and Nelson, 2007, Dahlman and Frischtak, 1993), the Brazilian National System on Innovation can be placed on an intermediate level of development. It happens because the country cannot promote an interactive dynamics between these actors ready to establish a positive process of retro alimentation between the scientific and technological spheres (Suzigan and Albuquerque, 2008).

This way, we stand out the importance of the actions developed by the universities and research institutes, as members of the National System of Innovation, as well as the productive system, whose firms are responsible for the technological dimension. These actions come from the interaction between these organizations, enabling the local development by means of an innovative virtuous circle with the universities and research institutes generating and transferring knowledge to the firms. These, on the one hand, accumulate technological knowledge, which are the generators of questions to be solved in the scientific field (Cohen et al, 2002 and Klevorick et al, 1995).

From an original data base composed only by firms which have interaction with universities or research institutes, this study aims at comprehending the dynamics of the interaction university-industry (I-U-I) in Brazil, identifying the relation of its determinants and the sorts of interaction with the innovative results to the firms. The main objective of the study is to identify the importance of the several determinants and the characteristics of the I-U-I and its impact on the technological innovation upon products and processes of the Brazilian firms. In order to accomplish the main objective, it will be necessary to reach some specific ones such as: verify if the sorts of I-U-I influence the development of the firms regarding technological innovation upon products and processes; and identify if the determinants of the interaction university-industry keep some relation with the technological innovation upon products and processes of the Brazilian firms.

2. Innovation and the National System of Innovation

The innovative activity is presented as an important means of economical development (Schumpeter, 1982), which can be characterized as an institutionalized process in which science and technology play a fundamental role in the technical changes of processes and products, as well as in the organizational forms.

The innovation process has a systemic nature, whereas the firms normally do not innovate in an isolated way, but in collaboration and interdependency with other firms, suppliers, competitors, customers, or even, with other organizations like universities, research institutes, government agencies, among others. The behavior of these organizations is shaped by rules, principles, laws and existing routines that can constitute incentives or obstacles to the innovation (Fagerberg, 2007).

Nelson & Rosenberg (1993) assert that a key characteristic of the national systems of innovation is the interlacement between science and technology. The authors summarize the complex interactions between these two dimensions highlighting that science is, at the same time, “leader and follower” of the technological progress. Rosenberg (2006) points out as main roles: a) a source of questions and problems to the scientific effort; b) a great deposit of empirical knowledge to be searched and evaluated by the scientists; c) a contribution to the formulation of an agenda for science; d) a source of instruments and equipment for research.

It is possible to notice the relevance of these two dimensions of the innovative activities, highlighting their characteristics and retro alimentation between science and technology mainly in developed countries and giving relevance to the intensification of this relation.

2.1 The interaction university-industry (I-U-I)

Universities are cited as fundamental actors in the systems of innovation (Nelson, 2006; Etzkowitz et al., 2000). Research carried out in these corporations play an important role as a source of knowledge and in the development of new technologies applied to industry. In recognition to this fact, since 1970, governments of industrialized countries have accomplished several initiatives to approximate universities to activities of industrial innovation (Mowery and Sampat, 2007). Many of these initiatives aim at stimulating the local economical development based on university research making use of the creation of scientific parks, incubators, support to incubated firms, availability of capital of risk and other forms of support institutions which promote a greater interaction between university and industrial innovation.

A thought which influenced the comprehension of the role of the university in the national systems of innovation was the so called "linear model" of innovation, mainly spread in the second half of the XX century. This model is based on the understanding that the role of accomplishing basic research belongs to the university, having a unidirectional flow of knowledge (from the university to the industry) in order to promote innovation.

Metcalfe (2003) asserts that the linear model covers just one fraction of the activities involved in the innovative process, while to Rosenberg (2006), this model is dead. The model was widely criticized (Balconi, Brusoni and Orsenigo, 2008), taking to a new insight of the role of university regarding research, a more interactive model (Cohen et al, 2002) in which the university researchers realize important contributions to the development of technology, as well as important basic research to some advancement inside the industry laboratories (Mowery and Sampat, 2007). Metcalfe (2003) points out that the technical knowledge is more dependent on practical experience than on theory and searches for economically feasible results acceptable by society – different from scientific knowledge which is, in general, encoded – to allow its diffusion.

One of the important roles of universities for the development of countries is the advancement in the boundary of knowledge aiming at the applicability in the productive sector. The universities are general sources of knowledge necessary to the basic research activities (Nelson, 2006), as well as specialized knowledge related to technologies applied in the firms (Klevorick et al, 1995), besides being responsible for the formation and training of scientists and engineers able to solve problems regarding the innovative process of the firms (Rosemberg and Nelson, 1994). Another important contribution of the universities to the innovative process is the generation of new firms with a technological basis inside the environment of the university (spin-offs) (Stankiewicz, 1994).

The interaction university-industry (I-U-I) consolidates and develops the national system of innovation and has to be understood as its constituent. Nevertheless, the intensity of the relations depends on the structural capacity of absorption of the involved ones according to Meyer-Kramer and Schmoch (1998). The characteristic of interaction university-industry is specific to each country, dependent on the national infrastructure of science and technology.

2.1.1 Determinants of the interaction university-industry

One of the important aspects in determining I-U-I is approached by the Resource Based View (Barney, 1991) which establishes that the internal resources of the firm develop an important role in its growth and prosperity. In the event of not having internal resources in the organization, it has to seek for it outside. Observing literature, which is strongly oriented to the developed countries, it is possible to notice that the main determinants of I-U-I are:

a) The characteristics of organization - countless studies indicate that the lack of resources in the micro, small and medium firms is one of the main factors taking these organizations to accomplish interactions with the universities or research institutes, however, Tether (2002) asserts that the big industries are the ones which have more effective results in this kind of cooperation, especially due to the presence of better internal resources.

b) The characteristics of the sector – it is important due to the difference between the technological growth rate among sectors (Klevorick et al, 1995; Malerba, 2002 and 2004) and the differences in the technological and innovative structural patterns of each sector (Pavitt, 1984). Pavitt (1984) argues that learning with the advances of technology is crucial to the industries based on science like, for example, the electronics and chemistry ones, to which interaction between university and firms can be more important. Literature also stands out the importance of this cooperation, asserting that the industry depends, strongly, on the progress of science and technology (Mayer-Krahmer & Schmoch, 1998; Santoro & Chakrabati, 2002).

c) The geographic localization – it is an important determinant because the institutional infrastructure support to innovation can contribute to the productive structure of the region where the firm is located (Doloreux, 2002), besides the exchange of tacit knowledge to the generation of innovation (Tödtling and Trippl, 2005).

d) Expectancies of the firm in I-U-I – it can be mainly summarized to the arousal of new products and/or services and new processes. To Geisler (2001), a present expectancy in the firms is the one of paying the investment regarding R&D (*payoff*) with immediate results and not at long run.

e) The benefits derived from the cooperation between university and industry - it represents the capacity of developing technology at lower investment in a shorter period of time and with fewer risks. The government, on one hand, sees the development fomentation of the country made easier through the lower level of investment in infrastructure and in installed capacity of research and development. Bonaccorsi &P

Piccaluga (1994) carried out a classification of the motivations so that the firms participate in inter-organizational relations with the university. The four main aspects of this classification are: a) obtain access to the scientific boundaries of knowledge; b) increase the predictive power of science; c) delegate, outsource or divide specific activities related to development; and d) lack of resources. To Santoro (2000), the prestige and strengthening of the image of the firm are also motivators to I-U-I.

f) Public policies for R&D - The government actions are fundamental to the financing of R&D activities to the firms that need it, as well as in the establishment of rules, facilities and incentives to innovation practices (Dogson, 1993; Mansfield, 1995) so that the partnership between the private institutions take place. Another important aspect concerning the government is related to the guarantee of property rights.

The model triple-helix (Etzkowitz, 2003) presents three ways of government participation: as a controller, regulator and financier of the interaction. Nevertheless, in the most recent model of triple-helix, the government plays the role of financier. The way of establishment of I-U-I, as well as its results, suffers the influence of the resources available in the organizations involved. In the firms, the organizational structure, the management structure, the individual behavior of the involved ones, the entrepreneurial behavior and the support of the superior management levels are important resources (Geisler, 2001; Bonaccorsi & Piccaluga, 1994). However, for Cohen and Levinthal (1990), the absorptive capacity of the involved ones is determining to the process.

2.1.3 Impact of I-U-I on the firm and on the university

The result of an I-U-I can take to an increment innovation in which the product or process is new to the firm, but already existing in the market or also to an increment in some competence existing in the firm. It can also come from I-U-I, a radical innovation in which the result is not only new to the firm, but also to the market as a whole (Monjon and Waelbroeck, 2003). Studies present some results of I-U-I, such as the temporary change of working place between the professionals, the use of equipment and installations of the ones involved, publications and seminars in partnership, definition of patterns, ideas for new projects (Geisler, 2001), patents, licensing of products or processes, patented or not (Santoro, 2000), new products, problems solving of the firm, inventions, innovations and *spin-offs* (Bonaccorsi & Piccaluga, 1994). To Belderbos et al (2004), I-U-I also generates an increase in the income of the firm coming upon the sales of new products, or, according to Faems et al (2006), products which were improved by innovations. However, its impact is not positive on the productivity of the firm; they asseverate that the increase in productivity happens due to other factors.

From the review of literature here presented, four research hypotheses arise. The hypotheses 3 and 4 are divided in four sub-hypothesis each one:

H1 – The technological innovation of products is related to the reasons which take to the interaction of the firm with the university or research institute.

H2 – The technological innovation in processes is related to the reasons which take to the interaction of the firm with the university or research institute.

H3 - The technological innovation of products of a firm with interaction with university is influenced by: i) characteristics and structure of the firm, ii) sector of the firm, iii) intensity of R&D of the firm, and iv) public policies for R&D.

H4 – The technological innovation in processes of an firm with interaction with a university is influenced by: i) characteristics and structure of the firm, ii) sector of the firm, iii) intensity of R&D of the firm: iv) public policies for R&D.

3. Methodological aspects

Regarding its characterization, this study can be classified as a quantitative correlating study. According to Sampieri, Collado and Lucio (2006, p. 104), "[…] the quantitative correlating studies measure the degree of relation between two or more variables (quantify the relations), in other words, measure each variable presumptuously related and after that, also measure and analyze the correlation".

3.1 Data source

For elaborating this study, we used a data base created by the research started in 2006 which is denominated as Interactions of Universities and Research Institutes with Firms in Brazil. It was elaborated by a group of researchers from several Brazilian universities and coordinated by Professor Wilson Suzigan (DPCT – Unicamp) and Eduardo Albuquerque (Cedeplar – UFMG) and also counting on the financing of CNPq, process number 478994/2006-0, IDRC, Fapesp and Fapemig.

The data base contains information on the firms which the research groups registered at CNPq, in the census of 2004 in the Directory of Research groups of CNPq, declared as having some kind of relationship with the productive sector. The total amount of firms questioned was 1.688, from which 325 answered the research, this way representing 19.3% of the population. The answers were organized, computed and put into the data bank "BR Survey Final Empresas.mdb" and "BR Survey Final Empresas.xls".

3.2 Characterization of the sample firms

Regarding localization, the 325 firms are concentrated in higher number in the Southeast and South regions of Brazil, where 79.9% of the firms are located. Seventy seven firms researched are located in the state of Minas Gerais, 60 in Rio Grande do Sul, 60 in São Paulo, 29 in Santa Catarina, 18 in Paraná and 15 in Rio de Janeiro; the last 18.3% are distributed among the other Brazilian states. Regarding the size, according to the criteria for industrial firms of SEBRAE – Brazilian Support Service for Micro and Small Enterprises, it is possible to notice that there is a balanced distribution, 34.2% are big ones, 31.4% are medium ones and 33.5% are classified as small or micro firms. The origin of their capital is predominantly national private 69.2%, 12% foreign private, 5.8% public firms and the others, mixed capital.

The firms of the data base were classified according to the segment of activity, major by firms of the transformation industry (62.8%), being divided in a balanced way among the four categories of technological intensity in which OECD (2003) segments the industrial activity.

Regarding the structure related to the research and development of the firms, the average number of employees involved in the activities of R&D in the firms of the data base is of 28.5% employees. It was observed that 84.4% firms declared that their activities of R&D are continuous. 67.1% of the firms declared to have a department of R&D.

The researched firms show lasting relationships, because 32.9% of the firms have cooperation with universities or research institutes for a period of 5 to 10 years and 34.9% of the firms assert having relationships with universities or research institutes for more than 10 years.

Regarding the financing of projects in collaboration with universities or research institutes, it is observed that the greatest financier is the firm, because 63.7% of the resources invested in the projects in collaboration with universities or research institutes come from the firms themselves, while the public resources represent 18.1% of the financing of the projects of the Brazilian firms surveyed.

3.2.1 Dependent variables

In order to detect the result obtained by the firms which had interaction between university and industry, four variables were identified (Figure 1).

Figure 1 – Characteristics of the dependent variables

Code	Variable	Description
CESS1	Innovation in products for the national market	Binary variable indicating the introduction of new product to the country in the last 3 years
CESS2	Innovation in processes for the national market	Binary variable indicating the introduction of new process to the country in the last 3 years
DUCT1	Innovation in products for the international market	Binary variable indicating the introduction of new product to the world in the last 3 years
DUCT2	Innovation in processes for the international market	Binary variable indicating the introduction of new process to the world in the last 3 years

Elaborated by the authors.

As the survey allowed the replier to check one or more options, the present study took into consideration just the answer with the highest level of innovation in relation to the market. The variables are binary where 1 indicates that there was the introduction of a new product or process into the indicated market and 0 indicates that there wasn't any.

3.2.2 Independent variables

In order to identify the reasons of the interaction, we accomplished factorial analyses of a list with ten reasons for the collaboration of the firm with the university and/or research institute, in which a scale of importance from 1 to 4 was attributed by the firm. Two factors were found: a) reason for the increase of the internal technological capacity of the firm; b) reason for searching for external physical resources whose components are presented in Figure 3.

Figure 3 – Results of the factorial analyses of the reasons for the interaction university-industry.

Name of the factor	Variables compounding the factor	Component	
		1	2
Reason for the increase of the internal capacity of the firm (R1).	Increase the ability of the firm to look for and absorb technological information.	0.775	
	Get information about engineers, scientists and/or R&D tendencies in the scientific areas	0.767	
	Make contacts with excellent university students for a future hiring, as soon as possible	0.752	
	Transference of university technology	0.707	
	Search for technological advice or consultancy with researchers and/or professors to solve problems regarding production	0.664	
Reason for searching for external physical resources (R2).	Accomplish necessary tests for products and processes of the firm		0.826
	Contract research which cannot be accomplished by the firm		0.793
	Use resources available in the universities and research laboratories		0.766
	Receive help in quality control		0.599
	Contract supplementary research necessary for the innovative activities of the firm in universities and institutes, laboratories or research centers	0.400	0.586

Extraction method: Analyses of main components. Rotation method: Varimax with Kaiser Normalization. Source: Exit report of SPSS

3.2.3 Control variables

The size of the firm (LOGEMP) is the first control variable used in the analyses measured by the number of employees expressed in logarithm. The use of the logarithm is due to the search for reducing the variability of the indicator. Sector group or technological category of the industry (CITEC), the second control variable was elaborated from the sector to which the firm belongs and the intensity classification of OECD. This last one is used when the firm is industrial and fits the classification OECD (2003). Otherwise, the firm is classified from the denomination of the section CNAE 2.0 to which the firm belongs. So, the scale of classification was defined as: 1 for the agriculture, 2 public services, 3 information and communication, 4 engineering and R&D, 5 other services, 6 extractive industry, 7 low technology industry, 9 medium-high technology industry and 10 high technology industry. The disposition in this classification was defined so that the high technology industry was placed in the end of the scale in order to calculate the *dummy* variable regarding this last category.

The variable R&D intensity (INTPD) is composed by the sum of the logarithm of the number of employees involved in R&D with a binary variable which considers 0 the occasional activities and 1 the continuous ones. We sum to this result the binary variable considered 0 if the firm does not have a R&D department and 1 if there is a R&D department in the firm.

And, finally, we have the control variable which takes into consideration the use of public policies for the interaction university-industry (PUBRES). So, we used as Proxy the information of the use of public financing by the firm to develop activities of collaboration with universities or research institutes. In the survey (question 20b), the firm answered about the percentage of the value financed on projects in collaboration with universities and research institutes using public resources. However, due to the high variability of answers, we opted to transform this variable into a binary one, considering 0 if any public resource was used and 1 if some was used.

Figure 4 shows the control variables used in the analyses.

Figure 4 – Summary of the control variables

Code	Variable	Description
PUBRES	Use of public resources in the interaction university-industry	Binary variable that indicates if the firm used or not public resources (1) or (0).
INTPD	Intensity of R&D	Metric variable that indicates if the firm has a R&D sector, if the activity of R&D is continuous or occasional and the logarithm of the number of employees in the sector of R&D.
LOGEMP	Size of the firm	Logarithm of the number of employees indicating the size of the firm.
CITEC	Sector or technological level of the industry.	Categorical variable that classifies the firm by categories of technological intensity of OECD or sector of the CNAE.

Source: Elaborated by the authors.

3.3 Method of data analyses

In order to answer the question of the research, the technique of logistic regression was used to make the analyses. It was used because it aims at explaining or predicting the values of a variable due to known values of other variables, but with the peculiarity that the dependent variable is binary or in dichotomy and admits independent metric and non metric variables simultaneously (Tabachnick and Fidello, 2001).

The strategy of regression adopted to test the effect of the predictive variables in the dependent variables is of hierarchic approach. Blocks of variables were formed and each block was included in the model, step by step, comparing the contribution of each block of entering variables with the basic block. That is, the strategy adopted is the one of testing the incremental effect of the variables to each incremented block in the basic model. Figure 5 shows the characteristics of the regression models.

Figure 5 – Characteristics of the models of logistic regression applied.

Variables to be tested	Model 1	Model 2
Control Variables	x	x
Reasons for the interaction university- industry		x

Source: Elaborated by the authors.

4. Results and interpretations

For each one of the dependent variables, the logistic regression was accomplished for the two models. After that, the model which most fitted was chosen and compared to the hypothesis. The most adjusted model was the one which presented the lowest Likelihood Value, higher Cox & Snell R^2 and Nagelkerker R^2 value, a non significant Hosmer and Lemeshow Test and Wald Test different from zero. As we can see on Table 2 the model that better fits is always the model 2.

Table 2 – Results of logistic regression.

Independent variable	DUCT1		DUCT2		CESS1		CESS2	
Parameter:	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
% de acerto do modelo	67.9	68.2	79.9	79.9	88.7	88.7	81.4	81.4
Omnibus Tests of Model Coefficient	0.132	0.046	0.005	0.009	0.230	0.056	0.012	0.005
Log Likelihood (-2LL)	381.56	375.03	293.49	292.56	209.40	201.35	285.97	279.31
Cox & Snell R^2	0.054	0.073	0.086	0.089	0.047	0.071	0.077	0.095
Nagelkerke R^2	0.075	0.102	0.135	0.139	0.092	0.139	0.124	0.152
Hosmer & Lemeshow Test	0.402	0.455	0.077	0.015	0.290	0.870	0.203	0.456

Source: Elaborated by the authors based on the exit report of SPSS.

Considering the most adequate model for each one of the regression, Table 2 shows the coefficients of regression (B), standard error associated (S.E.), Wald statistic with its rate of liberty and the significance, only the variables which present significance.

Table 2 – Summary of the variables in the equation of the best adjusted model in the regression.

Variável dependente	Variável dependente	B	S.E.	Wald	df	Sig.
DUCT1	INTPD	0.537	0.149	12.966	1	0.000
DUCT2	INTPD	0.533	0.189	7.929	1	0.005
CESS1	CITEC(7)	0.900	0.539	2.786	1	0.095
	INTPD	0.317	0.170	3.495	1	0.062
CESS2	INTPD	0.577	0.238	5.879	1	0.015

Source: Elaborated by the authors based on the exit report of SPSS.

The results of logistic regression do not indicate a significant relation of the number of employees with the other variables of analyses. This fact indicates that it is not the size of the firm, represented by the number of employees, which takes to a better development in terms of innovation and processes, but other variables related to the size of the firm. According to Tether (2002), the biggest firms are the ones which have most effective results in the cooperation due to the possession or access to a higher number of resources.

Regarding the role of the State in the interaction university-industry, we analyzed the control variable using public resources in the interaction university-firm – PUBRES and it was possible to verify that to some extent, 38, and 4% of the firms used public resources to finance the projects with interaction with university or research institutes. The logistic regression did not present any significant correlation with another variable. Taking into consideration the current model of triple helix of Etzkowitz (2003), in which the government would be a less controller and regulator agent of the interaction university-industry to take up the role of financer of the interaction, it was observed that among the Brazilian firms this process does not happen, or at least, the level practiced has not influenced the other variables analyzed.

The result of logistic regression indicated that the low technology industry – CITEC(7) influences the innovation in processes to the national market – CESS1, which takes us to infer that firms of lower technology level with interaction with universities or research institutes, tend to obtain greater results related to innovation in new processes to the country.

After analyzing the results related to the control variables, it was possible to test some initial hypotheses. The results of the logistic regression accomplished with the independent variables and innovation in products to the national market – DUCT1 and innovation in products to the international market – DUCT2, reject the hypotheses H3i, H3ii and H3iv, but confirm the hypothesis H3iii. Analyzing the independent variables with the innovative development in the processes of the firms to the national market – CESS1, the results take us to reject the hypotheses H4i and H4iv and to confirm H4ii and H4iii.

The influence of the types of reasons to establish interactions of the firms with the universities in the results of the firms, in the logistic regression, no reason for the interaction university-industry presented significance with any type of innovation, even in product or process to the national or international markets.

The results of the logistic regression take us to reject hypotheses H1 and H2, in other words, the technological innovation in products or processes, as to the national market as to the international market, is not influenced by the reasons that take the firms to establish a relation with a university or research institute. Figure 6 shows a summary of the test of the hypotheses of the work.

Figure 6 – Summary of the hypotheses test

Regression	H1	H2	H3i	H3ii	H3iii	H3iv	H4i	H4ii	H4iii	H4iv
DUCT1	R	-	R	R	C	R	-	-	-	-
CESS1	-	R	-	-	-	-	R	C	C	R
DUCT2	R	-	R	R	C	R	-	-	-	-
CESS2	-	R	-	-	-	-	R	R	C	R

R: rejected hypothesis, C: confirmed hypothesis
Source: elaborated by the authors.

5 – Final Considerations

This work aimed at contributing to the understanding and clarifying the characteristics of the interaction university-industry and the relation with the technological development of the Brazilian firms. More specifically, we searched for identifying if the determinants of the interaction university-industry and the types of interaction influence on the development regarding technological innovation in products and processes of the firms.

The results of this work indicate that the intensity of R&D as a determinant of the interaction university-industry is relevant for the technological development. The greater the R&D intensity of the firm, the greater the chance it has to introduce new products and processes in the market. Firms with a high intensity of R&D have greater capacity to absorb the knowledge generated by the interaction university-industry.

Another important contribution was the conclusion that, for this sample, the reason of interaction don't affect the result for the firms.

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