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**FIRMS' LINKAGES WITH UNIVERSITIES AND PUBLIC RESEARCH INSTITUTES IN
ARGENTINA: DRIVERS AND EFFECTS OF INTERACTING FROM A FIRMS'
PERSPECTIVE**

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Introduction

Universities and public research institutes (hereafter public research organisations, PRO) have a key role in the creation and diffusion of knowledge via traditional activities, such as teaching and research (Dasgupta and David, 1994, Nelson, 2004, Pavitt, 2001). During the last decades and as a response to specific demands from the industry, to PRO's funding needs and to policy recommendations by international multilateral organisations, new activities that involve linkages with the private sector have emerged in many emerging countries included Argentina.

In Argentina there are very few academic studies available related to the process of knowledge creation and diffusion in PRO, and even less that explicitly research about private-public interactions.³ The majority of those few papers related to the interaction between firms and PRO are based on case-studies, which either study the impact of linkages on firms' innovative capabilities⁴ or analyze the interaction dynamics from the point of view of the PRO.⁵ To the best of our knowledge, there are not studies that compare the knowledge activities of firms that interact against those that do not interact with PRO using robust statistical procedures.

Given this relative scarcity of systematic research on relations between PRO and firms in Argentina and their potential for improving the National Systems of Innovation (NSI), we intend to conduct a study of an exploratory nature that allows us to understand the drivers and effects of interactions. More specifically, on the one hand, we identify micro and meso determinants of interacting with PRO and motivations and obstacles for the interactions; and, on the other hand, we discuss what is different about linked firms in what respect to their innovative and financial behaviour and their perceptions about PRO outcomes and roles. Since we will provide a comprehensive mapping of the characteristic of interactive against non-interactive firms, we believe this paper will be particularly useful for policy makers in the area.

³ A list of those studies includes: Albornoz, 1993, Bisang, 1995, Estébanez, 1996, García de Fanelli, 1993a, García de Fanelli, 1993b, García de Fanelli, 1994, Llomovatte *et al.*, 2006, Tenti Fanfani, 1993 Bisang *et al.*, 1995, Chudnovsky and López, 1996, Decibe and Canela, 2003.

⁴ For example, Moori-Koenig and Yoguel, 1998 and Yoguel and López, 2001 conclude that linkages have positive impacts on innovative capabilities within regional clusters. In contrast, Lugones and Lugones, 2004 find that only one public firm managed to reach international competitiveness levels in spite of the linkages that PRO had with many private firms in the region.

⁵ For example, Dávila, 2006, who identifies incentives and obstacles that promote and limit interactions in the School of Agronomy of Buenos Aires University, Juarros, 2006, who analyzes the extent to which knowledge interactions between firms and PRO have modified the academic orientation of researchers involved in the case of the School of Pharmacy and Bio-chemistry of Buenos Aires University and Riquelme, 2008 who presents the results of an ambitious project studying the responses of three national universities to social and productive demands.

We use an original and representative dataset especially produced for this project. We follow a thorough methodology that allows us to control for biases that may emerged when setting cross-section comparisons. Our first research goal on the determinants of linking is achieved by estimating a Probit model on the probability of linking. The second research goal, which refers to the behaviours and perceptions of firms that interact with PRO as opposed to unlinked firms, is achieved using propensity score matching techniques.

The paper is divided in six more sections besides this introduction. Next section briefly discusses the international literature on PRO-firm linkages. The third section presents the strategy of data collection and discusses the main sample characteristics. The fourth section presents the methodology in which we discuss the propensity score matching techniques. The fifth section discusses the main determinants of the probability to interact and therefore assess our first research goal. The sixth section examines the empirical evidence on the average effect of interacting tackling the second research goal. Finally, last section, discusses the conclusions and main guidelines for policy making.

II) Conceptual framework and research goal

The traditional division of labour between PRO doing basic research and industry focusing on applied research seeking to convert scientific knowledge into usable technologies, which constitute the basic assumption of the linear model of innovation, has been largely questioned since the early 1990s.

On the one hand, it became clearer that many fields of research only advance scientifically in the context of application (Nelson, 2004, Rosenberg and Nelson, 1994). Therefore, basic research cannot be separated from applied research. Moreover, not only the knowledge required for scientific progress became ever more multidisciplinary but also technological change speeded up. This redounded in larger demands on R&D investment from multiple players.

On the other hand, the liberal ideology questioned the role of the State as the main founder of science and promoted a more active participation of the private sector as a key actor and guide of research activities (Dasgupta and David, 1994, Etzkowitz *et al.*, 2005, Nelson, 2004, Slaughter and Leslie, 1997). The emergence and expansion of venture capital and the widening of intellectual property rights, which accompanied this process, made entrepreneurial and commercial activities fairly attractive for some researchers, especially in developed countries.

Different conceptual framework emerged in the literature as a consequence of these changes, aiming at understanding the way scientific and technological knowledge should be produced and supported.

The first one directly tackling the change in the way knowledge was being produced was proposed by Gibbons (1994). This framework claimed knowledge production changed from the cognitive context governed by the academic interests of a disciplinary community (Mode 1) to a broader social and economic context of application of knowledge, which intends to be useful and usually involves more than one discipline and more than one community (Mode 2).

Later, Etzkowitz and Leydesdorff (1997)⁶ developed the concept of the ‘Triple Helix’. This framework claimed that innovation increasingly takes place in a knowledge infrastructure where three spheres (University, Industry and Government) are overlapped and taking the traditional roles of each other (the so called “Triple Helix”). Since there is no a-priory synchronisation of participants, puzzles might be generated but they would be solved within the network dynamics. The policy recommendation, therefore, is to support the creation of networks and to make institutions as permeable as possible so they could freely take the role of each other. More specifically, the Triple Helix perspective supports the so call “third mission of universities” –beyond teaching and research- and highlights the benefits associated to a more direct interaction and contribution to the industry.

Moreover, the literature of NSI was also very critical of the linear model of innovation. This literature places firms as central actors of innovation; but it claims that a necessary condition for successful innovative performance at country level is dependent on the development of a system of relationships between all organizations so as to allow a broad exchange of knowledge (Lundvall, 1992, Nelson, 1993). PRO and their interactions with the private sector play a central role in the creation and diffusion of knowledge in any system of innovation (Cooke, 2001, Charles, 2003). This is due to many reasons:

Firstly, of course, universities train graduates who are then employed and who contribute to innovative activities within the private sector. This occurs even if universities do not strategically orient their research and teaching programs to topics considered relevant by the industry.

Secondly, PRO renew the stock of scientific knowledge in a country. All users of scientific and technological knowledge need to build capabilities to assimilate and exploit different sources of knowledge. These capabilities are developed in a continuous, open minded and

⁶ Further developed in subsequent articles such as Etzkowitz *et al.*, 2005, Etzkowitz and Leydesdorff, 2000, Etzkowitz, 2001.

curiosity led learning process, which justifies public support for basic scientific research even in developing countries (LDC).

Moreover, as said above many fields of research need to draw on applied knowledge to advance in scientific developments. In this sense, the production of knowledge by PRO becomes more dynamic when interacting with firms due to challenges created in the resolution of specific production problems. This is especially true for the fields of research that the literature located in the 'Pasteur's Quadrant' (Stokes, 1997), which advance by doing basic and applied research simultaneously.⁷

Thirdly, the specific problems of industry are often so complex that require a combination of technologies that no individual firm could develop individually but that could well be generated from the pool of knowledge and resources created by the PRO (Patel and Pavitt, 1995). Some of these resources are new laboratory tools and analytical methodologies that constitute fundamentals inputs for the industry (Rosenberg, 1992). Moreover, PRO also produce knowledge related to the economic and social context where firms sell and produce, which could determine the final success of any innovation process (Fritsch and Schwirten, 1999).

Most of the theoretical and empirical research on the relationship between PRO and firms has been done in the context of developed economies.⁸ However, the situation in LDC is markedly different.

On the one hand, the socio-economic needs and therefore the policy strategies are different: unlike what happens in developed countries, large fractions of the population of LDC live in conditions of poverty or indigence. Also, income distribution is highly unequal and education and health systems are deficient, perpetuating inequality. In addition, pollution is distressing in LDC, which is largely explained by the use of outdated and polluting production technologies with no resources for environmental remediation. All these create specific demands to PRO, which are not necessarily comparable with the demands economy activity puts forward to PRO in developed countries.

On the other hand, both PRO and firms in LDC have specific and distinctive characteristics of their counterparts in developed countries. In Argentina, for example, the historical evolution of scientific production by PRO was once –and in certain fields still is– outstanding.⁹ Notwithstanding scientific quality, the most notable feature of the science and technology system is policy inconsistency over time and lack of persistence in the roles

⁷ For example, all types of engineering, biotechnology, metallurgy, computer science, etc.

⁸ The list of references is long, for example see: Acworth, 2008, Bramwell and Wolfe, 2008, Etzkowitz and Leydesdorff, 1997, Etzkowitz, 2003, Fritsch and Schwirten, 1999, Kaufmann and Todtling, 2001, Loof and Brostrom, 2008, Mansfield, 1998, Motohashi, 2005, etc.

⁹ For example, three Argentinean scientists working in Argentinean PRO won Nobel Prizes.

assigned to the PRO as key actors for development (López, 2007). In this context, the promotion of interactions between PRO and firms, although intensified in recent decades, was not part of a national plan for science and technology development, but was rather the result of isolated policy instruments.

Similarly, the average technological dynamism of firms in developing countries is not comparable to their counterparts in developed countries. In fact, the literature on linkages between PRO and firms in Latin America often claims that one important limitation for a wide diffusion of linkages is the lack of demand for sophisticated technological knowledge from the industry (e.g. Dagnino and Velho, 1998, Moori-Koenig and Yoguel, 1998). In the same vein, other authors note that the productive structure in Latin America is rather poor in the use of knowledge assets and therefore draws less from PRO –which, in turn, finds few opportunities to apply research in fields of the Pasteur’s quadrant (e.g. Arocena and Sutz, 2005, Casas *et al.*, 2000).

These differences suggest that modes of interactions and also their expected results are not likely to be what the literature from developed countries claims, which justifies specific research done on PRO-firm interactions in LDC. As said in the introduction, there is no systematic research on the characteristics of PRO-industry linkages in Argentina. Therefore, our aim is, firstly, to investigate the determinants of linking (in Section 5), and secondly, to assess differences in behaviour and perceptions between linked firms against those that do not interact with PRO (in Section 6). More specifically, we will assess whether firms that connect to PRO are more or less innovative than firms that do not, tend to patent more than their counterparts, whether they have different access to funds for innovation and whether they value differently the research outputs from PROs. All these elements, we believe, will be very informative for science and technology policy and in the Conclusions we present some implications in this sense that are derived from this research. The next two sections present the data (Section 3) and the methodology (Section 4).

III) Data collection and sample characteristics

3.1) Data Collection

This paper is based on information from the National Innovation Survey (hereafter *The Survey 2006*) whose fieldwork was carried out in December 2007 and managed by the National Institute of Statistics and Censuses (INDEC). The sample was designed so as to be representative of the Argentinean manufacturing sector (2055 firms were included in the original sample). The response rate was 73% (1496 firms answered the form).

In order to pursue this research, an especial section on firms-PRO interactions was included in the Survey and sent to 590 firms that had declared to have interactions with PRO¹⁰ in the innovation survey for the previous year (*The Survey 2005*). They represented 35% of the total number of firms included in *The Survey 2005*. The response rate to this section was 60% (354 firms).

Besides, another section with questions about firms-PRO interactions was sent to a control group of firms that did not have interactions with PRO in 2005. This control group was built taken into account the size and sector characteristics of linked firms. This form was sent to 384 firms and the response rate was 62% (238 firms).

3.2) Main descriptive statistics

In this section we present the main sample characteristics of the data used in the analyses. All variables to be analysed in this paper are listed and fully described in the appendix. Unless otherwise stated, all data in this paper refers to year 2005.

Table 1 classifies firms in the sample according to their size: small (less than 40 employees), medium (less than 116 employees) and big (more than 116 employees) using information for 2005.¹¹ It shows that a minority of linked firms are small, consequently that was also the case for control firms which were selected to match the sector and size characteristics of firms. In comparison to the size distribution of the full sample, there is an overrepresentation of big firms among linked firms.

(Insert Table 1 around here)

Table 2, in turn, organises firms according to their sector affiliation. The last column in the table relates the proportion of firms per sector among linked firms with the proportion of firms per sector in the full sample. Expectedly, the sectors in which firms are particularly likely to be linked to PRO are known to be knowledge based sectors (i.e. chemicals (24), machinery (29) and electrical machinery (31)).¹²

¹⁰ The definition of interactions was very broad, it ranged from joint R&D projects to informal information exchange Organizations included as PRO are: Universities, INTI (National Institute for Industrial Technology), INTA (National Institute for Agricultural Technology), ANPCyT (National Agency for the Promotion of Science and Technology), and other government organisations for science and technology.

¹¹ The limits were chosen accordingly to divisions by deciles in the full sample for *The Survey 2005*: small firms are firms in the first three deciles, medium firms in the next three, and larger firms in the last four deciles of the full sample.

¹² We have excepted sector 16 in this comment because *The Survey* includes very few firms from this sector

(Insert Table 2 around here)

Table 3 presents a matrix that relates sectors with fields of research for linked firms and it is inspired in Cohen (2002). Cells inform the percentage of firms per sector that answered that each field of research was moderately or highly important for innovation activities during the last ten years. Reading from the whole sample of linked firms (regardless of sectors) the most important fields of research are (in order of importance) industrial design, chemical engineering, mechanical engineering, and engineering of material and metallurgy.

The association of sectors to the fields of research works more or less as expected. For example, sector 24 (chemical industry) -in comparison to all linked firms- gives predominant importance to chemical engineering, chemistry, biology, physics, medicine, and veterinary; sector 29 (general machinery), to industrial design, mechanical engineering, engineering of material and metallurgy, electrical engineering, physics, mining engineering, and mathematics; sector 31 (electrical machinery), to industrial design, mechanical engineering, and electrical engineering. Another relevant sector that we may mention is 15 (food products), which gives particular importance to food science and technology, agronomy, biology, veterinary, chemical engineering and chemistry.

(Insert Table 3 around here)

Table 4 classifies linked and control firms according to different indicators of innovativeness. It is striking the large number of firms that consider themselves innovative. Around 64% of our sample (including linked and control firms) claims to have introduced new (or have improved significantly) processes or products. We believe this percentage is over-represented, highlighting the subjective nature of these kinds of indicators. For example, 16% of innovative firms have not spent anything on in-house innovative activities. In general, linked firms seem to be more innovative, especially in processes. However, Table 4 does not totally control for relevant variables that may affect linkages and innovativeness. This will be done later in Section 6.

(Insert Table 4 around here)

Table 5 presents the importance of different modes of interaction as stated by linked firms. The options presented in the table comprise all options available in the questionnaire. The

importance allocated to different modes, which in the questionnaire ranked from 1 to 4, were re-scaled 0.25 to 1 scale by dividing the original answers by 4. The same normalisation has been done in all tables that follow.

(Insert Table 5 around here)

The most common mode of interaction is informal information exchange, followed closely by publications and conferences. All the other modes of interaction are much less frequent. In general, it can be said that traditional modes of interactions such as publications, conferences and training graduates are the most important ones, follow by modes related to service provision (e.g. consultancies and contract research). The least frequent modes of interactions are the most commercial ones (e.g. spin off, incubators, patents/licences, etc.), which suggests that entrepreneurial capabilities at PRO are not highly developed. Moreover, activities that involve active participation at both sides of the interaction (e.g. networks, joint R&D and scientific parks) are not very frequent either.

Table 6 analyses the mains goals for interaction, as they were answered in *The Survey 2006*. The most important goals are related to the use of PRO's infrastructure, either to perform tests or for quality control. These are also the goals more frequently paid for. The goals that follow in importance are related to PRO's human resources, either to get technological advice from researchers or to recruit students. These goals are rarely paid for. Among goals related to firms' capabilities, it is more common that firms contact PRO to contribute rather than to supplement innovative activities.

It is striking the low incidence of firms that pay for the interaction with PRO. This may highlight that linkages are rather informal or at least that they are not formally paid for. For example, if we look at the incidence of payment for the three most important goals, only 55%, 48%, and 30% respectively declared to have paid for these services. In general, the pattern is that the more important the goal is conceived, the more likely it will be paid for. However, in the above mentioned examples, there are still around 19%, 25%, and 52% respectively of firms that although considering the goals *very* important, do not pay for the service.

(Insert Table 6 around here)

Table 7 shows that 88% of firms consider that the linkages with PRO were successful or expected to be successful in terms of their goals. Although success seems a little bit more frequent for innovative firms, the difference is not significant. In contrast, the bigger the firm, the larger is the probability of success.

(Insert Table 7 around here)

Those that considered that the collaboration failed (or expected to fail) pointed out that a “mismatch between available knowledge in PRO and the one the firm needed” was the most important reason (among nine) that explained the failure. The second most important was “low sensitivity of PRO to the demands of industry”, and the third, “PRO research too oriented to basic science”.

Most PRO-industry collaborations (69%) lasted less than five years (Table 8). Innovative firms seem to have longer-term collaboration than non-innovative firms; however the difference is not significant. On the contrary, there is a significant relation between size and duration: large firms seem to manage to establish longer-term collaborations than small firms.

(Insert Table 8 around here)

Table 9 presents the main reasons that explain firms’ lack of interactions with PRO. The most important reason why firms do not collaborate with PRO is that firms believe they do not need it because their in-house R&D is enough to obtain innovative results. Most control firms consider this reason of moderate importance, at least. However, there is a higher predominance of large firms in this group. The second most important reason is that firms consider that PRO do not have a proper understanding of their line of business, and the third reason is the difficulty in establishing contractual agreements with PRO.

(Insert Table 9 around here)

In sum, this section showed that linkages occur predominantly in some sectors, namely the chemical industry and the production of machinery. Linked firms are relatively large and they seem to be more innovative than unlinked firms –although we will verify this properly later in the paper. Firms connect to PRO mostly through traditional channel or to demand specific services. The primary goals for connecting to PRO are related to the use of PRO

infrastructure as a service provider of testing, monitoring and quality control. Linkages aiming at supplementing or contributing to firms' innovative activity are less important. Most linkages were considered successful in terms of their goals, there is a high incidence of unpaid interactions, and they very rarely last longer than five years, which may be related to the specificity of main goals pursued by linked firms –mostly connected to the use of PRO infrastructure. Firms that do not connect to PRO argue that they did not need so because their own R&D was enough to innovate.

IV) Methodology

Our research question requires comparing data for linked and unlinked firms. This resembles the type of analysis done in the evaluation literature, when some outcome variables are measured for treated and untreated units. Since the treatment decision is not usually random (i.e. certain firms are more likely than others to be involved with PRO) and the factors that affect treatment can also affect the outcome variables to be compared, in a seminal work Rosembaun and Rubin (1983) proposed a propensity score matching as a method to control for the bias that occurs when comparing outcome variables for treated and untreated data.

In other words, the goal is to construct a valid counterfactual group against which we may compare outcomes for the treated (i.e linked) group. In what follows we describe the method. Section 4.1 describes the propensity score method and presents the data requirement for an effective calculation. Section 4.2 presents the matching methods used in this paper to construct the counterfactual group.

4.1) The propensity score method

The propensity score method attempts to find a twin among the untreated observations for every single treated observation. Then, the treatment effect is calculated as the average difference of the specific outcome variable (e.g. innovative expenditures) between treated cases (e.g. linked firms) and their untreated twins (e.g unlinked matched firms).

The rationale for this approach is that the bias is reduced when the comparison of outcome variables is done for pairs that are very similar except for the fact that one has been treated and the other has not. In order to make this manageable,¹³ an index is calculated (i.e. the

¹³ If all relevant characteristics were attempted to be matched, it would be impossible to find pairs for every treated case (e.g. in our case, it may become impossible to find an unlinked firm that is of the same size, the same type of ownership, belongs to the same sector, etc that every single linked firm).

propensity score).¹⁴ This index reflects the probability of being treated conditional on relevant characteristics and it is defined as.

$$(1) \quad p(X) \equiv \Pr[D=1|X] = E[D|C]$$

Where $p(X)$ is the propensity score, D is a dummy for treatment and X is a multidimensional vector for pre-treatment characteristics.

Rosembaun and Rubin (1983) showed that if exposure to the treatment is random for all characteristics (X) it is also random for the index $p(X)$. In other words, matching based on a single index $p(X)$ (which reflects the probability of treatment) produces as consistent estimates of the treatment effect on the outcome variable as matching done based on all characteristics in the multidimensional vector X .

However, it could be the case that no twin could ever be found for a particular treated observation because there is no case in the untreated group that resembles closely enough the propensity score of such treated observation (i.e. the propensity score of the treated observation is an extreme value). In such a case, those ‘rare’ treated observations must be left out of the analysis. This is what is called the *common support requirement*. In our dataset this was not necessary as all treated observation lied within the common support region.

Before discussing the different methods to find matching twins it should be noted that the balancing hypothesis must be satisfied. This is to say that the characteristics of units with similar propensity scores are very similar, regardless of whether they are treated or not. In other words, the balancing test proves that that the procedure has managed to balance all relevant characteristics in the treated and untreated group, or to put it differently, that both groups resemble closely in all relevant dimensions. The propensity scores that we have calculated passed the balancing test.

4.2) The matching method

Once we have calculated the propensity score we need to construct the untreated group that would work as counterfactual. There are different methods available to select the best possible match.

The most straightforward is the *nearest-neighbour method*, which implies to find for each treated case the untreated case that shows the closest propensity score. Slightly more sophisticated is the *caliper method*, by which the twin is only searched within a range. When there is no untreated case within the range, the treated case is left out of the analysis. In

¹⁴ We use the `psmatch2` method developed by Leuven and Sianesi, 2003

other words, this method is forcing the common support requirement mentioned before. Both methods were performed with replacement, that is, one single untreated case could be used more than once in the counterfactual group if it appears to be the closest untreated firm of more than one treated case.

Two further methods were used in this paper: the kernel and the radius methods. These methods use multiple comparators rather than just the closest (or the closest within a range). The *kernel method* uses information for all non-treated cases to construct each twin. These are weighted according to their proximity in terms of the propensity score using a normal distribution centred in zero (i.e. the highest weight is given to non-treated cases whose difference to the treated case in terms of the propensity score is closest to zero). The *radius method* is similar to the *caliper* mentioned before although it considers all non-treated cases within the radius with equal weight.

V) Determinants of linking

This section we investigate the determinants of linking using a Probit model. Therefore, we identify micro and meso drivers for linking to PRO, which fulfils the first research goal (i.e. what drives firms' interactions with PRO). We will use this estimation to calculate the propensity score which is necessary to fulfil the second research goal (i.e. whether firms that interact behave in innovation and perceive PRO differently than those that do not interact).

A great part of the literature that studies firms' collaboration with PRO has been dedicated to identify firms', industries', and PRO's characteristics that affect the probability of forming linkages. The determinants more often investigated are firms' size¹⁵, industry or technology characteristics¹⁶, network related characteristics¹⁷, public policy promotion¹⁸, firms' knowledge bases¹⁹ and geographical proximity²⁰. Therefore, in our model on the firms' determinants for linking we include proxies for most of these variables, subject to data availability.

¹⁵ See, for example, Fontana *et al.*, 2006, Fukugawa, 2005 Cohen *et al.*, 2002, Godfrey, 2005, Ojewale *et al.*, 2001, Piergiovanni *et al.*, 1997, Rodriguez-Pose and Refolo, 2003, Santoro and Chakrabarti, 1999, Segarra-Blasco and Arauzo-Carod, 2008, Simonin, 2004

¹⁶ See, for example, Anselin *et al.*, 2000, Garcia-Aracil and De Lucio, 2008, Jaffe, 1989, Leydesdorff *et al.*, 2006, Segarra-Blasco and Arauzo-Carod, 2008

¹⁷ See, for example, Fontes, 2001, Klerck, 2005, MacPherson, 2002, Pittaway *et al.*, 2004, van Rijnsoever *et al.*, 2008

¹⁸ See, for example, Ballesteros and Rico, 2001, Echevarria *et al.*, 1996, Hayashi, 2003, Mendoza, 2007

¹⁹ See, for example, (Arundel and Geuna, 2004; Fontana *et al.*, 2003; Scharfetter *et al.*, 2002).

Fischer and Varga, 2002, MacPherson, 2002, Santoro and Chakrabarti, 1999

²⁰ Abramovsky *et al.*, 2007, Fritsch and Schwirten, 1999, Vedovello, 1997

Equation (2) presents a simplified version of our Probit model on the determinants of firms' linkages with PRO. There are three sets of explanatory variables: related to firms' characteristics, to network characteristics, and the sectoral specificities. The specific definition of all variables included in Equation (2) may be found in the Appendix.

$$(2) \text{ linked} = \alpha \text{ firm_charac} + \beta \text{ net_charac} + \gamma \text{ sector_charac} + u$$

We must highlight that we make our best to secure the goodness of fit of our participation (Probit) model trying different specifications. It is known that the quality of the matching is strictly related to the quality of the propensity estimate. Therefore, it is highly important to take good care of the participation equation. The variables included in the estimation were those indicated as important in the received literature, basically related to firm's size, firm's knowledge base, their networking capabilities and also sectoral specificities as mentioned above. In the Probit specification used to estimate the propensity score, we opted to include the proxies for those variables that better fit the model passing the balancing test. This implied, for example, that we included skill per size group in the Probit model to estimate the propensity to link to PRO (Table 10) because such specification shows the better joint significance.

The first set of variables in Equation (2) contains firms' specific characteristics: size and skills by quintile of size. The second set is about the network behaviour of the firm and it includes: a dummy for connection to suppliers and clients, another dummy for connections to other firms in the group, a final dummy for connections to the headquarter and finally a firm's owned evaluation on the importance of connections to other firms either to exchange information or to do research activities. Finally, the third set of variables is defined at sectoral level (2 digits ISIC). This is to account for unobservable factors that may occur at sectoral level. More specifically we account for unobservables related to three issues: intensity of investment in innovative activity, productivity, and propensity to link to PROs.

Table 10 shows the results. Size differences still persists in our sample²¹ and will be controlled for with our propensity score methods when comparing outcome variables between linked and unlinked firms. The sectoral variables, instead, are not significant, except for the one that measures the intensity of linking across sectors.

In relation to the network behaviour, the results are interesting. We have indicators of different nature to assess network behaviour.

²¹ . It is important to remind the reader that the group of unlinked firm that was included in *The Survey 2006* was selected to resemble the size and sector characteristics of linked firms. Thus, size and sectoral affiliation is somehow already controlled for and we would not expect strong difference in size and sectoral variables between linked and unlinked firms just because of the way the sample was constructed. In any case, we still find that size has a positive impact on the probability of connecting to PRO.

On the one hand, we have dummy variables that capture whether firms establish connections to other actors during the same period they establish linkages with PRO. For these indicators we find that firms that had connections with other firms in their value chain (*link_vert*) are more likely to be connected to PRO than firms that operate in isolation. This may be related to the existence of network capabilities widely reported in the literature. At the same time, we find that firms that establish linkages with the headquarters (*link_hq*) are less likely to establish linkages with PRO. In other words, foreign firms with connections to global networks are less likely to establish connections to the local public knowledge network, which may suggest that some sorts of global interactions work as substitutes to local networks.²²

On the other hand, we included two extra variables that capture networking behaviour with other firms regarding the *importance* that firms give to *two modes* of interaction: interacting for information exchange (*ch_of_info*) and interacting for research activities (*ch_of_reas*). We find that the higher the importance allocated by firms to information exchange with other firms, the less likely they will connect to PRO. This is not the case for the importance of interacting with other firms for research activity, which shows a positive sign albeit not significant.²³

Thus, it seems that while connectivity to private actors in the value chain anticipate connectivity to PRO, this is not the case when such connection is done primarily for information exchange²⁴ (i.e. they value primarily the connection to other firms via publications, participation in conferences, fairs and exhibition and through informal encounters). One may adventure that when information exchange is the primary goal for connectivity, this will be done *either* with PRO *or* with other firms. In other words, when looking primarily for information provision firms' connectivity to PRO may be a substitute for connectivity to other private actors. In contrast, for research activities, the connectivity with other firms or PRO seems to be more complementary.

(Insert Table 10 around here)

²² See Marín and Arza, 2009, forthcoming who suggest that international connectivity is one important role of subsidiaries in the NSI of LDC.

²³ It becomes significant if the dummy for vertical linkages (*link_vert*) is not included.

²⁴ Although the question about channels for linking does not strictly refer to *vertical* linkages (i.e. it refers to channels of interactions with “*other firms*” in general, which may be competitors, other firms in the group or others, besides clients and suppliers). In the absence of information about *vertical* channels specifically defined, we assume that the distribution of importance across channels is similar for connections with clients and suppliers as it is with “*other firms*” broadly defined.

Finally, our proxy for firm's knowledge bases (*skills*) does not seem to have a clear effect on the probability of linking. According to the literature, firms' knowledge bases (KB) should be an important factor that affects the formation of linkages between PRO and firms (Giuliani and Arza, 2009). However, while there are reasons to predict a positive effect, there are also others that justify a negative effect.

On the one hand, firms with more developed KB will be in an advantageous situation to search and exploit external knowledge, such as the one produced by PRO. This is similar to say that firms with more sophisticated KB enjoy better absorptive capacity (Cohen and Levinthal, 1990) since knowledge resides in skilled workers (Nelson and Winter, 1982). Moreover, PRO will also tend to prefer the connection with better prepared firms, especially when collaboration implies joint innovative activities.

On the other hand, as we said above, linking to PRO in our sample is very broadly defined and as we have seen in Table 5 firms do not usually connect to PRO to be involved in research activities themselves but they do so to acquire information or to contract services. This may not be very demanding on their skills. Similarly, the main goal for interacting is to use PRO infrastructure (Table 6) which may not require particular skills either. Moreover, some studies have highlighted that firms' sometimes connects to PRO to supplement areas of research²⁵ that otherwise they may have done in-house. In such a case, firms with poorer knowledge resources or with knowledge bases narrowly localised, may be found to connect to PRO with higher probability. This may be more likely among small firms, with lower human resources capacity to cover different areas of expertise.

Our results somehow confirm the latter presumption. We included the proportion of skilled workers divided by firms' size, assuming that firms' scale may interfere in the relation between KB and the probability of linking to PRO. We found that for fairly small firms (those in the 3rd and 4th decile of employment) the more skilled the human resources the less likely firms will be connected to PRO. This may imply that this group connects to PRO in order to overcome their poor knowledge capabilities. None of the other results on skills by size are significant.

VI) The average effects of linking

The literature that evaluates the effect of U-I interactions analyses the innovative behaviour (e.g. R&D intensity), innovative outcomes (e.g. products and process innovations and patents) and economic performance (e.g. productivity, export intensity, etc.). The most

²⁵ See e.g. Dussauge *et al.*, 2000; Miotti and Sachwald, 2003; Velho and Saez, 2002; Veugelers and Cassiman, 2005.

common indicator of interaction is cooperation in R&D between firms and PRO. However, there are also studies that consider other modes of interactions and there are some that just consider any type of linkage between PRO and firms. Moreover, some research has been done on the importance that firms give to university research regardless of whether they interact or not.²⁶

Regarding the effects of U-I interactions on firms' economic performance results are mixed²⁷ but they tend to be dependent on the goals of the interactions since many cooperative agreements target pre-competitive research.²⁸

Most studies that analyse R&D cooperation find a positive effect on innovative behaviour and performance.²⁹ Instead, some mixed results can be found when interactions are measured more broadly.³⁰

²⁶ For example, Nelson, 1986 reported that those firms that valued more the research done in universities were also those that invested a higher proportion of their sales on R&D. Mansfield investigated the extent to which firms could have been as innovative as they were without the research carried out in the academia. He performed the study with data for the US in 1975-1985 and in 1986-1994 and in both cases he found that over 10% of innovation could not have been done without the research done in academic institutions (Mansfield, 1991, Mansfield, 1998). Beise and Stahl, 1999 used a similar methodology and found similar results for a sample of 2500 manufacturing firms in Germany.

²⁷ George *et al.*, 2002 compared means for firms that interacted with universities and those that did not in US and found that the former showed better results in terms of quantity of patents produced but they did not find any significant effect on financial performance (measured by net sales over assets). Motohashi, 2005 studied the performance of Japanese firms as a consequence of their interactions with university. The paper did not find any a direct effect of firms' interaction with universities on their economic performance (measured by valued added). However, interactions seem seemed to intensify the positive effect of firms' R&D investment on value added, especially for young firms.

²⁸ For example, Benfratello and Sembenelli, 2002 evaluated firm's productivity according to whether firms participated or not on EU sponsored research joint ventures such as EUREKA programme and the Framework Programmes for Science and Technology (FPST). Both programmes involve a network of actors in which many universities are included.²⁸ However, while there were significant differences in productivity for firms that participated in EUREKA (in comparison to those that did not) the same result could not be found in relation to FPST. One noticeable difference between these programmes is that while EUREKA was market oriented and designed to improve firms' competitiveness, FPST focused on pre-competitive research. It is then to be expected that firms participating in the former had increased their productivity in the two-year period considered by the authors while firms participating in the latter did not.

²⁹ For example, Belderbos *et al.*, 2004 found that firms cooperating on R&D with universities sold a higher proportion of new products and Fritsch and Franke, 2004 showed that these firms were more likely to patent. Similarly, Kaufmann and Todtling, 2001 analysed the cooperation in innovation for firms in a group of European countries. As the previous authors, they also found that cooperation with universities was more likely to produce more radical innovation than cooperation with other partners. Similar results were found in France, but for firms collaborating with foreign universities (Monjon and Waelbroeck, 2003). In turn, Adams *et al.*, 2003 showed that firms that cooperated with federal laboratories patent more and were keener on investing their own resources on R&D. In the same vein, Loof and Brostrom, 2008 found that firms that collaborated with universities invested more in R&D, which was also more productive in terms of patent applications and proportion of sales due to new products..

³⁰ See Adams *et al* (2003), who contrast innovative performance of firms interacting via different modes with federal laboratories in the US; and Arvanitis *et al.* Arvanitis *et al.*, 2008, who compared the performance of Swiss interactive firms across different modes of interactions.

As we have explained in the methodological chapter, in this section we compare firms' performance in terms of a group of outcome variables. We use four different matching methods but the results do not vary widely among them, which enhance the robustness of our research design.

Having defined different counterfactual groups according to different matching methods, we pursue to measure the effect that linking has on different outcome variables. In particular, we are interested in knowing whether firm that connect to PRO are different in terms of a) innovative behaviour, b) success in achieving product or process innovation, c) attitude towards patenting their innovative outcomes, d) access to sources of finance for innovation, and e) conceptions about the importance of products and roles pursued by PRO.

We calculate the average treatment effect on the treated group (ATT), or in other words the average difference in the outcome variables between the treated group (i.e. firms linked to PRO) and the counterfactual group (i.e. twin firms –according to different matching methods- that are not linked to PRO). Table 11 lists all variables and the definition for each type of outcome a) to e). It is worth noting that this information is available for the same year for which the firm has declared to have been linked to the PRO (2005), therefore we are evaluating the contemporaneous effect.

(Insert Table 11 around here)

Tables 12a to 12e list the results on the impact of linking on the different group of variables listed in Table 11. The first columns in these tables list the relevant variables. The second columns present the matching methods. The third columns present the average values for all non-treated observation (all firms with no linkages). The fourth columns correct these values calculating the average only for the unlinked twins of linked firms (i.e. based on each specific matching method of the propensity scores). The fifth columns present the average value only for linked firms. Final the sixth column calculates the ATT which is the difference between the previous two columns. Finally, to assess the confidence of the estimated ATT we bootstrap the standard error of the estimate building up a confidence interval. We add to each ATT *** when it was significant at 1%, ** at 5%, and * at 10% based on the bootstrapping strategy.

Table 12a) presents the results for variables related to innovation inputs. Linked firms invest around 2.8% of their sales in innovative activities, which comprises 1.5% of sales in machinery, 0.9% of sales in in-house innovative activities. The remaining 0.5% of sales includes hardware and intangible technologies such as licenses, consultancy, external R&D and software. When compared against unlinked firms, linked firms invest significantly more in total innovative activities, machinery and in-house innovative activities. The

difference in all items suggests that investment intensity is around 25% higher for linked firms.

(Insert Table 12a around here)

Table 12b) presents the impact of linking on innovative outcome. Since the outcome variables and linking activities refer to the same year (2005), we cannot interpret the results as impacts for being linked to PRO, which may only become noticeable with some lag. We must interpret this result as difference predisposition towards innovation between linked and twin unlinked firms. Around 53% of linked firms have innovated in products and around 55% in processes. Among unlinked firms, 46% innovate in products and 44% innovate in process. Once relevant characteristics are matched, the difference shortens. Among twin unlinked firms, there are around 51% that innovate in products and around 45% that introduce process. Therefore, the ATT is only significant for process innovation calculated by most matching methods. In contrast, the ATT for product innovation is never significant.

(Insert Table 12b around here)

Interestingly, Table 12c) shows that linked firms linked obtain patents with higher propensity than unlinked firms. While 5% of linked firms obtained at least one patent in 2005, among twin unlinked firms, less than 1% obtained patents. For the same reasons expressed above, this cannot be interpreted as linked firms being more innovative; in fact, patenting will take even longer. Therefore, we interpret these results as linked firms being more prone to using appropriability tools such as patents.³¹ Arguably, by comparing twins we compare firms of similar size and other relevant micro characteristics. Thus, if it were true that linked firms are those particularly interested in using tools to guard the intellectual property rights, issues of concerns about the privatization of public knowledge could be raised.

(Insert Table 12c around here)

³¹ The preference for patenting (over secrecy) when firms establish cooperative agreements was showed by Arundel, 2001 in a paper that discusses the relative effectiveness in appropriation methods using European data.

Table 12d) shows the firms linked to PRO systematically use less internal sources of finance of their innovative expenditures than firms that do not connect. In any case, internal sources of financing are clearly very important for both groups: for linked firms they represent 78% of their innovative expenditures while for twin unlinked firms they represent 85%. On the contrary, linked firms use a larger proportion of funds provided by PRO. The difference is significant in two of the four matching methods, thus results are not robust. However, these sources represent a tiny proportion of funds used for innovative expenditures (a bit less than 2% in average for linked firms and 1% in the case of unlinked firms).

(Insert Table 12d around here)

Finally, Table 12e) presents different indicators on the perception that linked and unlinked firms have about PRO. The first four indicators are about the importance that firms allocate to different outputs produced by PRO. The last four are about the roles that firms perceive PRO should have.

It is not unexpected that linked firms value systematically more research outputs that need geographically close interactions to be exploited (e.g. such as instruments or laboratories). In average, linked firms answered that these outputs were of some importance, while in average unlinked firms considered them unimportant. On the contrary, it is interesting that both linked and unlinked firms consider publications as important and prototypes as unimportant. Thus, linking to PRO seems to have no effect on the importance that firms allocate to outputs that can be enjoyed at arm-length.

Finally, the roles that PRO should have according to firms' perception do not vary between linked and unlinked firms. All firms consider that the most important role is education followed by research. Although, linked firms seem to value research more than unlinked firms, the difference is not significant. In contrast, firms consider that social and entrepreneurial roles of PRO are much less important. Unlinked firms seem to give more value to the social role than linked firms, but again this difference is not significant.

(Insert Table 12e around here)

VII) Conclusions

This paper analyses PRO-industry linkages from the firm viewpoint seeking to fulfil two goals. Firstly, we analyse firms' drivers for linking to PRO. Secondly, we examine whether

innovative behaviour and firms' perceptions about PRO outputs and roles in the NSI were different for linked and unlinked firms.

The first goal was achieved by estimating a Probit model on the propensity to link to PRO. For the second goal, we use propensity score matching techniques. These techniques enable us to control for all relevant characteristics that may be influencing simultaneously the propensity to be linked and the outcome variables of behaviours and perceptions.

The data used comes from the Argentinean Innovation Surveys of 2005 and 2006. In the Survey 2006 an especial section was added to the general questionnaire to evaluate in detail firms' interactions with PRO that occurred in 2005 and also to a group of unlinked firms that resemble the characteristics of the linked group in terms of size and sectoral affiliation. Based on that group we construct the counterfactual to assess the effect of linking using propensity score matching techniques.

We first presented fairly comprehensive descriptive statistics on most variables included in the survey since this is the first time such dataset is analysed. Besides describing the characteristics of the sample, that section examined the main motivations and channels of interactions. It was showed that firms primarily collaborate to take advantage of PRO infrastructure and human resources and they do so to cover for the innovative activities they do not perform. Strikingly, there is a low incidence of payment for interacting. Nevertheless, most interactions were considered successful in terms of achieving the expected goals. The main channels were traditional channels such information exchange, publications, conferences and training graduates followed by channels that implied the provision of services.

In relation to our first goal our conclusions were:

- i. There was no clear effect of firms' knowledge bases on the probability to interact. For small firms the effect is negative (they seem to be replacing their weak capabilities with their interactions with PRO) and it is not significant for larger firms.
- ii. In relation to networking capabilities,
 - i) We found that firms that establish linkages with clients and suppliers are more likely to establish linkages with PRO as well.
 - ii) Firms that connect to headquarters, however, are less likely to establish linkages with PRO, which suggest that there is a sort of substitution effect for foreign firms between linking to global and to national partners (or at least PRO).

- iii) There is a substitutions effect between PRO and ‘the market’ for information exchange. Firms that interact to other firms for information exchange interact less with PRO. This does not occur for interactions motivated by research activities, for which there seems to be a weak form of complementation.

In relation to our second goal, we conclude that:

- iii. Linked firms invest more intensively in all innovative activities, but they still invest a much higher proportion in incorporated technologies than in in-house innovative activities (such as R&D and engineering and design).
- iv. Linked firms seem to be more successful in process innovation, although the robustness of this result is lower than the previous one. This should not be interpreted as differences in innovative performance because, due to data restrictions, we were bound to assess the contemporaneous effect of linking on innovative outcome. We interpret this finding as different *predisposition* towards innovation.
- v. Linked firms are more prone to patenting. Given the time lags between new ideas that may be triggered by the interaction with PRO and the opportunity to obtain patents, we interpret this finding as a differential strategy towards intellectual property protection by those firms that interact with PRO.
- vi. Linked firms use a lower proportion of internal resources and a higher proportion of PRO resources to finance their innovative activities.
- vii. Linked firms tend to value more than unlinked firms PRO research outputs that require geographically close collaboration (i.e. new tools, laboratories and equipment) but no significant difference was found for the value of research outputs that could be available at arm length (e.g. publications). Moreover, for both linked and unlinked firms, the primarily roles of PRO should be teaching and research rather than entrepreneurial or social roles.

These empirical conclusions derive the following thoughts that may become useful for future policy design.

Firstly, attention should be placed to the knowledge value implied in linkages with PRO. The rationale for the promotion of linkages is because they favour knowledge creation and diffusion within the NSI. However, in the Argentina case firms’ knowledge capabilities are not drivers for linking. In general, firms connected to PRO regardless of their skills and small firms with low level of skills are more likely to connect than small and skilful firms. Moreover, the main goals for linking are the provision of services and the use of PRO

infrastructure. This raises concerns about the extent to which PRO are misusing their knowledge resources when interacting with firms. We believe there is potential for knowledge creation and diffusion in PRO-industry interaction, but we also believe that not all types of interactions are equally valuable. For example, we also found that when firms interact seeking for information exchange (rather than pursuing research activities) they could substitute interacting with PRO for interacting with other firms. In such a case, when firms could satisfy their knowledge demands in the market –and especially if they cannot themselves offer high knowledge capabilities in the interaction- it would be better to discourage interactions with PRO. In fact, PRO research outputs may well be useful for firms' innovative activities even in the absence of direct interactions (e.g. unlinked firms value PRO publications as much as linked firms).

Secondly, we provide some evidence that suggest that linked firms have been, during the same period, more innovative than unlinked firms. However, we also found that firms usually interact to substitute for the innovative activities they do not perform and they seldom pay for the interaction. We believe it is important to develop policy tools that avoid crowding out effects in innovation. It is important that if firms link to PRO they do so to complement rather than to substitute their own innovative efforts. In this sense, it may be a good idea to attach some target in terms of investing in in-house innovation as a requirement for interacting with PRO.

Finally, especial attention must be placed on issues of intellectual property rights. In this paper we find the firms that are linked to PRO seem to be more prone to protecting their intellectual property via patents. In the Argentinean context where there is no systematic protection of publicly created knowledge, private firms may find little resistance when intending to patenting outputs triggered by their interactions with PRO. The effect of this on the strategic diffusion of publicly created knowledge must be analysed further. The challenge for S&T policy is to avoid what Nelson (2004) called the tragedy of the scientific commons, which may occur if actors maximizing their own benefits endanger the wide diffusion of (publicly created) knowledge. This may have clear socioeconomic and environmental consequences.

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References

- Abramovsky, L.; Harrison, R. and Simpson, H., (2007). 'University Research and the Location of Business R&D', *The Economic Journal*, Vol. 117, No. 519, pp. 114-41.
- Acworth, E. B., (2008). 'University-Industry Engagement: The Formation of the Knowledge Integration Community (Kic) Model at the Cambridge-Mit Institute', *Research Policy*, Vol. 37, No. 8, pp. 1241-54.
- Adams, J. D.; Chiang, E. P. and Jensen, J. L., (2003). 'The Influence of Federal Laboratory R&D on Industrial Research', *Review of Economics and Statistics*, Vol. 85, No. 4, pp. 1003-20.
- Albornoz, M., (1993). 'El Sistema Universitario Frente Al Desafío De La Competitividad', *Redes. Revista de Estudios Sociales de la Ciencia*, Vol. 4, No., pp. 12-22.
- Anselin, L.; Varga, A. and Acs, Z., (2000). 'Geographical Spillovers and University Research: A Spatial Econometric Perspective', *Growth and Change*, Vol. 31, No. 4, pp. 501-15.
- Arundel, A., (2001). 'The Relative Effectiveness of Patents and Secrecy for Appropriation', *Research Policy*, Vol. 30, No. 4, pp. 611-24.
- Ballesteros, J. A. and Rico, A. M., (2001). 'Public Financing of Cooperative R&D Projects in Spain: The Concerted Projects under the National R&D Plan', *Research Policy*, Vol. 30, No. 4, pp. 625-41.
- Beise, M. and Stahl, H., (1999). 'Public Research and Industrial Innovations in Germany', *Research Policy*, Vol. 28, No. 4, pp. 397-422.
- Belderbos, R.; Carree, M. and Lokshin, B., (2004). 'Cooperative R&D and Firm Performance', *Research Policy*, Vol. 33, No. 10, pp. 1477-92.
- Benfratello, L. and Sembenelli, A., (2002). 'Research Joint Ventures and Firm Level Performance', *Research Policy*, Vol. 31, No. 4, pp. 493-507.
- Bisang, R. (director); Bercovich, N.; Chprintzer, A. and A. Ramos,, (1995). *Las Actividades De Investigación En Las Universidades Nacionales*, Buenos Aires.
- Bisang, Roberto (dir.), (1995). *Las Actividades De Investigación En Las Universidades Nacionales*, Buenos Aires.
- Bramwell, Allison and Wolfe, David A., (2008). 'Universities and Regional Economic Development: The Entrepreneurial University of Waterloo', *Research Policy*, Vol. 37, No. 8, pp. 1175-87.
- Cohen, W. M. and Levinthal, D. A., (1990). 'Absorptive-Capacity - a New Perspective on Learning and Innovation', *Administrative Science Quarterly*, Vol. 35, No. 1, pp. 128-52.
- Cohen, Wesley M.; Nelson, Richard R. and Walsh, John P., (2002). 'Links and Impacts: The Influence of Public Research on Industrial R&D.' *Management Science*, Vol. 48, No. 1, pp. 1-23.
- Cooke, P., (2001). 'Regional Innovation Systems, Clusters, and the Knowledge Economy', *Industrial and Corporate Change*, Vol. 10, No. 4, pp. 945-74.
- Charles, P., (2003). 'Universities and Territorial Development: Reshaping the Regional Role of Uk Universities', *Local Economy*, Vol. 18, No. 1, pp. 7-20.
- Chudnovsky, Daniel and López, Andrés, (1996). 'Política Tecnológica En La Argentina: ¿Hay Algo Más Que Laissez Faire?' *Redes. Revista de Estudios Sociales de la Ciencia*, Vol. 3, No. 6.
- Dagnino, Renato and Velho, Léa, (1998). 'University-Industry-Government Relations on the Periphery. The University of Campinas, Brasil', *Minerva*, Vol. 36, No., pp. 229-51.
- Dasgupta, Partha and David, Paul, (1994). 'Toward a New Economics of Science', *Research Policy*, Vol. 23, No. 5, pp. 487-521.
- Dávila, Mabel, (2006). 'Vinculación Universidad-Sector Productivo-Estado En La Facultad De Agronomía De La Universidad De Buenos Aires: La Apertura Al Medio Como Eje De Transformación Institucional', in S. Llomovatte, F. Juarros, J. Naidorf and A. Guelman (ed.), *La Vinculación Universidad-Empresa: Miradas Críticas Desde La Universidad Pública*, Buenos Aires: Miño y Dávila editores.
- Decibe, Susana and Canela, Silvia, (2003). 'Estudios De Competitividad Sistémica. Componente E: Educación Y Sociedad Del Conocimiento.' Buenos Aires: CEPAL.
- Echevarria, R.G.; Trigo, E.J. and Byerlee, D., (1996). 'Institutional Change and Effective Financing of Agricultural Research in Latin America', *World Bank Papers*, Washington D.C.:
- Estébanez, M., (1996). 'Ciencia En La Universidad. Una Visión Global De Las Actividades Científicas En La Uba', *Pensamiento universitario*, Vol. 4, No. 4/5.

- Etzkowitz, H. and Leydesdorff, L., 1997, (Ed). *Universities and the Global Knowledge Economy: A Triple Helix of University-Industry-Government Relations*. London: Pinter/Cassel.
- Etzkowitz, Henry, (2003). 'Research Groups as 'Quasi-Firms': The Invention of the Entrepreneurial University', *Research Policy*, Vol. 32, No. 1, pp. 109-21.
- Etzkowitz, Henry; de Mello, Jose Manoel Carvalho and Almeida, Mariza, (2005). 'Towards "Meta-Innovation" In Brazil: The Evolution of the Incubator and the Emergence of a Triple Helix', *Research Policy*, Vol. 34, No. 4, pp. 411-24.
- Etzkowitz, Henry and Leydesdorff, Loet, (2000). 'The Dynamics of Innovation: From National Systems And "Mode 2" To a Triple Helix of University-Industry-Government Relations', *Research Policy*, Vol. 29, No. 2, pp. 109-23.
- Etzkowitz, Henry; Leydesdorff, Loet, (2001). 'The Transformation of University-Industry-Government Relations', *Electronic Journal of Sociology*, Vol., No., pp. 26.
- Fischer, M. M. and Varga, A., (2002). 'Technological Innovation and Interfirm Cooperation: An Exploratory Analysis Using Survey Data from Manufacturing Firms in the Metropolitan Region of Vienna', *International Journal of Technology Management*, Vol. 24, No. 7-8, pp. 724-42.
- Fontana, Roberto; Geuna, Aldo and Matt, Mireille, (2006). 'Factors Affecting University-Industry R&D Projects: The Importance of Searching, Screening and Signalling', *Research Policy*, Vol. 35, No. 2, pp. 309-23.
- Fontes, M., (2001). 'Biotechnology Entrepreneurs and Technology Transfer in an Intermediate Economy', *Technological Forecasting and Social Change*, Vol. 66, No. 1, pp. 59-74.
- Fritsch, M. and Franke, G., (2004). 'Innovation, Regional Knowledge Spillovers and R&D Cooperation', *Research Policy*, Vol. 33, No. 2, pp. 245-55.
- Fritsch, M. and Schwirten, C., (1999). 'Enterprise-University Cooperation and the Role of Public Research Institutions in Regional Innovation Systems', *Industry and Innovation*, Vol. 6, No. 1, pp. 69-83.
- Fukugawa, N., (2005). 'Characteristics of Knowledge Interactions between Universities and Small Firms in Japan', *International Small Business Journal*, Vol. 23, No. 4, pp. 379-401.
- García-Aracil, A. and De Lucio, I. F., (2008). 'Industry-University Interactions in a Peripheral European Region: An Empirical Study of Valencian Firms', *Regional Studies*, Vol. 42, No. 2, pp. 215-27.
- García de Fanelli, Ana, (1993a). 'Cambios En La Relación Entre Las Universidades Públicas Y El Sector Productivo En La Argentina', *CEDES, policopiado*, Buenos Aires:
- García de Fanelli, Ana, (1993b). 'La Articulación De La Uba Con El Sector Productivo: La Experiencia Reciente', *Documento del Cedes*, Vol., No.
- García de Fanelli, Ana, (1994). 'Universidad Nacional Y Sector Productivo', in M. Costa Morosini (ed.), *Universidades No Mercosul*, Sao Paulo: Ed. Cortez.
- George, G.; Zahra, S. A. and Wood, D. R., (2002). 'The Effects of Business-University Alliances on Innovative Output and Financial Performance: A Study of Publicly Traded Biotechnology Companies', *Journal of Business Venturing*, Vol. 17, No. 6, pp. 577-609.
- Gibbons, M.; Limoges, C.; Nowotny, H.; Schwartzman, S.; Scott, P. and Trow, M., (1994). *The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Societies*, London: Sage Publication.
- Giuliani, Elisa and Arza, Valeria, (2009). 'What Drives the Formation of 'Valuable' University-Industry Linkages? An under-Explored Question in a Hot Policy Debate', *Research Policy*, Vol. 38, No., pp. 906-21.
- Godfrey, S., (2005). 'Power and Knowledge: The Role of Industry Partners in Knowledge-Intensive Networks in New Materials Technology', *Industry and Higher Education*, Vol. 19, No. 2, pp. 189-97.
- Hayashi, T., (2003). 'Effect of R&D Programmes on the Formation of University-Industry-Government Networks: Comparative Analysis of Japanese R&D Programmes', *Research Policy*, Vol. 32, No. 8, pp. 1421-42.
- Jaffe, Adam B., (1989). 'Real Effects of Academic Research', *American Economic Review*, Vol. 79, No. 5, pp. 957-70.
- Juarros, Fernanda, (2006). 'Vinculación Universidad-Estado-Sector De La Producción De Bienes Y Servicios, Vista Por Los Docentes Investigadores. El Caso De La Facultad De Farmacia Y

- Bioquímica De La Universidad De Buenos Aires', in S. Llomovatte, F. Juarros, J. Naidorf and A. Guelman (ed.), *La Vinculación Universidad-Empresa: Miradas Críticas Desde La Universidad Pública*, Buenos Aires: Miño y Dávila editores.
- Kaufmann, Alexander and Todtling, Franz, (2001). 'Science-Industry Interaction in the Process of Innovation: The Importance of Boundary-Crossing between Systems', *Research Policy*, Vol. 30, No. 5, pp. 791-804.
- Klerck, G., (2005). 'Competition and Cooperation in South Africa's Biotechnology Sector', *Industry and Higher Education*, Vol. 19, No. 2, pp. 169-78.
- Leuven, E. and Sianesi, B., (2003). 'Psmatch2: Stata Module to Perform Full Mahalanobis and Propensity Score Matching, Common Support Graphing, and Covariate Imbalance Testing', <http://ideas.repec.org/c/boc/bocode/s432001.html>.
- Leydesdorff, L.; Dolfmsa, W. and Van der Panne, G., (2006). 'Measuring the Knowledge Base of an Economy in Terms of Triple-Helix Relations among 'Technology, Organization, and Territory'', *Research Policy*, Vol. 35, No. 2, pp. 181-99.
- Loof, H. and Brostrom, A., (2008). 'Does Knowledge Diffusion between University and Industry Increase Innovativeness?' *Journal of Technology Transfer*, Vol. 33, No. 1, pp. 73-90.
- López, A., (2007). *Desarrollo Económico Y Sistema Nacional De Innovación En La Argentina.*, Buenos Aires: Consejo Profesional de Ciencias Económicas de la Ciudad Autónoma de Buenos Aires.
- Lugones, Gustavo and Lugones, Manuel, (2004). 'Bariloche Y Su Grupo De Empresas Intensivas En Conocimiento: Realidades Y Perspectivas.' *Documentos de trabajo Centro Redes*,
- Lundvall, Bengt-Åke, (1992). *National Systems of Innovation : Toward a Theory of Innovation and Interactive Learning*, London ; New York
New York: Pinter Publishers; Distributed exclusively in the USA and Canada by St. Martin's Press.
- Llomovatte, Silvia; Juarros, Fernanda; Naidorf, Judith and Guelman, Anahí, (2006). *La Vinculación Universidad-Empresa: Miradas Críticas Desde La Universidad Pública*, Buenos Aires: Miño y Dávila editores.
- MacPherson, A., (2002). 'The Contribution of Academic-Industry Interaction to Product Innovation: The Case of New York State's Medical Devices Sector', *Papers in Regional Science*, Vol. 81, No. 1, pp. 121-29.
- Mansfield, E., (1991). 'Academic Research and Industrial-Innovation', *Research Policy*, Vol. 20, No. 1, pp. 1-12.
- Mansfield, E., (1998). 'Academic Research and Industrial Innovation: An Update of Empirical Findings', *Research Policy*, Vol. 26, No. 7-8, pp. 773-76.
- Marín, Anabel and Arza, Valeria, (2009, forthcoming). 'Chapter 10. The Role of Mncs (Multinational Corporations) in Innovation Systems of Developing Countries. From Technology Diffusion to International Involvement', in B.-A. Lundvall, K. Joseph, C. Chaminade and J. Van (ed.), *Handbook of Innovation Systems and Developing Countries – Building Domestic Capabilities in a Global Context*, Cheltenham: Edward Elgar.
- Mendoza, P., (2007). 'Academic Capitalism and Doctoral Student Socialization: A Case Study', *Journal of Higher Education*, Vol. 78, No. 1, pp. 71-96.
- Monjon, S. and Waelbroeck, P., (2003). 'Assessing Spillovers from Universities to Firms: Evidence from French Firm-Level Data', *International Journal of Industrial Organization*, Vol. 21, No. 9, pp. 1255-70.
- Moori-Koenig, Virginia and Yoguel, Gabriel, (1998). 'El Desarrollo De Capacidades Innovativas De Las Firms En Un Medio De Escaso Desarrollo Del Sistema Local De Innovación.' *Nota Técnica 20/98*, Río de Janeiro:
- Motohashi, K., (2005). 'University-Industry Collaborations in Japan: The Role of New Technology-Based Firms in Transforming the National Innovation System', *Research Policy*, Vol. 34, No. 5, pp. 583-94.
- Nelson, R. R., (1986). 'Institutions Supporting Technical Advance in Industry', *American Economic Review*, Vol. 76, No. 2, pp. 186-89.
- Nelson, Richard R and Winter, Sidney G, (1982). *An Evolutionary Theory of Economic Change*, Cambridge, Mass: Belknap Press of Harvard University Press.
- Nelson, Richard R., (2004). 'The Market Economy, and the Scientific Commons', *Research Policy*, Vol. 33, No. 3, pp. 455-71.
- Nelson, Richard R., 1993, (Ed). *National Innovation System*. New York: Oxford University Press.

- Ojewale, B. A.; Ilori, M. O.; Oyebisi, T. O. and Akinwumi, I. O., (2001). 'Industry-Academic Relation: Utilization of Idle Capacities in Polytechnics, Universities and Research Organizations by Entrepreneurs in Nigeria', *Technovation*, Vol. 21, No. 10, pp. 695-704.
- Patel, Pari and Pavitt, Keith, (1995). 'The Nature and Economic Importance of National Innovation Systems', *STI review. OECD*, Paris:
- Pavitt, K., (2001). 'Public Policies to Support Basic Research: What Can the Rest of the World Learn from Us Theory and Practice? (and What They Should Not Learn)', *Industrial and Corporate Change*, Vol. 10, No. 3, pp. 761-79.
- Piergiovanni, R.; Santarelli, E. and Vivarelli, M., (1997). 'From Which Source Do Small Firms Derive Their Innovative Inputs? Some Evidence from Italian Industry', *Review of Industrial Organization*, Vol. 12, No. 2, pp. 243-58.
- Pittaway, L.; Robertson, M.; Munir, K.; Denyer, D. and Neely, A., (2004). 'Networking and Innovation: A Systematic Review of the Evidence', *International Journal of Management Reviews*, Vol. 5-6, No. 3-4, pp. 137-68.
- Riquelme, G., 2008, (Ed). *Las Universidades Frente a Las Demandas Sociales Y Productivas*. Buenos Aires: Miño y Dávila.
- Rodriguez-Pose, A. and Refolo, M. C., (2003). 'The Link between Local Production Systems and Public and University Research in Italy', *Environment and Planning A*, Vol. 35, No. 8, pp. 1477-92.
- Rosenbaum, P. R. and Rubin, D. B., (1983). 'The Central Role of the Propensity Score in Observational Studies for Causal Effects', *Biometrika*, Vol. 70, No. 1, pp. 41-55.
- Rosenberg, N., (1992). 'Scientific Instrumentation and University Research', *Research Policy*, Vol. 21, No., pp. 381-90.
- Rosenberg, Nathan and Nelson, Richard R., (1994). 'American Universities and Technical Advance', *Research Policy*, Vol. 23, No. 3, pp. 323-48.
- Santoro, M.D. and Chakrabarti, A.K., (1999). 'Building Industry-University Research Centers: Some Strategic Considerations', *International Journal of Management Reviews*, Vol. 1, No. 3, pp. 225-44.
- Segarra-Blasco, A. and Arauzo-Carod, J. M., (2008). 'Sources of Innovation and Industry-University Interaction: Evidence from Spanish Firms', *Research Policy*, Vol. 37, No. 8, pp. 1283-95.
- Simonin, B. L., (2004). 'An Empirical Investigation of the Process of Knowledge Transfer in International Strategic Alliances', *Journal of International Business Studies*, Vol. 35, No. 5, pp. 407-27.
- Slaughter, S. and Leslie, L. . (1997). *Academic Capitalism: Politics, Policies and the Entrepreneurial University*, Johns Hopkins University Press.
- Stokes, D. E., (1997). *Pasteur's Quadrant: Basic Science and Technological Innovation*, Brookings Institution Press.
- Tenti Fanfani, E., (1993). *Universidad Y Empresa*, Buenos Aires: Miño y Dávila editores / CIEPP.
- van Rijnsoever, Frank J.; Hessels, Laurens K. and Vandeberg, Rens L. J., (2008). 'A Resource-Based View on the Interactions of University Researchers', *Research Policy*, Vol. 37, No. 8, pp. 1255-66.
- Vedovello, C., (1997). 'Science Parks and University-Industry Interaction: Geographical Proximity between the Agents as a Driving Force', *Technovation*, Vol. 17, No. 9, pp. 491-502.
- Yoguel, G. and López, M., (2001). 'Sistemas Locales De Innovación Y El Desarrollo De Las Capacidad Innovativa De Las Firms: Las Evidencias Del Cuasi Distrito Industrial De Rafaela', *DTN° 5/2001 Laboratorio de Investigación sobre Tecnología, Trabajo, Empresa y Competitividad*, Instituto de Industria. Universidad Nacional de General Sarmiento.:

Tablas

Table 1: Sample characteristics in terms of size of linked and control firms in 2005

	N	Size		
		Small (% of linked and control firms)	medium (% of linked and control firms)	big (% of linked and control firms)
Linked	355	16%	27%	56%
Control	238	21%	36%	43%
Full sample 2005	1675	30%	30%	40%

Source: The Survey 2005 & The Survey 2006

Table 2: Sample characteristics in terms sectors (ISIC Rev 3, 2 digits)

	% control firms, per sector	% linked firms, per sector	% of firms in full sample 2005, per sector	% linked firms over % firms in full sample, per sector
15 Manufacture of food products and beverages	16,4%	24,2%	22,0%	1,10
16 Manufacture of tobacco products	0,0%	1,4%	0,5%	2,95
17 Manufacture of textiles	7,6%	4,2%	8,4%	0,50
18 Manufacture of wearing apparel; dressing and dyeing of fur	1,3%	2,8%	2,7%	1,03
19 Tanning and dressing of leather; luggage, handbags, saddlery, footwear, etc	2,9%	2,3%	2,3%	0,97
20 Manufacture of wood and of products of wood and cork, except furniture	2,1%	2,3%	2,4%	0,92
21 Manufacture of paper and paper products	5,5%	1,7%	2,9%	0,59
22 Publishing, printing and reproduction of recorded media	3,8%	1,1%	5,1%	0,22
23 Manufacture of coke, refined petroleum products and nuclear fuel	1,3%	0,6%	0,8%	0,73
24 Manufacture of chemicals and chemical products	13,0%	14,1%	9,9%	1,43
25 Manufacture of rubber and plastic products	6,3%	5,6%	5,0%	1,14
26 Manufacture of other non-metallic mineral products	3,8%	4,5%	4,8%	0,94
27 Manufacture of basic metals	3,4%	3,1%	3,2%	0,98
28 Manufacture of fabricated metal products, except machinery and equipment	5,0%	4,2%	5,3%	0,80
29 Manufacture of machinery and equipment NEC (not elsewhere classified)	11,3%	13,5%	9,4%	1,44
30 Manufacture of office, accounting and computing machinery	0,4%	0,0%	0,2%	0,00
31 Manufacture of electrical machinery and apparatus NEC	4,6%	4,8%	3,5%	1,36
32 Manufacture of radio, television and communication equipment and apparatus	2,1%	0,8%	1,3%	0,64
33 Manufacture of medical, precision and optical instruments, watches and clocks	1,7%	1,4%	1,3%	1,12
34 Manufacture of motor vehicles, trailers and semi-trailers	4,2%	4,8%	4,4%	1,10
35 Manufacture of other transport equipment	1,3%	1,4%	1,6%	0,91
36 Manufacture of furniture; manufacturing NEC	2,1%	1,1%	3,2%	0,35
	100,0%	100,0%	100,0%	

Source: *The Survey 2005 & The Survey 2006*

Table 3: The relation between fields of research and sectors for linked firms

	N	Agronomy	Computer Science	Food Science and Technology	Biology	Industrial Design	Civil Engineering	Engineering of Materials and Metallurgy	Mining Engineering	Electrical Engineering	Mechanical Engineering	Chemical Engineering	Physics	Geosciences	Mathematics	Medicine	Veterinary	Chemistry
15 Manufacture of food products and beverages	86	48%	17%	62%	14%	21%	7%	10%	0%	21%	22%	34%	7%	2%	3%	5%	12%	26%
16 Manufacture of tobacco products	5	80%	20%	20%	20%	20%	0%	20%	0%	20%	0%	0%	0%	0%	0%	0%	0%	0%
17 Manufacture of textiles	15	20%	33%	13%	13%	53%	7%	13%	0%	13%	13%	40%	7%	0%	0%	0%	13%	33%
18 Manufacture of wearing apparel; dressing and dyeing of fur	10	10%	20%	0%	0%	30%	10%	30%	0%	0%	10%	10%	0%	0%	0%	10%	0%	0%
19 Tanning and dressing of leather; luggage, handbags, saddlery, footwear, etc	8	0%	13%	0%	0%	25%	0%	13%	0%	13%	38%	63%	13%	0%	0%	0%	0%	38%
20 Manufacture of wood and of products of wood and cork, except furniture	8	50%	25%	0%	0%	25%	0%	38%	0%	13%	13%	0%	0%	0%	0%	0%	0%	0%
21 Manufacture of paper and paper products	6	0%	0%	0%	0%	67%	0%	17%	0%	0%	0%	17%	0%	0%	0%	0%	0%	17%
22 Publishing, printing and reproduction of recorded media	4	0%	25%	0%	0%	25%	0%	0%	25%	25%	0%	25%	0%	0%	0%	0%	0%	25%
23 Manufacture of coke, refined petroleum products and nuclear fuel	2	0%	0%	0%	0%	50%	0%	50%	0%	50%	50%	0%	50%	0%	0%	0%	0%	0%
24 Manufacture of chemicals and chemical products	50	16%	14%	16%	24%	10%	0%	4%	2%	16%	14%	44%	10%	0%	0%	24%	8%	54%
25 Manufacture of rubber and plastic products	20	0%	15%	15%	0%	10%	5%	15%	0%	5%	15%	20%	0%	0%	0%	0%	0%	5%
26 Manufacture of other non-metallic mineral products	16	0%	13%	0%	0%	25%	31%	25%	38%	25%	31%	31%	0%	19%	0%	0%	0%	13%
27 Manufacture of basic metals	11	0%	27%	0%	0%	45%	27%	55%	0%	36%	27%	18%	0%	0%	0%	0%	0%	9%
28 Manufacture of fabricated metal products, except machinery and equipment	15	7%	27%	13%	0%	20%	20%	73%	0%	20%	33%	27%	13%	0%	0%	0%	0%	0%
29 Manufacture of machinery and equipment NEC (not elsewhere classified)	48	21%	17%	10%	0%	54%	8%	48%	6%	33%	48%	13%	13%	2%	10%	0%	0%	6%
31 Manufacture of electrical machinery and apparatus NEC	17	0%	6%	0%	0%	47%	12%	35%	12%	47%	41%	6%	0%	0%	6%	0%	0%	0%
32 Manufacture of radio, television and communication equipment and apparatus	3	0%	0%	0%	0%	0%	0%	0%	0%	67%	0%	0%	0%	0%	0%	0%	0%	0%
33 Manufacture of medical, precision and optical instruments, watches and clocks	5	0%	20%	20%	20%	20%	20%	0%	0%	20%	0%	40%	20%	0%	20%	20%	0%	20%
34 Manufacture of motor vehicles, trailers and semi-trailers	17	0%	18%	0%	0%	35%	0%	29%	0%	6%	29%	6%	0%	0%	0%	0%	0%	6%
35 Manufacture of other transport equipment	5	0%	60%	0%	0%	80%	0%	40%	0%	0%	40%	0%	0%	0%	0%	0%	0%	0%
36 Manufacture of furniture; manufacturing NEC	4	0%	50%	0%	0%	25%	0%	50%	0%	25%	50%	25%	0%	0%	0%	0%	0%	25%
All sectors	355	20%	18%	21%	8%	30%	8%	24%	4%	21%	25%	26%	6%	2%	3%	5%	5%	19%

Source: *The Survey 2005 & The Survey 2006*

Table 4: Sample characteristics in terms of innovativeness linked and control firms in 2005

	Innovative in products		Innovative in processes		Innovative in products or processes	Innovative in products & processes
	Total	Introducing new products	Total	Introducing new processes		
% of Linked	54.0%	39.7%	55.6%	31.3%	67.3%	42.0%
% of Control	46.2%	27.3%	44.1%	19.7%	59.7%	30.7%

Source: *The Survey 2005 & The Survey 2006*

Table 5: Modes of interaction

	Classification of modes	Average importance 0-1 scale	% of linked firms with importance >0.5
Informal Exchange	Traditional	0,58	51%
Publications	Traditional	0,56	47%
Conferences	Traditional	0,54	46%
Hiring graduates	Traditional	0,44	27%
Consultancies	Service	0,44	26%
Research contracts	Service	0,42	26%
Joint R&D	Joint activities	0,42	25%
Licences	Commercial	0,38	16%
Networks	Joint activities	0,37	15%
Patentes	Commercial	0,37	15%
Scientific parks	Joint activities	0,35	12%
Internships	Service	0,34	10%
Incubators	Commercial	0,3	5%
University owned firms	Commercial	0,27	3%
Spin off	Commercial	0,27	2%

Table 6: Goals of the cooperation

Goals	Related to:	Average importance 0-1 scale	% of linked firms that consider the goals at least moderately important (>0.5)	The service was paid (% over those that consider the goal of some importance > 0.25)
To perform tests necessary for your products/processes	PRO's infrastructure	0.56	46%	55%
To help in quality control	PRO's infrastructure	0.52	41%	48%
To get technological/consulting advice from researchers and/or professors in solving production-related problems	PRO's human resources	0.48	34%	30%
To make earlier contact with excellent university students for future recruiting	PRO's human resources	0.44	27%	24%
To contract research to contribute to the firm's innovative activities	Firms' capabilities	0.42	21%	29%
Technology transfer from the university	PRO' knowledge resources	0.41	23%	31%
To use resources available at universities and public labs	PRO's infrastructure	0.41	21%	30%
To augment the firm's limited ability to find and absorb technological information	Firms' capabilities	0.41	21%	17%
To get information about engineers or scientists and/or trends in R&D in the field	PRO' knowledge resources	0.40	19%	10%
To contract research that supplement research that the firm do not perform	Firms' capabilities	0.38	14%	28%

Source: The Survey 2006

Table 7: Frequency of success of firms – PRO collaboration

	Innovativeness		Size			Total
	Non-innovative	Innovative	Small	Medium	Big	
Successful linkage	58%	64%	52%	60%	66%	62%
Failed linkage	13%	9%	21%	8%	9%	10%
Success expected	26%	26%	23%	30%	25%	26%
Failure expected	3%	1%	4%	2%	1%	2%
Total firms	115	238	56	97	200	353

Source: The Survey 2006

Table 8: Duration of firms – PRO collaboration

	Innovativeness		Size			
	Non-innovative	Innovative	Small	Medium	Big	Total
Less than one year	38%	30%	47%	37%	26%	33%
Less than two years	13%	18%	18%	14%	16%	16%
Less than five years	20%	20%	13%	19%	22%	20%
Less than ten years	12%	7%	2%	11%	9%	9%
More than ten years	18%	26%	20%	19%	26%	23%
Total firms	112	238	55	97	198	350

Source: *The Survey 2005 & The Survey 2006*

Table 9: Main reasons for not collaborating with PRO

Reasons	Average importance 0-1 scale	% of linked firms that consider the goals at least moderately important (>0.5)
Our firm's R&D is enough to innovate	0.48	53%
Universities/Public research institutes have no understanding of our line of business	0.43	31%
Contractual agreements are difficult	0.43	29%
University concerned only with big science	0.40	22%
Intellectual property issues	0.38	25%
Quality of research is low	0.38	14%
Difficulties in dialogue	0.37	13%
Lack of trust	0.37	16%
Geographic distance	0.34	11%

Source: *The Survey 2006*

Table 10: Probit estimation on the probability of connection to PRO.

Variable name	Short description	Marginal effects
Size	Deciles based on employment for the full sample	0.026** [0.011]
Skill_size1	Skill in deciles 1 and 2	0.005 [0.387]
Skill_size2	Skill in deciles 3 and 4	-0.882* [0.485]
Skill_size3	Skill in deciles 5 and 6	0.246 [0.220]
Skill_size4	Skill in deciles 7 and 8	-0.112 [0.235]
Skill_size5	Skill in deciles 9 and 10	0.093 [0.258]
Link_vert	Vertical linkage	0.316*** [0.045]
Link_group	Linkage within the group	0.082 [0.058]
Link_hq	Linkage with the headquarters	-0.111* [0.066]
Ch_of_info	Importance of information exchange with other firms	-0.549*** [0.119]
Ch_of_res	Importance of research activities with other firms	0.169 [0.135]
IA_sector	Innovative activities over sales for the sector full sample	0.568 [1.908]
q_sector	Productivity for the sector full sample	0.011 [0.011]
Linked_sector	Quantity of linked firms in the sector	0.003*** [0.001]
Observations		592
Pseudo R-squared		0.12
Wald		88.91***

Robust standard errors in brackets

* significant at 10%; ** significant at 5%; *** significant at 1%

Source: *The Survey 2005 & The Survey 2006*

Table 11: Outcome variables to assess the ATT on linked firms

Variable group	Variable Name	Type of data	Variable Definition
a) Innovative behaviour	IA_sales	Ratio	Total expenditures in innovative activities over sales
	imaq_sales	Ratio	Expenditures in machinery for innovation over sales
	inhouse_sales	Ratio	Expenditures in R&D and Design and Engineering over sales
b) Innovative outcome	inn_prod	Dummy	Whether the firm obtained innovations in products (new or significantly improved)
	inn_proc	Dummy	Whether the firm obtained innovations in processes (new or significantly improved)
c) Appropriability behaviour	patent	1-4 scale normalised to 0-1	Whether the firm obtained patents
d) Sources of financing innovation	fin_int	Percentage	Percentage of total innovative activities financed by own resources, including resources from other firms within the group and headquarters
	fin_pro	Percentage	Percentage of total innovative activities financed by PRO
e) Perception of PRO	import_pro_	1-4 scale normalised to 0-1	Four categorical variables that accounted for the importance of PRO outcomes as perceived by firms: 1) Publications (import_pro_pub), 2) Prototypes (import_pro_prot), 3) Techniques and tools (import_pro_tech), 4) Laboratories / Metrology (import_pro_lab)
	role_pro_	1-4 scale normalised to 0-1	Four categorical variables that accounted for the roles PRO should pursued as perceived by firms: 1) Education (role_pro_edu), 2) Research (role_pro_res), 3) Social (role_pro_soc), 4) Entrepreneurial (role_pro_entr)

Source: *The Survey 2005 & The Survey 2006*

Table 12a) ATT of linking to PRO on firms' innovative behaviour

a) Innovative behaviour					
Variables	Weight methods	All unlinked firms before matching	Unlinked firms after matching (control group)	Linked firms	Difference of means of linked - unlinked firms
					Means
IA_sales	Nearest Neighbour	0.0224	0.0164	0.0280	0.0116***
	Kernel (normal)	0.0224	0.0192	0.0280	0.0088**
	Radius	0.0224	0.0182	0.0285	0.0104**
	Caliper	0.0224	0.0169	0.0285	0.0117***
imaq_sales	Nearest Neighbour	0.0136	0.0086	0.0152	0.0065**
	Kernel (normal)	0.0136	0.0102	0.0152	0.0050*
	Radius	0.0136	0.0093	0.0157	0.0064**
	Caliper	0.0136	0.0088	0.0157	0.0069**
inhouse_sales	Nearest Neighbour	0.0051	0.0050	0.0089	0.0039*
	Kernel (normal)	0.0051	0.0055	0.0089	0.0035*
	Radius	0.0051	0.0054	0.0088	0.0034*
	Caliper	0.0051	0.0052	0.0088	0.0036**

Source: The Survey 2005 & The Survey 2006

Table 12b) ATT of linking to PRO on firms' innovative outcomes

b) Innovative outcome					
Variables	Weight methods	All unlinked firms before matching	Unlinked firms after matching (control group)	Linked firms	Difference of means of linked - unlinked firms
					Means
inn_prod	Nearest Neighbour	0.4599	0.5256	0.5369	0.0114
	Kernel (normal)	0.4599	0.4921	0.5369	0.0448
	Radius	0.4599	0.5094	0.5315	0.0221
	Caliper	0.4599	0.5075	0.5315	0.0240
Inn_proc	Nearest Neighbour	0.4388	0.4773	0.5540	0.0767
	Kernel (normal)	0.4388	0.4418	0.5540	0,1122***
	Radius	0.4388	0.4337	0.5556	0,1218**
	Caliper	0.4388	0.4595	0.5556	0,0961*

Source: The Survey 2005 & The Survey 2006

Table 12c) ATT of linking to PRO on firms' appropriability behaviour

c) Appropriability behaviour					
Variable	Weight methods	All unlinked firms before matching	Unlinked firms after matching (control group)	Linked firms	Difference of means of linked - unlinked firms
		Means			ATT
patent	Nearest Neighbour	0.0169	0.0057	0.0511	0.0455***
	Kernel (normal)	0.0169	0.0090	0.0511	0.0422***
	Radius	0.0169	0.0090	0.0450	0.0361***
	Caliper	0.0169	0.0060	0.0450	0.0390***

Source: The Survey 2005 & The Survey 2006

Table 12d) ATT of linking to PRO on firms' uses of sources of finance for innovation

d) Sources of financing innovation					
Variables	Weight methods	All unlinked firms before matching	Unlinked firms after matching (control group)	Linked firms	Difference of means of linked - unlinked firms
		Means			ATT
fin_int	Nearest Neighbour	0.8416	0.8548	0.7848	-0.0700*
	Kernel (normal)	0.8416	0.8448	0.7848	-0.0601**
	Radius	0.8416	0.8589	0.7825	-0.0764**
	Caliper	0.8416	0.8685	0.7825	-0.0860***
fin_pro	Nearest Neighbour	0.0111	0	0.0185	0.0185***
	Kernel (normal)	0.0111	0.0089	0.0185	0.0095
	Radius	0.0111	0.0088	0.0184	0.0096
	Caliper	0.0111	0	0.0184	0.0184***

Source: The Survey 2005 & The Survey 2006

Table 12e) ATT of linked and unlinked perceptions about PROs

e) Perception of PRO					
Variables	Weight methods	All unlinked firms before matching	Unlinked firms after matching (control group)	Linked firms	Difference of means of linked - unlinked firms
		Means			ATT
Import_pro_pub	Nearest Neighbour	0.3270	0.3175	0.3700	0.0526
	Kernel (normal)	0.3270	0.3303	0.3700	0.0398
	Radius	0.3270	0.3280	0.3694	0.0413
	Caliper	0.3270	0.3086	0.3694	0.0608
import_pro_prot	Nearest Neighbour	0.2289	0.2237	0.2514	0.0277
	Kernel (normal)	0.2289	0.2322	0.2514	0.0193
	Radius	0.2289	0.2355	0.25	0.0145
	Caliper	0.2289	0.2305	0.25	0.0195
import_pro_tech	Nearest Neighbour	0.3112	0.2912	0.4055	0.1143***
	Kernel (normal)	0.3112	0.3071	0.4055	0.0984***
	Radius	0.3112	0.3003	0.4039	0.1036***
	Caliper	0.3112	0.292	0.4039	0.1119***
import_pro_lab	Nearest Neighbour	0.2753	0.2443	0.3842	0.1399***
	Kernel (normal)	0.2753	0.2806	0.3842	0.1036***
	Radius	0.2753	0.2733	0.3821	0.1088***
	Caliper	0.2753	0.2447	0.3821	0.1374***
role_pro_edu	Nearest Neighbour	0.7691	0.7138	0.7521	0.0384
	Kernel (normal)	0.7691	0.7512	0.7521	0.001
	Radius	0.7691	0.7591	0.7553	-0.0038
	Caliper	0.7691	0.7222	0.7553	0.033
role_pro_res	Nearest Neighbour	0.6568	0.6634	0.7031	0.0398
	Kernel (normal)	0.6568	0.6632	0.7031	0.0399
	Radius	0.6568	0.6736	0.7035	0.0299
	Caliper	0.6568	0.6577	0.7035	0.0458
role_pro_soc	Nearest Neighbour	0.6176	0.6065	0.5774	-0.0291
	Kernel (normal)	0.6176	0.6237	0.5774	-0.0463
	Radius	0.6176	0.6244	0.5841	-0.0403
	Caliper	0.6176	0.6029	0.5841	-0.0188
role_pro_entr	Nearest Neighbour	0.5742	0.5582	0.527	-0.0313
	Kernel (normal)	0.5742	0.5821	0.527	-0.0551
	Radius	0.5742	0.5865	0.5338	-0.0551
	Caliper	0.5742	0.5563	0.5338	-0.0225

Source: The Survey 2006

Appendix: Variables' definition

Variable group	Variable Name	Type of data	Variable Definition
	linked	Dummy	Firms' connected to PRO for information exchange for innovative projects or for joined research activities
	linked_act	Dummy	Active linkages, when firms give a 3 or 4 importance in a 1-4 scale to channels of interactions that implied active participation in knowledge/research activities
	link_vert	Dummy	participation in research networks, incubators, and scientific parks)
	link_group	Dummy	Firms that linked to suppliers or clients
	link_hq	Dummy	Firms that linked to other firms within the group
	link_int	Dummy	Firms that linked to headquarters
	ch_of_info	1-4 scale normalised to 0-1	Firms that linked to its own network (within the group or with the headquarters)
	ch_of_res	1-4 scale normalised to 0-1	Importance of channels for knowledge transfer to other firms related to information exchange (i.e. publications, conferences, informal information exchange)
			Importance of channels for knowledge transfer to other firms related to research activities (i.e. contracted research, joined research, products, licences)
			Six categorical variables: one for six different goals for linking to PRO: 1) to improve absorptive capabilities (goal_abs), 2) to contribute to innovative activities (goal_suppl), 4) to take advantage of PRO's human resources (i.e. to get advices from researchers and to hire students at an early stage), 3) to take advantage of PRO's infrastructure and machinery resources (i.e. quality control, monitoring and testing and other resources) (goal_cap), 6) to take advantage of PRO's knowledge (i.e. to get advices from researchers and to hire students at an early stage) (goal_k)
Firms' network behaviour	goals_	1-4 scale normalised to 0-1	transfer and other information from the scientific field) (goal_k)
	pay_	Dummies	Six dummy variables to account for whether firms pay or not to pursue each of those goals
Firms' characteristics	size	0-10	Deciles based on employment defined for the full ENIT 2005 (1675 firms). Deciles' upper limits were: 1 = upto 16 employees, 2 = 27, 3=40, 4=60, 5=85, 6=110, 7=140, 8=175, 9=220, 10 = bigger than 411
	skills	Ratio	Professional over total employment
	IA_sales	Ratio	Total expenditures in innovative activities over sales
	imaq_sales	Ratio	Expenditures in machinery for innovation over sales
	inhouse_sales	Ratio	Expenditures in R&D and Design and Engineering over sales
	fin_int	Percentage	Percentage of total innovative activities financed by own resources, including resources from other firms within the group and headquarters
	fin_pro	Percentage	Percentage of total innovative activities financed by PRO
	patent	1-4 scale normalised to 0-1	Whether the firm obtained patents
Firms' innovative behaviour	inn_prod	Dummy	Whether the firm obtained innovations in products (new or significantly improved)
	inn_proc	Dummy	Whether the firm obtained innovations in processes (new or significantly improved)
	IA_sector	Ratio	Total employment over sales for the whole sample of ENIT 2005 for 8 groups of sectors (see INDEC 2008))
Sector characteristics	q_sector	Ratio	Total employment over sales for the whole sample of ENIT 2005 per sector (2 digits ISIC)
	linked_sector	Ratio	Sum of firms that were connected to PRO per sector (2 digits ISIC)