THE UNIVERSITY INDUSTRY LINKAGES AND THE FIRM'S INNOVATIVE PERFORMANCE: EVIDENCE FOR BRAZIL

Gisele Spricigo[1]
Sérgio Marley Modesto Monteiro[2]
Ricardo da Silva Freguglia[3]

Resumo:

As Instituições de Ensino Superior (IES) são consideradas um repositório de conhecimento que pode contribuir para o desempenho inovador das empresas, através de uma relação cooperativa, colaborativa ou interativa. Poucos estudos avaliam quantitativamente a importância da cooperação entre universidades e empresas, considerando o desempenho inovador das mesmas, para o caso do Brasil. Este estudo visa preencher esta lacuna, investigando os efeitos das interações universidade-indústria (IUE) sobre os resultados da inovação nas empresas brasileiras, através de um método não-paramétrico, *Propensity Score Matching* (PSM), baseado em algoritmos de pareamento de indivíduos (no caso, empresas) pertencentes a grupos distintos, cujo objetivo é julgar os efeitos de determinado tratamento. O método foi aplicado aos microdados de 2008 e 2011 da Pesquisa de Inovação Tecnológica (PINTEC) do Instituto Brasileiro de Geografia e Estatística (IBGE). Mediu-se o desempenho da inovação por solicitação de patentes e por vendas líquidas e exportações de produtos novos ou significativamente aprimorados. Estimativas com dados de 2008 não mostraram associação significativa entre IUE e O desempenho da empresa inovadora. Em 2011, não se obteve resultados sobre os efeitos relevantes da IUE sobre as vendas líquidas de produtos inovadores. O único resultado robusto foi um efeito positivo e significativo da IUE sobre a exportação de novos produtos, em 2011. No geral, os resultados deste estudo revelam uma fraca relação entre a colaboração com a universidade e desempenho da empresa inovadora no Brasil.

Palavras-chave: Interação Universidade Empresa (IUE); inovação; patentes; *propensity score matching*.

Abstract:

Higher Education Institutions (HEIs) are considered a repository of knowledge that can contribute to firm's innovative performance through cooperative, collaborative or interactive relationship. Few studies evaluate quantitatively the importance of cooperation between universities and firms to innovative performance in Brazil. This study aims to fill this gap, investigating the effects of university-industry linkages (UIL) on the results of innovation in Brazilian firms through a non-parametric method of matching estimator to calculate the average treatment effect on the treated (ATT). Using firm level data obtained from the Technological Innovation Survey (PINTEC), collected by the Brazilian Institute of Geography and Statistics (IBGE) in 2008 and 2011, we measured innovation performance by patent applications and by net sales and exports of new or significantly improved products. Estimates

[1] Universidade do Vale do Rio dos Sinos (UNISINOS) - Av. Unisinos, 950 - São Leopoldo/RS, Brazil - 93030-000 - giselespricigo@hotmail.com
[2] Universidade Federal do Rio Grande do Sul (UFRGS) - Av. João Pessoa, 52 - Porto Alegre/RS, Brazil - 90040-000 - sergio.monteiro@ufrgs.br
[3] Universidade Federal de Juiz de Fora (UFJF) - Rua José Lourenço Kelmer, s/n - Campus Universitário - Bairro São Pedro - Juiz de Fora/MG - 36036-900 - ricardo.freguglia@ufjf.edu.br

with data in 2008 showed no significant association between UIL and innovative firm performance. In 2011 we did not find relevant effects of UIL on net sales of innovative products. The only robust result was a positive and significant effect of UIL on the export of new products in 2011. Overall, the results of this study reveal a weak relationship between collaboration with the university and innovative firm performance in Brazil.

Key-words: University Industry Linkages; Innovation; Patents; Propensity Score Matching.

1 Introduction

Innovation is related to search, discovery, adoption of new products and new processes, and new management techniques, as stated by Dosi (1982). According to Freeman (1987) and Lundvall (1998), for theoretical purposes, the concept of National Innovation System (NIS) should be the institutional framework for understanding the role of innovation on economic growth. The experiences of developed and developing countries show that differentiated learning processes to promote innovation are the foundation of economic development. For this reason, learning activities – its nature, its determinants, and its economic effects – should become the focus of attention of public policy, including those aimed at developing the role of higher education institutions (HEIs) in promoting innovation.

The elements that underlie the relationship between universities and firms, in order to promote innovative activities, constitute the so-called university industry linkages (UIL). The UIL is one of the ways used to promote innovation and is the focus of analysis of this study. The role of universities and public scientific and technological institutions goes beyond providing skilled labor for the labor market. Companies have been surrounded by instruments that facilitate the possibilities of innovation in their products and services. Given the importance of techno-scientific processes, strengthened by partnerships between universities and companies, the literature considers that innovation is the way for a long-term sustained economic growth (Jaffe, 1989; Langford, 2000; Etzkowitz, 2009).

This study aims to investigate the effects of university-industry linkages (UIL) on the results of innovation in Brazilian firms. We use data from the Technological Innovation Survey (PINTEC), collected by the Brazilian Institute of Geography and Statistics (IBGE) in the years 2008 and 2011, including firms in manufacturing and service sectors. The results of innovation that will be considered in this paper are patent applications, domestic sales of new or significantly improved product, and exports of new or significantly improved product. Two empirical strategies are used to assess the importance of UIL for innovation in Brazil: cross-sectional ordinary least squares (OLS) regressions and matching estimators to compute the average effect of treatment on the treated (ATT). The estimates are based on a 2008 sample with 7,957 firms and a 2011 sample with 6,882 firms.

This paper is structured as follows. Section 2 reviews the literature on the role of UIL on the firm's innovative performance. Section 3 presents the methodology and describes the database used in the empirical analysis. Section 4 provides and discusses the results. Section 6 presents some concluding remarks.

2 Innovations and University-Industry Linkage (UIL)

We use the concept of National Innovation System (NIS) to characterize the innovative environment. NIS is an arrangement that connects businesses and institutions in a network in which there may be changes in terms of technology and knowledge, in order to promote the accumulation of skills and learning (Lundvall, 1998). Higher education institutions (HEI), universities and research centers, are part of this network, and they play a key role in technology transfer processes to promote innovation and to improve the performance of the firm.

Freeman (1988) and Nelson (1993) characterize the NIS as an institutional construction. It could be the product of a planned and conscious action, or the result of unplanned and uncoordinated decisions, but it is aimed at giving impetus to the technological progress in complex capitalist economies. Lundvall (1998) explains that the concept of NIS involves the dynamics of a system that aggregates organizations to promote science, technology and innovation. According to Lundvall (2007), the leading institutions in the NIS are the HEIs, because they function as a source of information for businesses and of skilled labor. The graduates of universities act both as innovators and as agents that balance the relationship between higher education and economic change through innovation.

According to Freeman (1987) and to Lundvall (1998), the NIS is a network of institutions in the public and in the private sector that promotes activities that initiate, import, modify and diffuse knowledge and technology. The NIS has several participants: the firms, with its R&D laboratories and their cooperation and interaction networks; the educational institutions, such as universities and/or research institutes; the financial system, capable of providing funding in support of innovative activities; the legal system and the governments; and the coordinating institutions. It should be emphasized that the concept of NIS presented here postulates the capillarity of agents and actions that give shape to the institutional environment.

Patel and Pavitt (1994) mention the elements that form the basis of a NIS, including the structures and incentives that drive technological knowledge for the promotion of economic development. Similarly, Freeman and Soete (1997) depict the NIS as a network of public and private institutions that carry out activities related to the process of creation and diffusion of new technologies. According to these authors, the analysis of NIS allows to identify the causes, directions and rhythms of creation of these new technologies. They also address the importance of a national system, requiring up external agents that contribute to the innovative process, and the subsequent technical progress resulting from economic growth.

A retrospective of the NIS's is presented by Nelson (1992), including an analysis for 15 countries. Dating from the early 1990s, this study alludes to the relevant "spirit" concerning the nationwide technologies. There is a combination of technological capabilities of firms as a key source of competitive performance, built at the national level. And here lies the importance of universities, which assume two key roles: (i) be a place where scientists, engineers, and other professionals get their formal training; (ii) be a place where there is a high concentration of research in the disciplines associated with the development of technologies. Therefore, two important functions of the university can be highlighted: teaching and research. Nelson (1993) specifically refers that when universities or public research laboratories contribute to national companies, there tends to be a direct interaction between companies and members of faculties or research groups, either through consulting, or by other bond mechanisms.

Despite the benefits and gains offered by a structured and consolidated NIS as a space for promoting innovation, this system also receives criticism, focusing especially on the NIS as a methodological apparatus of analysis. Broström (2008b) criticizes the approach of the innovation system applied by Freeman (1987) and Lundvall (1998) arguing that it does not provide a robust guide on how to evaluate and analyze the possibilities of measuring the creation of knowledge. For example, the R&D area is not necessarily configured as a measurement of innovation. Broström affirms that the NIS is just a concept, not an analytical tool. He proposes an analytical instrument for the study of the dynamics of innovative activities through a new concept called *Innovation System Services.* This system can be defined as a set of factors that have potential influence on the opportunities in certain groups of actors to perform innovative activities efficiently.

Broström (2008b) conducted a case study with multinational companies that invest in R&D in Sweden. He identified three types of factors that influenced the process of investment in R&D, including: (i) people with solid educational background, language skills, multiple skills and long-term commitment; (ii) opportunities for the creation of networks of contacts among similar firms, consultancies and governments to ensure high-level research on a global level; (iii) joint funding opportunities in R&D, leading to the creation of new networks of contacts. In his study, Broström suggests a migration from NIS along the lines of Freeman and Lundvall, which focuses on countries, regions or sectors, to a NIS with focus on stakeholder analysis (actors-activities nexus at hand). Showing a similar point of view, Mowery and Sampat (2006) understand that the NIS – and other instruments designed to understand the institutional framework of innovation – demonstrated deficiencies with regard to criteria to compose a data collection guide and to define indicators on innovation activities. The concept of NIS is, in broad sense, relevant and interesting. However, there is some difficulty in collecting data about it, identifying the stakeholders and systematizing the research that could portray the NIS. Regarding the role of HEIs in NIS, Mowery and Sampat (2006, p.210) argue that there is a process of reconceptualization of universities and their institutional role in national and regional innovation systems: "[...] a growing number of industrial-economy and developing-economy governments seek to use universities as instruments for knowledge-based economic development and change".

Villela and Magacho (2009) present a historical approach on the NIS development in Brazil. According to the authors, it is a consensus that Brazil has an immature and inefficient NIS compared to the developed countries innovation systems. There is in Brazil a lacking infrastructure of science and technology, with low articulation with the productive sector, and reduced contribution to the country's economic performance.

Mansfield and Lee (1996), based on data from 1975 to 1985 for the United States indicate that about 10% of new products and processes in high-tech industries have developed based on academic research. According to Arbo and Benneworth (2007)[4], universities are the "key-players" in the NIS. Even if universities show certain "isolation" in terms of practical applications in business, they promote the diffusion of ideas. However, as they are located in a dedicated institutional setting, the impacts of their activities occur at a regional level, especially considering the "local support" that universities can provide, for example, in terms of laboratory experiments. Bell and Pavitt (1993) highlight the importance of the institutes of basic and applied research to generate new products, processes and services.

According to Langford (2000), for a long period of time the HEIs were studied with focus on its role of transfering knowledge or technology, although this is a linear way to understand its participation in the innovation process. Over time, this framework has become insufficient. Uyarra (2008) reinforces this point when he says that organizations are complex and therefore take a number of activities that end up having direct and indirect impacts on the economy. He also points out the changes in the tasks of HEI over the last 25 years: from simply producing knowledge to creating "links" in the higher education system and in the different economic sectors.

Jaffe (1989) conducted a study analyzing the influence of the university in generating patents and R&D in US companies. He found that university engenders R&D in firms, but the

[4] The authors focused on the analysis of Regional Innovation Systems (RIS).

process does not necessarily occur in the opposite direction. According to him, a government that enhances its system in partnership with a university tends to increase the generation of local innovation, expanding R&D in companies and increasing their productivity.

Bosch et al. (2005) performed econometric exercises for Latin America with a focus on human capital and on absorptive capacity of firms. The authors found that the lack or shortage of UIL in Latin America delays its development. Still on Latin American context, Sutz (2000) emphasizes the efforts of universities to promote relationships with industry, and the provision of managed state funds to encourage innovation in the firm.

Table 1 shows some selected studies on the impact of the UIL on innovation. The table is not exhaustive. Studies show similar results, in the sense that UIL is considered beneficial to innovation, but cooperation with the university is not always a determining factor to firm's innovative performance. Cooperation is closely linked to industry and to firm characteristics, and may be improved by government support. There are also sectoral differences. As Lööf and Broström (2008) asserts, the collaboration with universities had a positive effect on innovation activity of large manufacturing companies, but this effect was not confirmed for companies in the service sector. Another difference to be highlighted is related to the type of innovation. According to Robin and Schubert (2013), cooperation with the university had an effect on product innovation, but the same result was not observed for the innovation process.

Table 1 Selected studies on the impact of UIL

Source	Object, method and database	Country	UIL Result
Tether (2002)	Analyze patterns of cooperation between innovative firms and external partners, including universities, by multivariate analysis with the CIS-2 data.	United Kingdom	There is not a clear significance partnerships in the development of innovations, since it depends on the type of firm and understanding of innovation.
Benfratello and Sembenelli (2002)	Analyze whether the participation of companies in two joint projects funded by the European Union (EU) has an impact on performance through the adoption of three measures: worker productivity, total factor productivity and price cost margin.	Italy, Belgium, Germany, France, UK, Netherlands, Austria and Ireland	In one project (EUREKA), the results were positive. The same did not occur for another project (FPST).
Brimble and Doner (2007)	Analyze the UIL in four sectors: automotive, textile, agro-industrial and electronic, through questionnaire by 40 managers.	Thailand	The UOL is beneficial for producers, but proves to be fragile.
Broström (2008a)	Understand the reasons for the UIL through the application of questionnaire and interview to R&D managers of 50 companies.	Sweden	The UIL is beneficial to generate innovation and companies seek HEI to have access to services.
Blasco and Carod (2008)	Identify the determinants of cooperation agreements for R&D of innovative firms and universities through a logistic model with data from the Community Innovation Survey (CIS-3).	Spain	The cooperation is closely linked to industry characteristics and firm.
Giuliani and Arza (2008)	Understand the factors that lead to the formation of UIL links through the Heckman model in two stages.	Wine Cluster in Italy and Chile	Cooperation is significant and can best be exploited by the government, since, when companies had greater support, the results were better.
Lööfe and Bröstrom (2008)	Analyze the impact of collaboration with universities on the innovation output of firms using a method of correspondence (matching) using a data set of 2,071 companies in the Community Innovation Survey (CIS).	Sweden	The collaboration with the university has a positive effect on innovation activity of large industrial companies, but this was not confirmed for service sector companies.
Eom and Lee (2010)	Identify the determinants of cooperation between university and industry and university, industry and government agency through a probit model (for two tests) and a sample selection model (for the third test), with data from KIS Korea Innovation Survey.	Korea	Cooperation cannot ensure the success of the firm in technological innovation. The results, say the authors, may reflect the current stage of development of the country and NIS.

Source	Object, method and database	Country	UIL Result
Yonamini and Gonçalves (2010)	Estimate the average effect of interactions with universities and research centers in innovation in companies through probit model with data from PINTEC.	Brazil	The companies that establish cooperative relations with universities and research centers have significantly greater effects than the others, considering only the year 2005. However, there was a gradual increase in both the coefficient when the significance level over the analysis period.
Robin and Schubert (2013)	Assess the impact of cooperation between public research and product and process innovation through Generalized Tobit Model with the CIS data.	Germany and France	Cooperation had an effect on product innovation, although these have not been found to process innovation.

3 Methodology and database

The evaluation of the role of university-industry linkages (UIL) on the innovative output of firms in this paper was based on innovation results (patent application) and on the firm performance linked to innovation (domestic sales of new or significantly improved products and exports of new or significantly improved products by Brazilian companies). The empirical strategy used to measure the effect of these linkages is a non-parametric method of matching estimator, developed by Abadie and Imbens (2002) and Abadie et al. (2004), to calculate the average treatment effect on the treated (ATT). Although the matching estimator is more adequate, since it reduces the selection bias due to the fact that companies that have interaction with the university are more likely to innovating, the OLS estimator is useful to establish a preliminary analysis of the relationship between innovation and UIL as a benchmark.

3.1 Ordinary Least Squares (OLS)

The OLS estimates for the years of 2008 and 2011 are used to identify the relationship between UIL and three dependent variables: (i) the patent application, (ii) the domestic sales of new or significantly improved products, and (iii) the exports of new or significantly improved products by Brazilian companies[5]. The idea is to find the effect of UIL on innovation, controlling for other possible explanatory factors, which are based on the characteristics of firms that influence their innovative capacity. The literature on the impact of university-industry linkages suggests a long list of characteristics that affect the firm's decision to establish a relationship with universities, such as: adoption of foreign technology, size of company, R & D expenses, market share, market structure, prices of inputs, labor relations, property rights, among other institutional aspects of the firms (Karshenas and Stoneman, 1995). The choice of the independent variables in this study follows the literature and was based on Lööf and Broström (2008), with adjustments for the data available in our source of data, the Technological Innovation Survey (PINTEC)[6]. Equation (1) was specified to investigate the relationship between innovation and interaction with the university.

$Dependent\ variable = \alpha + \beta_0\ UIL + \beta_1\ innov\_input + \beta_2\ hum\_cap + \beta_3\ innov\_exports + \beta_4\ employment\_sit + \beta_5\ micro\_small\_comp + \beta_6\ large\_comp + \beta_7\ inc\_fiscal\_1 + \beta_8\ inc\_fiscal\_2 + \beta_9\ econ\_subvention + \beta_{10}$

[5] The information about patent applications is not available in 2011. For this reason, the regressions in this year were specified only for net sales and exports.

[6] Lööf & Broström (2008) used the Community Innovation Survey (CIS) III in Sweden and this study used the Technological Innovation Survey (PINTEC) in Brazil. Both surveys are inspired by the Oslo Handbook (FINEP, 2005). The Handbook was developed in the early 1990s and was intended to serve as guidance for the data gathering on technological innovation.

financ_proj_without_coop + β_{11} *financ_with_coop_proj* + β_{12} *scholarship* + β_{13} *other_suppor* + β_{14} *patent_invention* + β_{15} *patent_model* + β_{16} *scarcity_financ* + β_{17} *scarcity_skilled* + β_{18} *impact_1* + β_{19} *impact_2* + β_{20} *impact_3* + β_{21} *impact_4* + β_{23} *market_br* + ε *(1)*

In this specification, the dependent variables are *patents*, *innov_net_sales*, and *innov_exports*[7]. Table 2 presents the description of the variables used in the regressions.

3.2 ATT matching estimator

The second empirical strategy makes use of the ATT matching estimator. A discussion about ATT matching estimators can be found on Rubin (1977), Rosenbaum and Rubin (1983), Heckmann and Ichimura (1997), Wooldrige (2002), Heckmann and Navarro-Lozano (2004), Imbens (2004), Abadie et al. (2004) and Imbens and Wooldrige (2008). The first step to estimate the ATT is to calculate the propensity score matching (PSM), obtained by separating the firms into two groups according to the importance attached to universities or research institutes as partners for innovative activities. A categorical variable about the importance of UIL to the firm, reported in PINTEC's questionnaire, was used to classify the firms in each group. For each firm in the treatment group (firms with collaboration with universities) we identify firms in the control group (firms without collaboration with universities) whose characteristics are similar. The idea of matching is to identify firms with no collaboration with the university with the same probability to interact with universities as the collaborative firms.

Table 2 Definition of the variables

Variable	Definition
Patents	Dummy variable considering whether the firm applied for a patent during the period of the survey
Innov_net_sales	Sum of percentages of internal sales of new or significantly improved products
Innov_exports	Sum of percentages of exports of new or significantly improved products
UIL (University-Industry Linkage)	The firm attached "high" or "medium" importance to universities or research institutes as partners for innovative activities
Innov_input	Sum of values (R$1,000) of expenditures on: R & D, external acquisition of R&D, acquisition of other external knowledge, software acquisition, purchase of machinery and equipment, training, introduction of technological innovations in the market, and other preparations for production and distribution
Hum_cap	Employees with university education
Employment_sit	Employed persons informed in the PIA/PAS [8]
Firm size: (i)Micro_small_comp, (ii) Medium_comp, (iii) Large_comp	Dummy variables for employed persons in the firm: (i) micro and small company (10-99 employees), (ii) medium company (100-499 employees), (iii) large company (500 or more employees)
Inc_fiscal_1	The firm used tax incentives for R&D and technological innovation as government support for their innovative activities
Inc_fiscal_2	The firm used the tax incentive of Informatic Law as government support for their innovative activities
Econ_subvention	The firm used subsidies to R&D and to the inclusion of researchers as government support for their innovative activities
Financ_proj_without_coop	The firm used financing to R&D and technological innovation projects without partnership with universities as government support for their innovative activities
Financ_proj_with_coop	The firm used financing to R&D and technological innovation projects with partnership with universities as government support for their innovative activities
Scholarship	The firm used scholarship grants offered by foundations that support research at firms as government support for their innovative activities
Other_support	The firm used other types of government support for their innovative activities
Patent_invention[9]	The firm has a patent to protect product and/or processes innovations
Patent_model[10]	The firm used a model patent to protect product and/or process innovations
Scarcity_financ	The firm attached "high", "medium" or "low" importance to the shortage of appropriate funding sources as an obstacle to innovative activities

[7] When *innov_exports* is the dependent variable, it is excluded from the list of independent variables.
[8] Annual Industrial Survey (PIA) and Annual Services Survey (PAS), conducted by the Brazilian Institute of Geography and Statistics (IBGE).
[9] It does not apply to 2011.
[10] It does not apply to 2011.

Scarcity_skilled	The firm attached "high", "medium" or "low" importance to the lack of qualified personnel as an obstacle to innovative activities
Impact_1	The firm attached "high", "medium" or "low" importance to the impacts of innovations implemented to expand market share
Impact_2	The firm attached "high", "medium" or "low" importance to the impacts of innovations implemented to opening new markets
Impact_3	The firm attached "high", "medium" or "low" importance to the impacts of innovations implemented to expanding the range of products
Impact_4	The firm attached "high", "medium" or "low" importance to the impacts of innovations implemented to improving the quality of products
Market_br	The main market of the firm is domestic

A logistic model was used for calculating the PSM. The dependent variable refers to the probability of the firm to interact with the university. The firms are matched according to the PSM. The model must contain the relevant variables to explain the propensity to interact with universities and these variables should be chosen based on firm's characteristics that influence the decision to engage in collaboration with the university. Following the literature, the variables in the OLS regression described in the previous section were used to estimate the logistic model. The methodology used in the empirical model is described in Abadie et al. (2004).

In formal terms, we consider a firm i, $i=1,\ldots,N$ and an innovation performance variable Y (patent application, for example). There are two possible outcomes: $Y_i(1)$ is the performance of firm i when it attributed high or medium importance for universities or research institutes as partners for innovative activities (UIL =1); $Y_i(0)$ is the performance of firm i when it attributed low importance or did not developed partnerships for innovative activities (UIL=0). We are interested in the difference $\tau(i) = Y_i(1) - Y_i(0)$. The problem is that $\tau(i)$ can't be calculated, since $Y_i(1)$ and $Y_i(0)$ are not both observable for the same firm. We use the matching approach to solve this problem.

Matching the firms requires a conditional independence assumption. Conditional on a vector of explanatory variables X to innovation performance, the fact that the firm maintains or not a collaborative relationship with the university must be independent of the non-collaborative firm performance. This is why the logistic model should include all the variables that are relevant to explain both collaboration and performance of non-collaborative firms. Each individual of the treatment group (firms with collaboration with the university) will have a pair in the control group (firms without collaboration with the university) with similar values of the variables that compose X. In this sense, conditional on X, $Y_i(0)$ for UIL=0 has the same distribution of $Y_i(0)$ for UIL=1. Comparing the two groups allow us to estimate the average effect of treatment on the treated (ATT).

3.3 Database

The data used in this study was provided by the Technological Innovation Survey (PINTEC), conducted by the Brazilian Institute of Geography and Statistics (IBGE). PINTEC builds national and regional industry indicators about technological innovation activities in Brazilian firms and is considered the main source on innovation in Brazil. We used 2008 and 2011 surveys in our investigation. PINTEC 2008 refers to information collected from 2006 to 2008, and PINTEC 2011 refers to 2009 to 2011 period. In PINTEC's questionnaire, firms are asked about the importance of universities or research institutes as partners for innovative activities[11]. We considered firms with university-industry linkages (UIL) those that pointed out alternatives 1 (high importance) or 2 (medium importance) in the questionnaire. Those that marked alternative 3 (low importance) or alternative 4 (did not develop partnership with the university), and those who did not answer the question were considered firms without UIL[12].

The 2008 data has 7,957 innovative firms, including manufacturing and services sectors. The sample used in this study consisted of 626 firms with UIL (treatment group) and 7,331 without UIL (control group). In the group of innovative firms stand out the food products manufacturing industries (786 firms), the information technology services (629 firms) and machinery and equipment manufacturing (568 firms). In the group of innovative firms with UIL, the activities of information technology services (82 firms) and manufacture of computer equipment, electronic and optical products (57 firms) are noticeable.

The sample of 2011 contains 6,882 firms in the manufacturing and services sectors. The available data cover a total of 735 firms with UIL (treatment group) and 6,147 firms without UIL (control group). The main activities in the group of innovative firms are support to the extraction of minerals (682 firms) and machinery and equipment manufacturing (572 firms). In the group of innovative firms with UIL stands out the sector of food products manufacturing (86 firms).

4 Findings

According to the OLS estimates in 2008 (Table 3), the *UIL* coefficient is positive and significant for patent applications and for net sales and exports, suggesting that there is a positive effect of collaboration between firms and universities on innovation. In addition to *UIL*, the variables *inc_fiscal_2, patent_invention* and *patent_model* also showed positive and significant coefficients for the three dependent variables. The variable *innov_exports*, which was included as an independent variable in the first two models, also showed positive and significant coefficients. Thus, when firms used tax incentives of Informatics Law as government support for their innovative activities (*inc_fiscal_2*) and when they had patents to protect product and/or process innovations (*patent_invention* and *patent_model*), the firms achieved positive results in terms of patent applications and domestic sales and exports of new or significantly improved products. In the case of exports (*innov_exports*), the estimates show it has positive effects on the patent application and on net sales.

The results of 2011 show that the *UIL* coefficients are positive and significant for net sales and exports, confirming the results of 2008 with respect to the relevance of the interaction of the firm with the university on innovation. Other independent variables also exhibited positive and significant coefficients. This is the case of the coefficient of *inc_fiscal_2*, which reinforces the results obtained in the 2008 regression. The coefficient of the variable *financ_proj_without_coop*, that refers to firms that used funding to R&D and technological innovation projects without partnership with universities or research institutes, show that the firms that requested such funding obtained positive results on net sales and on exports. The variable *impact_2*, which refers to the "high", "medium" or "low" importance that the firm attaches to the impacts of product and process innovations implemented to open new markets,

[11] Variable number 140 in PINTEC's survey.
[12] Similar to what was done by Yonamini and Gonçalves (2010).

presented coefficients that suggest that this kind of innovation has positive effects on net sales and exports.

Taking into account the results of 2008 and 2011, the variable *market_br*, with respect to the main market of the firm, should be highlighted. In the case of the dependent variable *innov_net sales*, the coefficient of *market_br* was positive and significant. This result makes sense, since it refers to the income of domestic sales of new or significantly improved product. If the focus is the domestic market, it is expected positive effect of the product with innovation on domestic sales. On the other hand, the coefficient for this variable is negative and significant for the dependent variable *innov_export*. According to the model, there is a negative relationship between the performance of exports linked to innovation and the fact that the main market of the firm is domestic.

Table 4 shows the results of the logistic model used to compute the propensity score with 2008 and 2011 data. In 2008 estimates, the largest part of the independent variables showed positive and significant coefficients for the dependent variables *patents*, *innov_net_sales* and *innov_exports*. Two results stand out. The first refers to the variable *market_br*, which presented negative and significant coefficients, indicating that the firm

Table 3 OLS regression results for different dependent variables (2008 and 2011)

	2008						2011			
	Patents		Innov_net sales		Innov_exports		Innov_net sales		Innov_exports	
Variable	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE
UIL	0.06396 ***	0.01084	2.54898 **	1.21639	1.37202 *	0.70208	2.21699 **	1.13316	2.69817 ***	0.66350
Innov_input	-1.64e-08 *	6.66e-08	0.00002 **	7.48e-06	-1.57e-06	4.32e-06	0.00002***	5.71e-06	-7.17e-06 **	3.34e-06
Hum_cap	0.00013 ***	0.00004	-0.00336	0.00532	-0.00143	0.00307	-0.00733 *	0.00453	0.00535**	0.00265
Innov_exports	0.00077 ***	0.00017	0.53224 ***	0.01945	-	-	0.47565 ***	0.02059	-	-
Employment_sit	-2.40e-06	1.91e-06	-0.00031	0.00021	0.00005	0.00012	-0.00034 **	0.00020	-0.00011	0.00012
Micro_small_comp	-0.00392	0.00577	6.66584	0.64700	-0.97820 *	0.37337	1.75542 **	0.71134	-0.67370 *	0.41693
Large_comp	0.01123	0.00847	-0.54023	0.95012	0.57933	0.54849	0.85283	1.06502	2.71819 ***	0.62349
Inc_fiscal_1	0.05017 ***	0.01423	1.48505	1.59711	3.16335 ***	0.92136	1.15779	1.12167	2.46334 ***	0.65689
Inc_fiscal_2	0.00351 *	0.01647	5.17261 ***	1.84815	2.45201 **	1.06663	5.86461 ***	1.87939	4.03188 ***	1.10069
Econ_subvention	-0.00381	0.01889	0.82573	2.11995	2.04503 *	1.22368	2.37082	1.91530	5.27508 ***	1.12101
Financ_proj_without_coop	0.02728	0.01876	0.63810	2.10437	2.62874 **	1.21454	7.26251 ***	1.75521	3.37477 ***	1.02816
Financ_proj_with_coop	0.04205 **	0.02013	-0.91314	2.25868	0.59252	1.30397	-2.24662 ***	2.12170	1.56785 **	1.24367
Scholarship	0.02688	0.02699	-2.41526	3.02824	7.28969 ***	1.74636	-3.29462	3.45251	-5.37700 ***	2.02295
Other_support	0.01565	0.00984	0.65553	1.10439	0.08755	0.63759	-0.70063	1.24722	0.59261	0.73113
Patent_invention	0.35379 ***	0.00822	2.33002 **	0.92220	2.25102 ***	0.53181	-	-	-	-
Patent_model	0.72819 ***	0.01087	2.52897 **	1.21981	2.59231 ***	0.70362	-	-	-	-
Scarcity_financ	0.01508 **	0.00696	-0.77502	0.78086	-0.41635	0.45079	-0.04700	0.96609	-0.42288	0.56634
Scarcity_skilled	-0.0067721	0.0066616	-1.384.331 *	0.74745	0.55674	0.43148	0.95216	0.94266	0.58417	0.55258
Impact_1	-0.01841 **	0.00912	-1.20962	1.02351	-0.68410	0.59084	3.46108 ***	1.10290	-0.01382	0.64656
Impact_2	0.01912 ***	0.00793	-0.14189	0.89024	1.81361 ***	0.51355	1.83411 *	0.96599	1.63806 ***	0.56595
Impact_3	0.02735 ***	0.00756	2.50377 ***	0.84880	0.77492	0.48995	9.08804 ***	0.92364	1.32627	0.54124
Impact_4	-0.01124	0.00793	-3.00031***	0.89057	0.95455 *	0.51403	2.93165 ***	1.00370	0.50696	0.58831
Market_br	-0.01100	0.01198	6.96203 ***	1.34368	-1.05619***	0.76662	4.49948 ***	1.51033	-7.44462 ***	0.88083
Constant	0.02600 *	0.01366	7.81678 ***	1.53218	1.08825 ***	0.87608	-3.82853 **	1.72698	7.02573**	1.00886
Number of observations	7,957		7,957		7,957		6,882		6,882	
R^2	0.547		0.108		0.059		0.1400		0.0552	

Note: * p < 0,10; ** p < 0,05; *** p < 0,01; (-) not available

Table 4 Logit estimation of the propensity score (2008 and 2011)

	2008				2011			
	Patents and Innov_net sales		Innov_exports		Innov_net sales		Innov_exports	
Variable	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE
Innov_input	-1.03e-07	1.08e-06	-1.14e-07	1.08e-06	-6.45e-07	6.08e-07	-7.09e-07	6.16e-07
Hum_cap	0.00425***	0.00161	0.00431***	0.00160	0.00033	0.00050	0.00040	0.00053
Innov_exports	0.00295	0.00249	-	-	0.00668 ***	0.00204	-	-
Employment_sit	0.00003	0.00002	0.00003	0.00002	0.00006 **	0.00002	0.00005**	0.00002
Micro_small_comp	-0.044695	0.11615	-0.79011***	0.13238	-0.25395 **	0.10654	-1.24239***	0.12617
Medium_comp	-	-	-0.74166 ***	0.13215	-	-	-0.98582 ***	0.11507
Large_comp	0.74083***	0.13216	-	-	0.96340 ***	0.11546	-	-
Inc_fiscal_1	0.30473 *	0.17337	0.31691 *	0.17282	0.67448 ***	0.11207	0.68951 ***	0.11199
Inc_fiscal_2	0.76852***	0.20915	0.77530 ***	0.20902	0.55091 ***	0.18552	0.56862 ***	0.18583
Econ_subvention	1.09014 ***	0.21180	1.10022 ***	0.21159	0.52555 ***	0.18510	0.56901 ***	0.18380
Financ_proj_without_coop	0.48057 **	0.23521	0.48723 **	0.23531	0.18957	0.18471	0.22233	0.18315
Financ_proj_with_coop	2.55098 ***	0.19923	2.55309 ***	0.19908	1.83056	0.17782	1.83670 ***	0.17779
Scholarship	1.56357 ***	0.30895	1.59158 ***	0.30806	0.82258 **	0.32223	0.78494 **	0.32204
Other_support	0.38580 **	0.15902	0.38633 ***	0.15897	0.30435 **	0.15201	0.31044 **	0.15145
Patent_invention	0.66255***	0.11743	0.66819 ***	0.11729	-	-	-	-
Patent_model	0.28394 *	0.15321	0.29429 *	0.15287	-	-	-	-
Scarcity_financ	0.59413 ***	0.11816	0.59203 ***	0.11809	0.27670 **	0.12461	0.27168 **	0.12427
Scarcity_skilled	0.06388	0.11753	0.06613	0.11746	0.31917 ***	0.12289	0.32111 ***	0.12254
Impact_1	0.06796	0.18442	0.06714	0.18439	-0.05471	0.16026	-0.05495	0.16022
Impact_2	0.08081	0.15356	0.08791	0.15334	0.39325 ***	0.14442	0.41112 ***	0.14417
Impact_3	0.43147***	0.16192	0.43548 ***	0.16188	0.08806	0.13674	0.09971	0.13664
Impact_4	0.21766	0.17069	0.22312	0.17068	0.17349	0.15071	0.18146	0.15054
Market_br	-0.29423 *	0.17933	-0.32447 *	0.17756	-0.07686	0.17713	-0.13166	0.17611
Constant	-3.84027 ***	-0.24611	-3.07183 ***	0.24324	-3.34826 ***	0.22866	-2.31581 ***	0.23193
Log-Likehood	-17.05589		-17.06268		-19.51525		-19.56550	
Number of observations	7,957		7,957		6,882		6,882	

Note: * p < 0,10; ** p < 0,05; *** p < 0,01; (-) not available whose main market is domestic is less likely to UIL. The second relates to the size of the firm. The logistic model for patents and net sales showed a positive and significant coefficient for the variable *large_comp*, pointing out that companies with 500 or more employees are more likely to UIL, compared to medium and small and micro companies. The logistic model for exports, which has the large company as reference, presented negative and significant coefficients for *micro_small_comp* and *medium_comp* variables. This reinforces the result of higher tendency of large companies to UIL.

The logistic model for 2011 also presented most of the independent variables with positive and significant coefficients. The results accentuate the importance of the size of the firm for the propensity to UIL. In the model for net sales, in which the variable *medium_comp* was the reference, the coefficient of *large_comp* was positive and significant, while the coefficient of *micro_small_comp* was negative and significant. In the model for exports, the *large_comp* was the reference, and the coefficients of *micro_small_comp* and *medium_comp* were negative and significant. In both models, the results of 2008 were confirmed: the larger the company, the higher the propensity to interact with the university. This result corroborates what was found in Varzim and Monsueto (2011).

In order to obtain the estimated ATT, the propensity score was used for pairing the group of innovative firms with UIL with the group of similar firms that are not engaged in UIL. We used four matching algorithms to increase the robustness of the results and give more consistency to the analysis: (1) One-to-one, (2) Nearest neighbor, (3) Radius, and (4) Kernel. The results are in Tables 5 and 6. In all types of matching, the effect of UIL on innovation was positive for the dependent variables *patents*, *innov_net_sales*, and *innov_exports* in 2008 (Table 5). The same is observed in 2011 (Table 6) for the dependent variables *innov_net_sales* and *innov_exports*. However, in 2008 the ATT was significant only for the variable *patents* in kernel-based matching. In 2011 the ATT was significant for the variable *innov_exports* in all kinds of matching and for the variable *innov_net_sales* in kernel-based matching. Although some results seem to prove that the relationship with the university affects the innovation performance of firms, other results do not allow establishing this conclusion. The results for 2011, for example, suggest that the influence of collaboration with the university is significant for the exports of products with innovation. However, the 2008 results do not confirm this inference.

The results found in this study are related to what was described in the literature presented in section 2, which reports mixed results on the effects of UIL on innovation. In the case of patents, where data is available only in the 2008 survey, the results confirm what was found by Marins (2010). According to him, despite being a traditional indicator of innovation in developed countries, patent applications are not as relevant in developing countries. Lööf and Broström (2008) also refer to inconclusive results of UIL on innovation when samples are separated by type of firm. They found that collaboration with the University positively influences the sales innovation as well as the propensity for submission of patents for industrial companies with 100 or more employees. However, considering the total number of companies, including manufacturing and services, the results show no significant association between collaboration with universities and innovation. According to the authors, "some of the estimates suggest interaction between universities and firms affects innovation performance and some does not. The differences are on the one hand explained by firm size and by sector, on the other hand by the different applications of matching estimators" (Loof, Broström, 2008, p 87). In our paper most ATT estimates were not significant, revealing a weak association of UIL with innovation.

Table 5 Treatment effects estimations for different dependent variables in 2008

	Patents				Innov_net sales				Innov_exports			
Matching algorithm	One-to-one	Nearest Neighbour	Radius	Kernel	One-to-one	Nearest Neighbour	Radius	Kernel	One-to-one	Nearest Neighbour	Radius	Kernel
ATT	0.0461	0.0470	0.0232	0.0751***	2.138	2.1249	-	1.1264	1.7921	1.8086	1.0665	0.8920
Number of treated obs.	626	626	626	626	626	626	-	626	626	626	626	626
Number of untreated obs	7,331	7,331	7,331	7,331	7,331	7,331	-	7,331	7,331	7,331	7,331	7,331
Quality of matching												
Pseudo R2 before	n/d	0.224	0.224	0.224	0.224	0.224	-	0.224	0.224	0.224	0.224	0.224
Pseudo R2 after	n/d	0.028	0.008	0.013	0.028	0.028	-	0.013	0.025	0.024	0.006	0.014
Mean absolute standardised bias before matching	35.1	35.9	35.1	35.9	35.9	35.9	-	35.9	35.9	35.9	35.9	35.9
Mean absolute standardised bias after matching	8.7	8.8	4.1	5.5	8.8	8.8	-	5.5	8.1	8.0	2.8	5.9

Note: * p < 0,10; ** p < 0,05; *** p < 0,01; (-) not available

Table 6 Treatment effects estimations for different dependent variables in 2011

	Innov_net_sales				Innov_exports			
Matching algorithm	One-to-one	Nearest Neighbour	Radius	Kernel	One-to-one	Nearest Neighbour	Radius	Kernel
ATT	1.8066	1.6225	1.3146	2.9227 **	3.5973 ***	3.6000 ***	3.0369 ***	3.5269 ***
Number of treated obs.	735	735	735	735	735	735	735	735
Number of untreated obs	6,147	6,147	6,147	6,147	6,147	6,147	6,147	6,147
Quality of matching								
Pseudo R2 before	0.168	0.168	0.168	0.168	0.168	0.168	0.168	0.168
Pseudo R2 after	0.011	0.012	0.007	0.003	0.023	0.023	0.009	0.007
Mean absolute standardised bias before matching	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3
Mean absolute standardised bias after matching	4.3	4.4	3.6	2.3	5.4	5.6	3.0	3.1

Note: * p < 0,10; ** p < 0,05; *** p < 0,01

The quality of the matching procedures can be assessed in the last lines of Tables 5 and 6 by the pseudo R^2 and by the mean absolute standardized bias, before and after matching. It is expected a lower pseudo R^2 (near zero) after matching, which occurred in all cases. There should be no systematic differences in the distribution of covariates between the two groups, therefore the pseudo R^2 must be reasonably low (Caliendo and Kopeining, 2005). Finally, we observed bias reduction after matching in all estimates.

5 Conclusions

The aim of this study was to evaluate the university-industry linkages (UIL) in terms of their effects on innovation, focusing on the performance of Brazilian firms. Although some of the literature on the subject supports the hypothesis that there is influence of cooperation with the university on the innovative capacity of the firm, some studies do not identify causal relationship between UIL and innovation. The results of our study indicate that, in Brazil, collaboration with the university has a weak relationship with innovation, when it is measured by patent applications and net sales and exports of new or significantly improved products.

We used two empirical strategies to evaluate the effect of collaboration with the university on innovation. In the first strategy, we run cross-sectional ordinary least squares regressions with 2008 and 2011 data. The results showed a positive and significant influence of the collaboration with the university on the innovative performance of the firm. However, the second empirical strategy, which consisted in the use of matching estimators to determine the average effect of treatment on the treated (ATT), exhibited ambiguous results. Estimates made with the 2008 sample, despite having positive coefficients for the UIL, showed no significant association between collaboration with universities and innovative firm performance, measured in terms of patent applications and net sales and exports of new or significantly improved products. According to estimates in 2011, which did not include patent applications for lack of data, there is also no association between UIL and net sales of innovative products. Considering different matching algorithms, the only robust result was a positive and significant effect of UIL on the export of new products in 2011.

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