cenit

centro de investigaciones para la transformación

DT 39/2009

FIRMS' LINKAGES WITH UNIVERSITIES AND PUBLIC RESEARCH INSTITUTES IN ARGENTINA: MODES OF INTERACTIONS AND THEIR *KNOWLEDGE VALUE*

Dr. Valeria Arza[1]

This paper is one of the research outputs for the project: **Interactions between universities and firms: searching for paths to support the changing role of universities in the South**, funded by IDRC.

[1] Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Centro de Investigaciones para la Transformación (CENIT), varza@fund-cenit.org.ar

Abstract

There are benefits and risks involved in interactions between public research organisations (PRO) and the productive sector. The better the balance between them the larger the *knowledge value* of linking. This paper proposes a conceptual framework that associates actors' motivations for linking and modes of interaction. It suggests that under specific conditions related to knowledge capabilities and behaviour some modes of interactions have better *knowledge value* and thus should be promoted against others. The main claim is that *bi-directional* modes of interactions (i.e. knowledge flowing from PRO to firms and *viceversa*) optimise the *knowledge value* of linking conditioned to both actors having high knowledge capabilities and behaving proactively. Using propensity score matching techniques with original data for linked firms, the paper found that those conditions were met for firms forming bi-directional linkages with PRO in Argentina.

Keywords: public-private partnerships, public research institutes, universities, modes of interaction, knowledge diffusion, innovation, firms, Argentina

I) Introduction

Linkages between the private sector and universities and public research institutes (hereafter public research organisations, PRO) have a broad potential to create and diffuse knowledge (Dasgupta and David, 1994, Nelson, 2004, Pavitt, 2001, Slaughter and Leslie, 1997). Firstly, PRO widen the industry capacity to solve concrete problems, thus aiding at incremental innovations. Some problems demand a combination of technology that no single firm could develop on its own, but which could nevertheless be solved using the knowledge stock available in PRO (Patel and Pavitt, 1995). In some cases, these knowledge flows may even increase the likelihood of generating radical innovations. Secondly, and on the other side of the coin, many fields of research get inspiration from industry[2] (Nelson, 2004, Rosenberg, 1996, Rosenberg and Nelson, 1994); thus, through interactions the production of scientific knowledge may become more dynamic. Thirdly, PRO develop new laboratory instrument and analytic methodologies that constitute a fundamental input for industry (Rosenberg, 1992). Finally, linkages also allow PRO to gain access to new sources of funding for their research (Geuna, 2001).

However, the relation between PRO and the private sector is not free from controversies. The main ones are related to: i) the goals of public research (e.g. must the research agenda be oriented to solve concrete problems in the industry?, or rather, it must not be conditioned in any way so as to exploit to the maximum the creative potential in PRO?)[3]; ii) the opportunity costs of linkages (i.e. the time that researchers use for interacting with firms is less time devoted to teaching and research[4] and also industry demand may divert lines of research from social goals[5]); and iii) the risk of privatization of public research outputs

---

[2] This is particularly the case of those fields of research located in the "Pasteur quadrant" (Stokes, 1997, 1997), which progress doing basic and applied research simultaneously (e.g. all types of engineering, biotechnology, metallurgy, computer science, etc.)

[3] One possible threat of interactions is the risk of lock-in effect. Since interactions tend to be path dependent, it is likely that when they are too tightly defined, new avenues of research and potential new paradigms are neglected (or not recognised sufficiently fast). Meyer-Krahmer and Schmoch (1998) argue that in order to reduce the probability of a lock-in effect it is necessary to promote a broad network of firms and PRO interconnected loosely and flexibly. Another important threat of interactions is related to ethics or conflict of interest that may come up between teaching and research against interacting with private actors. This has been largely studied in the area of clinical research, see Blumenthal *et al.*, 1997, Blumenthal *et al.*, 1996, Blumenthal *et al.*, 2006, Campbell and Blumenthal, 1999, Gelijns and Thier, 2002

[4] Regarding these issues see Blumenthal *et al.*, 1996, Campbell, 1997, Crespo and Dridi, 2007, Hackett, 1990, Lee and Rhoads, 2004, Rothaermel and Thursby, 2005 among others. This risk is particularly important when PRO are usually subject to binding financial constraints and need to use a high proportion of time seeking for private funds. Financial constraints in PRO is acute in developing countries

[5] By linking research by PRO may become oriented towards paths that benefit linked firms' own interests (or those of some consumers and producers) but which do not necessarily meet the needs of the majority of the population (see Lee, 1996, Mollis and Marginson, 2002, Webster, 1994, Blumenthal *et al.*, 1996, Florida,

which are necessary to continuing doing research downstream (e.g. what would be the private sector role in diffusing publicly created knowledge?).[6]

Given the likelihood of conflicting interests, to take the most of the public/private interactions, benefits and costs of the interactions must be evaluated.

This paper explores linkages between PRO and the private sector in Argentina. It suggests that some modes of interactions, particularly those that enable a bi-directional flow of knowledge, are more valuable than others under certain conditions. Those conditions are i) high knowledge capabilities of players choosing bi-directional linkages and ii) high proactive behaviour towards learning and against opportunism of firms linked using those modes.

If these conditions were met by actors involved in bi-directional linkages, virtuous cycles of knowledge creation and diffusion could emerge *pari pasu* the expansion of these modes. The empirical goals of this paper are to assess the extent to which those conditions are attained in Argentina when *firms* form bi-directional linkages. This paper is relevant for policy makers in the area of science, technology and innovation because it discusses whether some modes of interactions should be promoted against others to upgrade the knowledge capabilities of the National System of Innovation (NSI) as a whole.

The paper is divided in five more sections besides this introduction. Next section discusses the conceptual framework and the research goals. Section 3 presents the strategy of data collection and the main sample statistics. Section 4 discusses propensity score matching techniques, which constitutes the methodological approach. Section 5 examines the main determinants of interaction using bi-directional linkages and the relation between those modes and firms' innovative behaviour. Finally, the last section discusses the conclusions and presents some implications for policy making.

1999, Godfrey, 2005, among others). This is especially true in contexts of high inequality -as in many developing countries- and could be reversed if there were strategic research lines promoted as part of the science and technology policy.

[6] Nelson, 2004 convincingly argued that fundamental knowledge from science, even when belonging to fields of research with semi-immediate application (like the ones in the Pasteur's Quadrant), must remain open to public use. There is evidence that shows that when interacting firms demands either exclusive rights over patents or secrecy. For example, Blumenthal *et al.*, 1996 claimed that secrecy is a requirement more likely to be imposed by industrial partners to universities than by other partners. Besides, Godfrey, 2005 who studied three networks involving universities and firms in the field of new materials in South Africa, found that firms were always sufficiently powerful to set the requirements on disclosure of information and participants in the networks.

II) Conceptual framework

The introduction mentioned the most important risks and benefits related to interactions between PRO and private firms. The analytical framework put foward in this section identifies extremes forms of motivations for linking, whose combination results in different modes of interactions. Moreover, the framework proposes that some of those modes have better balance of benefits and risks (i.e they have better *knowledge value*), when certain behavioural and knowledge related conditions are met. Therefore, from the standpoint of public policy, the framework argues that some modes of interactions should be promoted against others under different conditions.

Figure 1 illustrates the analytical framework. The axes reflect the motivation that PRO (vertical axis) and firms (horizontal axis) have for linking. These motivations are not dichotomous and should be read as a continuum between extremes: on the one hand, for PRO, the extremes are either strictly intellectual motivations (i.e. learning in the context of application) or strictly financial reasons (i.e. accessing to new sources funding).[7] On the other hand, for firms, the extremes are given by either motivations related to exploiting the physical and human capital stock -generally offered by PRO at subsidized rates- or motivations related to get access to external sources of top-level scientific knowledge, which would enhance their own innovative capabilities. For the sake of exposition, I call 'passive' motivations to the former and 'active' motivations to the latter.

(insert Figure 1 around here)

Thus, four quadrants are defined. Southwest quadrant (SW) contains interactions motivated by PRO's financial needs and passive motivations of firms. This results in interactions that could be associated with the provision of scientific and technological services in exchange for money, where knowledge flows from PRO to firms (e.g. consultancy, use of equipment for quality control, tests and monitoring, etc.). The opposite quadrant, the northeast (NE), includes interactions that originate from intellectual motivations of PRO and active motivations by firms. In this case the knowledge flow is bi-directional and there is joint learning. This quadrant includes joint R&D projects, participation in networks, scientific-technological parks, etc.

By comparing these opposite quadrants we can conclude that the balance of benefits and risks is optimized in the NE quadrant because knowledge flows in both directions and

[7] This classification was inspired on *intellectual* or *financial imperatives* proposed by Kruss, 2005.

therefore there are opportunities for both actors to learn from each other (i.e. potential benefits exist for both). Risks are also lower in the NE quadrant than in the SW quadrant. Opportunity costs are lower for PRO because interactions are motivated by their own intellectual curiosity, which means that time devoted to interactions is learning time. Besides, research would follow the lines related PRO's original intellectual motivations.

However, for this balance to occur two conditions must be met: i) players that choose these modes of interactions must have relatively high scientific and technological capabilities; ii) both players, once linked, must show proactive behaviour towards *learning* (i.e. avoiding opportunism). If either of both condtions are not met, the flow of knowledge would be poor or would not occur resulting in interactions of poor knolwede value. This, in tun, would create opportunity costs for either actor or both.

The other two remaining quadrants are defined by financial motivations of PRO and active motivations of firms (southeast quadrant, SE) or intellectual motivations of PRO and pasive motivations of firms (northwest quadrant, NW). The latter case defines a type of interaction where the knowledge also flows one way, from PRO to firms, but where contents are defined by the traditional functions of PRO (e.g. training, publications, conferences, etc.). All these interactions could imply a lack of response to the needs of the NSI since scientific developments are not guided by specific needs. The SE quadrant, on the other hand, defines extremely commercial modes of interactions, where the main motivations by PRO are driven by the attempt to commercialise their already achieved scientific outcomes. Emblematic examples of these modes are spin-off companies and incubators. Here we could also include patents (appropriated by the private sector who may pay royalities to PRO) of products or processes developed as a result of the interaction. Modes of interaction in this quadrant embody the risk of private appropriation of research conducted in part with public funds.

In sum, the analytical framework suggests that the initial motivations of players define modes of interaction that under certain conditions result in a better balance of risks and beneftis and therefore enjoy better knowledge value. Those conditions are related to the knowledge capabilites and behavioural practices of both players.

This paper assesses the knowledge capability, motivations and behaviour of **firms**[8] that link to PRO using bi-directional modes of interactions. We identify those modes of interactions taking into consideration the expected direction of knowledge flows.

[8] This paper is based on a *firm survey*. Therefore, this research will not be able to assess researchers or PRO characteristics. Nevertheless, the received literature on public research in Argentina suggests that research in

The research question of this paper is: **are the necessary conditions for optimising the *knowledge value* of bi-directional linkages met in the Argentinean case?** To answer this question the paper address two research goals: Firstly, it evaluates weather firms that choose bi-directional linkages enjoy relatively better knowledge capabilities. Secondly, it assess whether firms involved in bi-directionally linkages behave rather proactively towards learning. The former goal is empirically assessed by estimating a model on the determinants of firms' choosing bi-directional linkages. The latter goal is assessed using propensity score matching techniques which allows for unbiased comparison between firms that choose different modes of interactions.

In Argentina there are very few academic studies available related to the process of PRO's knowledge creation and diffusion, and even less papers that explicitly research about private-public interactions.[9] The great majority of the very few academic papers available related to the interaction between firms and PRO is based on case-studies, which either study the impact of those linkages on firms' innovative capabilities[10] or analyze the interaction dynamics from the point of view of the PRO.[11] To the best of our knowledge, there is no study that compares firms interacting through different modes of interactions.

Therefore, the contribution of this research is conceptual and empirical. Firstly, we propose for the first time that the *knowledge value* of linking differs for different modes of interactions, and we thoroughly evaluate the knowledge capabilities, behaviours and motivations of firms that choose different modes of interaction. Secondly, we use propensity score matching techniques, which allow us to construct a control group against which we may establish unbiased comparisons, on an original and representative survey database which is used for the first time in this project.

III) Data and descriptive statistics

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

PRO is fairly good quality although interactions with the private sector are rather weak (see Bisang and Malet, 1998, Dussel, 1973, García de Fanelli, 1993b, García de Fanelli, 1994, Katz and Bercovich, 1988, López, 2007).

[9] An incomplete 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.

[10] See Moori-Koenig and Yoguel, 1998, Yoguel and López, 2001 and Lugones and Lugones, 2004.

[11] See Dávila, 2006, Juarros, 2006 and Riquelme, 2008.

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 PRO[12] in the innovation survey of 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% (355 firms).

3.2. Classification of modes of interactions

Both research goals require an empirical identification of bi-directional linkages. Table 1 presents statistics about 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.

(Insert Table 1 around here)

As can be seen, 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.

Three modes of interaction that by definition involve knowledge flowing in both directions were identified: joint R&D projects, networks, and scientific or technological parks. Among them, the first one does not require much justification; if there is *joint* R&D knowledge must be flowing in both directions. Networks' full denomination in the questionnaire was "participation in networks with PRO". These networks are usually consortiums of firms and PRO doing joint research, which is a common mode of collaboration for which there exists public support in Argentina. Finally, in the literature, scientific parks and incubators are usually analysed as similar phenomena, which raises doubts on the extent to which scientific parks are really bi-directional modes. In fact, we believe that incubators are not different from spin-off firms and university owned firms (all of them are options available in the questionnaire) in what concerns to the directions of knowledge flows. In all these cases, we remain unsure about the extent to which knowledge

[12] 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.

flows from firms to PRO or whether rather these firms are being nursed by PRO' technical knowledge or just commercialising already produced research ouputs. However, in Argentina the case of scientific parks is different. These parks do not aim at incubating new firms, but rather they aim at relocating technically better prepared firms to the proximities of PRO so as to increase the likelihood of knowledge spillovers in the region. Therefore, we believe that firms that answer that scientific parks were important modes for interacting with PRO are likely to be those targeted firms, which would be actively involved in knowledge exchange with PRO.

All other listed interactions do not usually imply technical knowledge flowing from firms to PRO. These are either *traditional* modes of interactions that imply PRO diffusion of their research outputs (e.g. publication, conferences, hiring graduates, and informal exchange), or consist of *service* provision from the PRO to firms (e.g. consultancy, internships, and contract research) or comprise tools for the *commercialisation* of already produced research outputs (e.g. spin off, university owned firms, incubators, licences, and patents). Among them, it is controversial whether the direction of knowledge in 'contract research' goes always from PRO to firms. It could well constitute one of these modes whether PRO learn from sophisticate problems raised by firms. However, we know that this item also includes the types of service provisions that involve using PRO infrastructure, such as tests, quality control or monitoring. For this reason, this item was excluded from the group of bi-directional modes because it does not *necessarily* imply knowledge flowing both ways.

This taxonomy identifies 37% (130) of linked firms that value at least one bi-directional mode as moderately (or highly) important. Interactions through service provision are important for a larger group of firms (45%), but yet, traditional types of interactions are the most important among linked firms; 81% assessed these modes as important.[13] The least important modes are the commercial forms of interactions (only 30% considered them as fairly important), which may be interpreted as a reflection of PRO poor entrepreneurial performance.

3.3) Main characteristics of the firms in the sample

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

Table 2 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.[14] It shows that a minority of linked firms are small. In comparison to

[13] This group contains 'informal information exchange', which is an ambiguous classification since it might also involve some sort of service provision. However, even when excluded from the traditional group, the remaining traditional interactions (i.e. publications, conferences or hiring graduates) continued to be important for the wide majority of firms (72%).

[14] 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.

the size distribution of the full sample, there is an overrepresentation of big firms among linked firms. This is even more noticeable for firms that linked through bidirectional linkages, which tend to be larger than firms that link to PRO through other modes of interaction.

(Insert Table 2 around here)

Table 3, in turn, organises firms according to their sector affiliation. The first column shows the proportion of linked firms per sector. The second column does the same only for firms that use bi-directional linkages. The third column shows the sectoral distribution for the full sample of 2005 (1675 firms). The fourth last column calculates the ratio between column 1 and 3. 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))[15]. The last column compares columns 2 and 3. Proportionally, bi-directional linkages also have a higher weight of sectors 24 and 29. Besides these sectors, bi-directional linkages are predominantly important in precision instruments (33).

(Insert Table 3 around here)

IV) Methodology

The first goal was to identify whether firms that choose bi-directional linkages are among the most capable ones. This is done with a Probit model, presented in Section 4.1, which estimates the determinants of choosing bi-directional linkages in which skills of the working force is the main explanatory variable.

The second goal was to examine whether firms involved in bi-directional linkages have a rather proactive behaviour towards learning (rather than a passive, opportunistic behaviour). This is tackled using propensity score matching techniques introduced in section 4.2 by which the behaviour of firms linked to PRO using bi-directional modes is contrasted against the behaviour of very similar firms which nevertheless have chosen other modes of interactions.

[15]Sector 16 was excepted from this comment because *The Survey* includes very few firms from this sector.

4.1) Probit model to assess 1st research goal

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' size,[16] industry or technology characteristics,[17] network related characteristics,[18] public policy promotion,[19] firms' knowledge bases[20] and geographical proximity.[21] Therefore, in our model on the firms' determinants for linking using bi-directional linkages we include proxies for most of these variables, subject to data availability.

Equation (1) presents a simplified version of a 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.

$$(1)\ BiL = \alpha \ \ firm\_charac + \beta \ net\_charac + \gamma \ \ \mathrm{sec}tor\_charac + u$$

The first set of variables in Equation (1) contains firms' specific characteristics: size and skills. The second set is about the network behaviour of the firm and it includes: a dummy for connection to suppliers or clients, another dummy for connections to other firms in the group (included headquarters). 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 two issues: intensity of investment in innovative activity and propensity to use bi-directional linkages with PRO.

4.2.) Propensity score matching techniques to assess 2nd research goal.

Our second research goal requires comparing behaviour for firms that linked using bi-directionally linkages against those that use other linkages. 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 (e.g certain firms are more likely than others to be involved in bi-directional linkages) 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.

---

[16] 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

[17] 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

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

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

[20] See, for example, (Arundel and Geuna, 2004; Fontana *et al.*, 2003; Schartinger *et al.*, 2002). Fischer and Varga, 2002, MacPherson, 2002, Santoro and Chakrabarti, 1999

[21] Abramovsky *et al.*, 2007, Fritsch and Schwirten, 1999, Vedovello, 1997

This 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. firms that use bi-directional modes of interactions) and their untreated twins (e.g firms that use other modes).

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,[22] an index is calculated (i.e. the propensity score).[23] This index reflects the probability of being treated conditional on relevant characteristics and it is defined as.

(2) $p(X) \equiv \Pr[D = 1 \mid X] = E[D \mid C]$

Where p(X) is the propensity score, D is a dummy for treatment and X is a multidimensional vector for pre-treatment characteristics. In our case, the equation (1) presented above specifies the propensity score in equation (2)

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.

Finally, the *balancing hypothesis* must also be satisfied, which states that the characteristics of units with similar propensity scores must be 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.

In sum, the quality of propensity score matching methods heavily depends on the quality of the propensity estimate (i.e. the goodness of fit of the Probil). Therefore, it is highly important to take good care of the participation equation (1). In this paper, the variables included in that estimation were those indicated as important in the literature and the

[22] 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 a firm linked to PRO using other modes of interactions that is of the same size, the same type of ownership, belongs to the same sector, etc that every single linked firm using bi-directional linkages).

[23] This paper uses the psmatch2 method developed by Leuven and Sianesi, 2003.

specific proxies for them were those that better fit the model while passing the balancing test.

Once the propensity score was calculated, it is necessary 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 sophisticate 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 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) Firms' capabilities, modes of interactions and firms' behaviour

This section empirically assesses the research goals of the paper: section 5.1 presents the results of the Probit model described in 4.1 and section 5.2. presents the results of the propensity score matching techniques described in section 4.2.

5.1) The firms' determinants of choosing bi-directional modes of interaction

Table 4 presents the Probit estimation: firm size and the sectoral propensity of linking using bi-directional modes are significant determinants of the propensity to link bi-directionally. This means, firstly, that the larger the scale (variable size is measured in deciles) the higher the probability of using bi-directional linkages.

Secondly, there are sectoral differences in the propensity to choose bi-directional linkages, as suggested by Table 3.

The network indicators are not significant, which is not very much surprising since all firms included in this estimation are linked firms (either through bi-directional modes or through other modes).

The main explanatory variable in the model is skills. As can be seen, the higher the proportion of engineers in the workforce the more likely the firm would choose to form bi-directional linkages. This is mostly explained by the difference in skills between small firms that link using bi-directional modes and small firms that choose other modes (results not presented here). This is an interesting result that tackles the first research goal of this paper.

In sum, in Argentina skills drive the formation of bi-directional linkages. Different explanations may justify this fact. This may reflect a selectivity phenomenon. When PRO decide who they join in knowledge interactions, they may select the better prepared firms. It may also suggest that firms with better skills are more ambitious in their research activities and requires external sources of knowledge to fulfil their research goals, since it is very difficult that a single firm could posses all the necessary knowledge resources to perform ambitious innovations. In any case, the interesting result is that so far one out of two identified conditions for optimising the *knowledge value* of bi-directional linkages seems has been met for our data: the higher the knowledge assets of firms, the more likely they will be involved in bi-directional linkages.

(Insert Table 4 around here)

Next section assess whether the second condition is also met: once firms have adopted bi-directional linkages: do they behave proactively towards learning?

5.2) The average effects on innovative behaviour of linking using bi-directional linkages

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 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.[24]

Regarding the effects of U-I interactions on firms' economic performance results are mixed[25] but they tend to be dependent on the goals of the interactions since many cooperative agreements target pre-competitive research.[26]

---

[24] 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.

[25] 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

Most studies that analyse R&D cooperation find a positive effect on innovative behaviour and performance.[27] Instead, some mixed results can be found when interactions are measured more broadly. These latter studies are more relevant for the purpose of this paper because they highlight that different modes of interactions may have different impact.

Adams *et al* (2003) found that firms cooperating in R&D with federal laboratories in the US perform better in terms of their innovative outcome than those that do not cooperate, but this could not be replicated for firms involved in other modes of interaction.[28] Similarly, Arvanitis *et al.* (2008) compared the performance of Swiss interactive firms across different modes of interactions. Like in this paper they used propensity score matching methods. They found that innovative sales represented a higher proportion of total sales for firms that cooperate in research[29] and in education[30] but there were not significant differences for firms interacting with universities via consulting[31] or via using the technical infrastructure[32] against those that did not use these modes of interaction. Moreover, they found that firms intensively involved in consulting with universities, invest less intensively in R&D and were less effective in terms of reducing average production

---

found 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.

[26] 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.[26] 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.

[27] 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..

[28] They assessed modes such as licensing of government patents, inflows of scientists from government laboratories, use of industry-government technology transfer centers, etc.

[29] i.e. joint R&D, long-term research contracts and research consortium.

[30] e.g. Training, joint doctoral students, students' participation in firms' R&D, attending to courses, etc. In the case of cooperation with educational purposes they also found that firms were more effective in reducing average production costs due to process innovation.

[31] i.e. Expertise and consulting

[32] i.e. Common laboratory, use of university technical infrastructure

costs with process innovation[33] than firms that did not hire consulting services from universities.

This paper assesses differences in behaviour for firms that linked using bi-directional linkages (BiL) against counterfactual groups (according to different matching methods) of firms that linked using other modes of interactions (OL). In particular, we are interested in knowing whether firm that use BiL differ from similar firms that chose OL in terms of a) innovative behaviour, b) attitude towards patenting their innovative outcomes, c) motivations for interacting and d) whether firms pay or not by type of goals, all of which are described in Table 5.

(Insert Table 5 around here)

The average treatment effect on the treated group (ATT) was calculated, or in other words the average difference on the outcome variables between the treated group (i.e. firms linked using BiL) and the counterfactual group (i.e. twin firms –according to different matching methods- using OL).

Tables 6 to 9 list the results on the impact of using BiL on the different group of variables listed in Table 5. 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 OL). The fourth columns correct these values calculating the average only for firms with OL which are twins of firms with BiL. The fifth columns present the average value only for firms with BiL. 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 6 compares innovative behaviour of firms using BiL and those using OL. Very interestingly, although these groups invest similar amount of their sales in general innovative activities, firms that choose BiL invest significantly more in in-house innovative activities. Firms with BiL invest as much in in-house innovative activities as in incorporated technologies (machinery),[34] which is not at all the case of firms with OL. Since in-house innovative activities typically increases firms' absorptive capabilities (Cohen and Levinthal, 1990), it seems safe to interpret that firms involved in BiL have a proactive attitude towards learning. The relatively higher participation on in-house innovative activities among these firms when compared against firms that choose OL but have similar characteristics (included similar skills), seems to suggest that this type of

[33] This result appeared when they used the "Caliper" method for matching but it did not when they used the "nearest neighbour" method.

[34] This innovative strategy was called 'balanced' by Lugones *et al.*, 2004. The authors found that firms that followed balanced strategies in Argentina during the period 1992-2001 enjoyed better economic performance and were more able to retain employment in a context of recession.

behaviour may be triggered by the very research activities included in the BiL. Although the reverse causality is cannot be fully discarded,[35] the important point to stress here is that firms implicated in BiL show a relatively proactive behaviour towards learning, which complies with the second condition for optimising the knowledge value of BiL.

(Insert Table 6 around here)

Table 7 shows that round 8% of firms with BiL have obtained at least one patent, while this percentage is much lower for the control group (between 1.5% and 3.5% depending on the matching method).[36] These significant differences in patenting activities between firms with BiL and those with OL, cannot be interpreted as differences in innovative performance due to the interaction, since cooperating and patenting will not be done contemporaneously. Rather we interpret this much more as a question of firms' appropriability behaviour: firms involved in BiL seem to prefer patents (and seem to have the necessary resources and capabilities to obtain patents) more than firms choosing OL. 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.

Although there is neither evidence that patent rights are of exclusive ownership of firms nor that the patented outputs had been obtained as a result of the interaction, it is clear that firms involved in BiL have privileged access to publicly created knowledge. Therefore, the very existence of such marked difference in appropriability behaviour between these groups of firms raise issues of concern about the likelihood of privatisation of publicly created knowledge. Therefore, efforts should be made from policy makers to ensure that the knowledge exchanged through BiL remains, in Nelson (2004) terms, as part of the scientific commons.

(Insert Table 7 around here)

In the survey firms were requested to identify the importance of different motivations (goals) for interacting. We re-classify the goals in six groups: 1) to improve absorptive capabilities (goal_abs), 2) to contribute to innovative activities (goal_contr), 3) to supplement innovative activities (goal_suppl), 4) to take advantage of PRO's human

---

[35] It could well be that PRO select to interact with firms that invest large amounts in R&D, even among firms with similar skills. To be sure about the direction of the causality we should have longitudinal information.

[36] 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.

resources (goal_hr), 5) to take advantage of PRO's infrastructure and machinery resources (goal_cap), 6) to take advantage of PRO's knowledge resources (goal_k).

Table 8 shows that in average firms with BiL consider all these goals more important than those with other OL. In other words, firms that collaborate actively value more the interaction in many different fronts. This confirms that firms that select BiL are more committed to interacting with PRO than OL and therefore value better all goals of the interaction.

The goals for which the difference is more prominent are: to take advantage of PRO's knowledge resources and to contribute to innovative activities. In contrast, the goal for which the difference was the least important was to take advantage of PRO's infrastructure and human resources, which is coherent with our analytical framework of Figure 1. In other words, the importance of knowledge resources *vis* à *vis* infrastructure and human resources that firms with BiL show, confirms the *active* nature of motivations for forming BiL. Firms that choose BiL are mostly interested in contacting PRO because of their exclusive knowledge assets and not for other purposes that could be equally satisfied by other providers.[37]

Finally, the issue of preference for contributing rather than for supplementing research is quite relevant. The literature provides various insights.[38] On the one hand, a number of works show that firms that make intensive use of external knowledge are likely to focus their internal capabilities on only certain areas of advanced knowledge, supplementing other areas with external sources (including PROs) (e.g. Dussauge *et al.*, 2000, Miotti and Sachwald, 2003, Velho and Saez, 2002, Veugelers and Cassiman, 2005). This behaviour may impinge on their potential for knowledge diffusion: it is possible that the type of knowledge that these firms are able to transfer is too specialised to be of general interest to researchers with whom they interact. On the other hand, some suggest that, in certain industries, firms need to develop internal capabilities in a variety of areas of knowledge, even if they mainly rely on external sources for some of this knowledge. This may be because it may be difficult for the firm to control the timing of knowledge or technology transfer from external sources (Brusoni *et al.*, 2001). In these cases, linkages with PRO do not lead to over-specialisation by firms in certain technological areas and may be more profitable in terms of learning at both sides of the interaction (i.e. they have better *knowledge value*).

Our results show that firms that select BiL are particularly prone to contributing rather than to supplementing which confirms that learning is not bound to occur in one single direction (from PRO to firms) as would have been the case if the supplementing goal had been the most important. Moreover, this result also re-emphasizes firms' proactive behaviour

[37] As can be seen in the Appendix, goals related to human resources include: technological advice from researchers to solve concrete problems related to production and early recruitment of students. In turn, goals related to infrastructure include: quality control, testing and monitoring and other uses of PRO's resources. Finally, goals related to knowledge include: technological transfer and information about new trends within the scientific field where the firm operates.

[38] The thoughts in this paragraph were originally elaborated in Giuliani and Arza, 2009.

towards learning when they are involved in BiL, which was a condition for optimising the *knowledge value* of these linkages.

(Insert Table 8 around here)

Finally, Table 9 presents the average frequency of firms' payment for every other important goal from Table 8. This table was calculated only for firms that answer that the goals listed in Table 8 were rather important (i.e. excluding answers 1 -that consider the goal as unimportant- in the scale 1 to 4). It shows that firms that choose BiL pay for their interactions with PRO more often than firms that choose OL. This suggests that BiL are more formally established than OL. This finding is valid for all goals of the interaction except for using PRO's infrastructure. This kind of interaction, which includes testing and monitoring, quality control and use of other resources, resembles the provision of services that firms may contract externally, either with PRO or other organizations. It is sensible that these modes of interaction are generally paid for. Still it is striking that around 40% of firms that declare that this goal was of some importance do not pay for the interaction.

If we were stricter and we took only answers when goals were valued as 3 or 4 in the scale 1 to 4 (results not presented here), we find that firms that choose BiL pay more often than firms that choose OL only when using human resources from PRO. Recall that this category includes answers to question on whether the firms interact with PRO for an early recruitment of students and to receive advice from researchers. We believe that the fact that firms that choose BiL more often than firms that choose OL pay for this is related to the degree of formality of the interaction, especially formality in getting advice from PRO researchers.

In any case, it is striking the low incidence of payments in all interactions. Among firms that consider the goal of some importance, around 12% of (firms with) OL and 20% of (firms with) BiL pay for interacting with PRO to increase their absorptive capabilities; 11% of OL and 39% of BiL pay when interacting to contribute to their own innovative activities, 16% of OL and 33% of BiL pay to supplement their innovative activities; 26% of OL and 45% of BiL pay to take advantage of PRO's human resources; 57% of OL and 62% of BiL pay when using PRO's infrastructure; and finally, 12% of OL and 36% of BiL pay when taking advantage of PRO's knowledge.

(Insert Table 9 around here)

VII) Conclusions

This paper claims that benefits and risks associated to linkages between the productive sector and public research organisations (PRO) are not the same across different modes of interactions. Some modes involve shared intellectual resources and outputs by both PRO and industry (e.g. joint R&D, research networks, scientific parks etc.), called here 'bi-directional linkages' (BiL) while others imply a unilateral provision of intellectual resources, from PRO to the firms (e.g. consultancy, training, etc) or the commercialisation or already produced research outputs (e.g. spin-off). All linkages that are not bi-directional are called here 'other linkages' (OL).

The analytical framework developed in this paper suggests that benefits and risks are better balanced -and therefore linkages have better knowledge value- when firms form BiL and two conditions are met. Firstly, knowledge capability is a driver for BiL and secondly firms involved in BiL behaved proactively towards learning avoiding opportunistic behaviour.

This paper aims at evaluating empirically whether those conditions were met for the case of Argentina. The database used comes from the Argentinean Innovation Surveys of 2005 and 2006, which is representative of the manufacturing sector of the country. In *The Survey 2006* an especial section was added to evaluate in detail firms' interactions with PRO that occurred in 2005

To assess whether the first condition was met, a Probit model was estimated on the determinants for choosing BiL. Variables related to size, network capabilities, sectoral specificities were used as control variables. The main explanatory variable was skills: proxied by participation of engineers in the workforce. Results confirmed that the first condition was met: firms with higher knowledge capability were more likely to form BiL.

To assess whether the second conditions was met, the paper used propensity score matching techniques. These techniques control for all relevant characteristics that may be influencing simultaneously the propensity to be linked using BiL and firms' innovative behaviour.

It was found that firms involved in BiL allocate a significantly higher share of their sales to investments in in-house innovative activities (they invest fairly the same in these activities as they do in incorporated technologies) than linked firms using OL. This result suggests that the former group behaves proactively towards learning, since investing in in-house activity is a primary strategy to improve the absorptive capabilities.

This finding was further confirmed when comparing firms using BiL and those using OL regarding their goals towards contributing to their own knowledge capabilities rather than supplementing capabilities they did not have. In contrast to firms choosing OL firms involved in BiL tend to interact to PRO to contribute rather than to supplement their own capabilities.

Moreover, when analysing in general the motivations for linking it was further confirmed that in general firms involved in BiL linked to PRO to take advantage of knowledge resources exclusively available in PRO rather than just seeking to use PRO infrastructure.

It was also found that linked firms involved in BiL are more prone to patenting, which raises issues of concerns about the privatisation on publicly created knowledge due to their privileged access to that knowledge.

Finally, it was striking the low incidence of formal payment for all interactions. Firms involved in BiL are more likely to pay when interacting with PRO, which may reflect about the more formal nature of these interactions. This is particularly the case when seeking human resources available at PRO.

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

Firstly, although the scientific community and the society at large may be better off when the former is integrated into the needs of the latter, it is worth highlighting that not all interactions have similar potential. Since there are benefits and risks involved in the interaction with PRO, policy makers need to be fully aware of their balance before pushing too much for formation of linkages.

This paper found that modes of interactions that involved a bi-directional flow of knowledge have better *knowledge value* since they improved the learning opportunities of PRO. These firms have better knowledge assets involved in the interaction and they show more proactive behaviour towards learning. They invest higher proportion of their sales in in-house innovative activities and they tend to interact to contribute rather than to supplement their own innovative activities. Their motivation to interact is to take advantage of PRO exclusive knowledge assets rather than to use PRO infrastructure and human capital which can be contracted elsewhere in the market.

For these reasons, PRO will be investing their time more productively when interacting with this group of firms -than with any other firm or than not interacting at all- because such interactions could be rewarding in terms of contribution to PRO's knowledge capabilities. Moreover, since firms involved in BiL are not only better prepared but actively seeking to learn, these modes of interactions could create virtuous cycles of knowledge creation and diffusion. Research outputs that result from these interactions may become sources of inspirations for future research and may results in valuable inputs for radical innovations. Thus, although these findings must be complemented with an analysis of behaviour of researchers, the evidence discussed here clearly illuminates the higher potential of BiL to optimise the balance between benefits and risks and therefore the knowledge value of interactions. This justifies the design of policy tools that promote these types of linkages against others.

Secondly, and in spite of the paragraphs below, especial attention must be placed on issues of intellectual property rights. This paper showed that firms that used BiL to link to PRO, which therefore have privileged access to publicly created knowledge, are particularly keen on patenting. Although, there may not be anything worrisome about this, 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.[39] The effect of this on the strategic diffusion of publicly created knowledge must be analysed further. The challenge for science and technology 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.

.

[39] See for example the sound case of Monsanto interaction with the National Institute of Agricultural Technology (INTA) for the development the Guasuncho 2000 -a genetically modified cotton seed. Monsanto patented genes were engineered into INTA germ-plasms that have proved to be suitable for local conditions. Since INTA does not have the germ-plasm registered, Monsanto could use it to claim rights on the seed.

Acknowledgments

The author is very grateful for the efficient collaboration of Martín del Castillo in the empirical analysis of this paper and for useful comments on previous version received by Andrés López, Jo Lorenzen and Keun Lee. The usual disclaimers apply. This paper was produced with the financial support of CONICET (National Council for Science and Technology Research) - Argentina, IDRC (International Development Research Centre) – Canada, and *La Ville de Paris* (City Government of Paris) - France.

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.

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.

Arvanitis, S.; Sydow, N. and Woerter, M., (2008). 'Is There Any Impact of University-Industry Knowledge Transfer on Innovation and Productivity? An Empirical Analysis Based on Swiss Firm Data', *Review of Industrial Organization*, Vol. 32, No. 2, pp. 77-94.

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, R. and Malet, N., (1998). 'El Sistema Nacional De Innovación De La Argentina, Documento De Trabajo', *Universidad Nacional de General Sarmiento, Argentina*, Vol., No.

Bisang, Roberto (dir.), (1995). *Las Actividades De Investigación En Las Universidades Nacionales*, Buenos Aires.

Blumenthal, D.; Campbell, E. G.; Anderson, M. S.; Causino, N. and Louis, K. S., (1997). 'Withholding Research Results in Academic Life Science - Evidence from a National Survey of Faculty', *Jama-Journal of the American Medical Association*, Vol. 277, No. 15, pp. 1224-28.

Blumenthal, D.; Campbell, E. G.; Causino, N. and Louis, K. S., (1996). 'Participation of Life-Science Faculty in Research Relationships with Industry', *New England Journal of Medicine*, Vol. 335, No. 23, pp. 1734-39.

Blumenthal, D.; Campbell, E. G.; Gokhale, M.; Yucel, R.; Clarridge, B.; Hilgartner, S. and Holtzman, N. A., (2006). 'Data Withholding in Genetics and the Other Life Sciences: Prevalences and Predictors', *Academic Medicine*, Vol. 81, No. 2, pp. 137-45.

Brusoni, Stefano; Prencipe, Andrea and Pavitt, Keith, (2001). 'Knowledge Specialization, Organization Coupling, and the Boundries of the Firm: Why Do Firms Know More Than They Make?' *Administrative Science Quarterly*, Vol. 46, No. 4, pp. 597-625.

Campbell, E. G. and Blumenthal, D., (1999). 'Perils of University-Industry Collaboration', *Issues in Science and Technology*, Vol. 16, No. 1, pp. 15-15.

Campbell, T. I. D., (1997). 'Public Policy for the 21st Century: Addressing Potential Conflicts in University-Industry Collaboration', *Review of Higher Education*, Vol. 20, No. 4, pp. 357-&.

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.

Crespo, Manuel and Dridi, Houssine, (2007). 'Intensification of University–Industry Relationships and Its Impact on Academic Research', *Higher Education*, Vol. 54, No. 1, pp. 61-84.

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.

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.

Dussauge, P.; Garrette, B. and Mitchell, W., (2000). 'Learning from Competing Partners: Outcomes and Durations of Scale and Link Alliances in Europe, North America and Asia', *Strategic Management Journal*, Vol. 21, No. 2, pp. 99-126.

Dussel, G., (1973). 'Diagnóstico Del Sistema De Ciencia Y Técnica Nacional', *Jornadas de política científica y política tecnológica para la reconstrucción y liberación nacional.*, Buenos Aires:

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.

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.

Florida, R., (1999). 'The Role of the University: Leveraging Talent, Not Technology', *Issues in Science and Technology*, Vol. 15, No. 4, pp. 67-73.

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.

Garcia-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.

Gelijns, A. C. and Thier, S. O., (2002). 'Medical Innovation and Institutional Interdependence - Rethinking University-Industry Connections', *Jama-Journal of the American Medical Association*, Vol. 287, No. 1, pp. 72-77.

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.

Geuna, A., (2001). 'The Changing Rationale for European University Research Funding: Are There Negative Unintended Consequences?' *Journal of Economic Issues*, Vol. 35, No. 3, pp. 607-32.

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.

Hackett, E. J., (1990). 'Science as a Vocation in the 1990s - the Changing Organizational Culture of Academic Science', *Journal of Higher Education*, Vol. 61, No. 3, pp. 241-79.

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.

Katz, J. and Bercovich, N, (1988). 'Innovación Genética, Esfuerzos Públicos De Investigación Y Desarrollo Y La Frontera Tecnológica Internacional: Nuevos Híbridos En El Inta', *Desarrollo Económico*, Vol. 110, No.

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.

Kruss, G., (2005). 'Harnessing Innovation Potential? Institutional Approaches to Industry-Higher Education Research Partnerships in South Africa', *Industry and Higher Education*, Vol. 19, No. 2, pp. 131-42.

Lee, J. J. and Rhoads, R. A., (2004). 'Faculty Entrepreneurialism and the Challenge to Undergraduate Education at Research Universities', *Research in Higher Education*, Vol. 45, No. 7, pp. 739-60.

Lee, Yong S., (1996). '`Technology Transfer' and the Research University: A Search for the Boundaries of University-Industry Collaboration', *Research Policy*, Vol. 25, No. 6, pp. 843-63.

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.; Dolfsma, 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, Andrés, (2007). *Desarrollo Económico Y Sistema Nacional De Innovación: El Caso Argentino Desde 1860 Hasta 2001*, 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*,

Lugones, Gustavo; Peirano, Fernando; Suárez, Diana and Giudicatti, Miguel, (2004). 'Estrategias Innovativas Y Trayectorias Empresariales ', *REDES Working paper*, Vol. 20, No.

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.

Mendoza, P., (2007). 'Academic Capitalism and Doctoral Student Socialization: A Case Study', *Journal of Higher Education*, Vol. 78, No. 1, pp. 71-96.

Miotti, L. and Sachwald, F., (2003). 'Co-Operative R&D: Why and with Whom? An Integrated Framework of Analysis', *Research Policy*, Vol. 32, No. 8, pp. 1481-99.

Mollis, Marcela and Marginson, Simon, (2002). 'The Assessment of Universities in Argentina and Australia: Between Autonomy and Heteronomy', *Higher Education*, Vol. 43, No. 3, pp. 311-30.

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 Firmas 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., (2004). 'The Market Economy, and the Scientific Commons', *Research Policy*, Vol. 33, No. 3, pp. 455-71.

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 Airea: 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, (1996). 'Uncertainty and Technological Change', in R. Landau, T. Taylor and M. Wright (ed.), *The Mosaic of Economic Growth*, Standford: Standford University Press.

Rosenberg, Nathan and Nelson, Richard R., (1994). 'American Universities and Technical Advance', *Research Policy*, Vol. 23, No. 3, pp. 323-48.

Rothaermel, F. T. and Thursby, M., (2005). 'Incubator Firm Failure or Graduation? The Role of University Linkages', *Research Policy*, Vol. 34, No. 7, pp. 1076-90.

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.

Velho, L. and Saez, W.T., (2002). 'R&D in the Public and Private Sector in Brazil: Complements or Substitute?' *UNU/INTECH Discussion Papers*, Vol. 1564-8370, No.

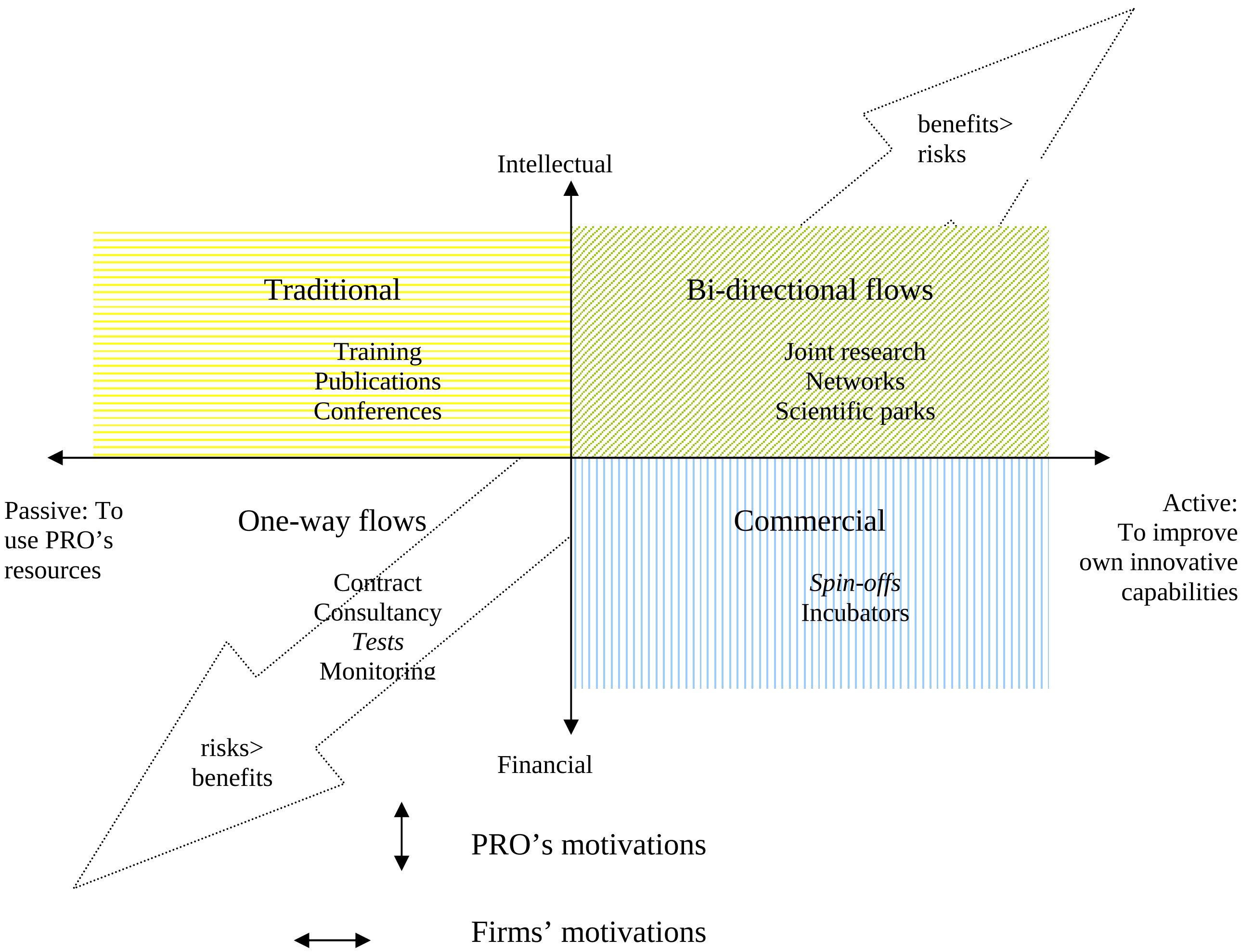
Veugelers, Reinhilde and Cassiman, Bruno, (2005). 'R&D Cooperation between Firms and Universities. Some Empirical Evidence from Belgian Manufacturing', *International Journal of Industrial Organization*, Vol. 23, No. 5, pp. 355-79.

Webster, A., (1994). 'University-Corporate Ties and the Construction of Research Agendas', *Sociology-the Journal of the British Sociological Association*, Vol. 28, No. 1, pp. 123-42.

Yoguel, G. and López, M., (2001). 'Sistemas Locales De Innovación Y El Desarrollo De Las Capacidad Innovativa De Las Firmas: 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.:

FIGURES

Figure 1: Initial conditions, motivations and modes of interactions



|

Necessary conditions to optimise the balance of benefits and risks:

High scientific capabilities of PRO

High technological capabilities of firms

High scientific and technological capabilities of PRO

TABLES

Table 1: Modes of interaction

	Average importance 0.25-1 scale	% of linked firms with importance >0.5
Informal Exchange	0.58	65%
Publications	0.56	58%
Conferences	0.54	57%
Hiring graduates	0.44	34%
Consultancies	0.44	33%
Research contracts	0.42	30%
Joint R&D	0.42	30%
Licences	0.38	19%
Networks	0.37	19%
Patents	0.37	18%
Scientific parks	0.35	16%
Internships	0.34	14%
Incubators	0.3	7%
University owned firms	0.27	3%
Spin off	0.27	3%
Traditional modes	0.53	81%
Service provision	0.40	45%
Bi-directional modes	0.38	37%
Commercial modes	0.32	30%

Source: The Survey 2006

Table 2: Sample characteristics in terms of size for different modes of interactions

		Size		
	N	Small (% of linked and control firms)	medium (% of linked and control firms)	big (% of linked and control firms)
Linked	355	16%	27%	56%
bi-directional	225	14%	22%	64%
other modes	130	18%	30%	52%
Full sample 2005	1675	30%	30%	40%

Source: The Survey 2005 & The Survey 2006

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

	% linked firms, per sector	% bi-directionally linked per sector	% of firms in full sample 2005, per sector	% linked firms over % firms in full sample, per sector	% bi-directionally linked firms over % firms in full sample, per sector
15 Manufacture of food products and beverages	24,20%	23,80%	22,00%	1,1	1,09
16 Manufacture of tobacco products	1,40%	2,30%	0,50%	2,95	4,83
17 Manufacture of textiles	4,20%	2,30%	8,40%	0,5	0,27
18 Manufacture of wearing apparel; dressing and dyeing of fur	2,80%	3,10%	2,70%	1,03	1,12
19 Tanning and dressing of leather; luggage, handbags, saddlery, footwear, etc	2,30%	2,30%	2,30%	0,97	0,99
20 Manufacture of wood and of products of wood and cork, except furniture	2,30%	1,50%	2,40%	0,92	0,63
21 Manufacture of paper and paper products	1,70%	0,80%	2,90%	0,59	0,27
22 Publishing, printing and reproduction of recorded media	1,10%	0,00%	5,10%	0,22	0
23 Manufacture of coke, refined petroleum products and nuclear fuel	0,60%	0,80%	0,80%	0,73	0,99
24 Manufacture of chemicals and chemical products	14,10%	20,80%	9,90%	1,43	2,11
25 Manufacture of rubber and plastic products	5,60%	3,80%	5,00%	1,14	0,78
26 Manufacture of other non-metallic mineral products	4,50%	2,30%	4,80%	0,94	0,48
27 Manufacture of basic metals	3,10%	3,80%	3,20%	0,98	1,22
28 Manufacture of fabricated metal products, except machinery and equipment	4,20%	3,10%	5,30%	0,8	0,59
29 Manufacture of machinery and equipment NEC (not elsewhere classified)	13,50%	16,90%	9,40%	1,44	1,81
30 Manufacture of office, accounting and computing machinery	0,00%	0,00%	0,20%	0	0
31 Manufacture of electrical machinery and apparatus NEC	4,80%	3,80%	3,50%	1,36	1,09
32 Manufacture of radio, television and communication equipment and apparatus	0,80%	0,00%	1,30%	0,64	0
33 Manufacture of medical, precision and optical instruments, watches and clocks	1,40%	2,30%	1,30%	1,12	1,84
34 Manufacture of motor vehicles, trailers and semi-trailers	4,80%	3,80%	4,40%	1,1	0,88
35 Manufacture of other transport equipment	1,40%	0,80%	1,60%	0,91	0,5
36 Manufacture of furniture; manufacturing NEC	1,10%	1,50%	3,20%	0,35	0,48
	100,00%	100,00%	100,00%		

Source: The Survey 2005 & The Survey 2006

Table 4: Probit estimation on the probability of choosing bi-directional modes of interactions with PRO.

		marginal effects
Skills	Professionals over total employment	0.355*
		[0.192]
Size	Deciles based on employment for the full sample	0.022**
		[0.010]
IA_sector	Innovative activities over sales for the sector full sample	0.819
		[2.323]
Linked_act_sector	Quantity of actively linked firms in the sector	0.006**
		[0.002]
Link_vert	Vertical linkage	0.085
		[0.060]
Link_int	Linkage within the firm network	0.018
		[0.058]
Observations		354
Pseudo R-squared		0.04
Wald		18.51***

Robust standard errors in brackets

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

Source: The Survey 2005 & The Survey 2006

Table 5: Outcome variables to assess the ATT of bi-directional linkages

Variable group	Variable Name	Type of data	Variable Definition
a) Innovative behaviour	IA_sales imaq_sales inhouse_sales	Ratio Ratio Ratio	Total expenditures in innovative activities over sales Expenditures in machinery for innovation over sales Expenditures in R&D and Design and Engineering over sales
b) Appropriability behaviour	patent	1-4 scale normalised to 0-1	Whether the firm obtained patents
c) Motivations for interacting	goal_abs goal_contr goal_suppl goal_hr goal_cap goal_k	1-4 scale normalised to 0-1	Six categorical variables: one for six different goals for linking to PRO: 1) to improve absorptive capabilities (goal_abs), 2) to contribute to firms' innovative activities (goal_contr), 3) to supplement innovative activities (goal_suppl), 4) to take advantage of PRO's human resources (goal_hr), 5) to take advantage of PRO's infrastructure and machinery resources (goal_cap), 6) to take advantage of PRO's knowledge resources (goal_k)
d) Firms' payment for linking	pay_abs pay_contr pay_suppl pay_hr pay_cap pay_k	Dummies	Six dummy variables to account for whether firms pay or not to pursue each of the above-mentioned goals

Source: The Survey 2006

Table 6) ATT of being involved in bi-directional linkages on firms' innovative behaviour

a) Innovative behaviour					
Variables	**Weight methods**	**All firms involved in other linkages (OL)**	**OL after matching (control group)**	**Firms involved in bi-directional linkages (BiL)**	**Difference of means of BiL - OL (control group)**
		Means			**ATT**
AI_vtas	Nearest Neighbour	0,0258	0,0211	0,0316	0,0105
	Kernel (normal)	0,0258	0,0237	0,0316	0,0079
	Radius	0,0258	0,0223	0,0321	0,0098
	Caliper	0,0258	0,0212	0,0321	0,0109
imaq_vtas	Nearest Neighbour	0,0161	0,0129	0,0133	0,0004
	Kernel (normal)	0,0161	0,0149	0,0133	-0,0016
	Radius	0,0161	0,0136	0,0136	0,00005
	Caliper	0,0161	0,0133	0,0136	0,0004
inhouse_vtas	Nearest Neighbour	0,0060	0,0064	0,0139	0.0075*
	Kernel (normal)	0,0060	0,0056	0,0139	0.0083**
	Radius	0,0060	0,0057	0,0143	0.0086**
	Caliper	0,0060	0,0062	0,0143	0.0081*

Source: The Survey 2005 & The Survey 2006

Table 7) ATT of being involved in bi-directional linkages on firms' appropriability behaviour

b) Appropriability behaviour					
Variable	**Weight methods**	**All firms involved in other linkages (OL)**	**OL after matching (control group)**	**Firms involved in bi-directional linkages (BiL)**	**Difference of means of BiL - OL (control group)**
		Means			**ATT**
patent	Nearest Neighbour	0,0357	0,0154	0,0769	0.0615**
	Kernel (normal)	0,0357	0,0355	0,0769	0,0414
	Radius	0,0357	0,0295	0,0794	0.0498*
	Caliper	0,0357	0,0159	0,0794	0.0635*

Source: The Survey 2005 & The Survey 2006

Table 8) ATT of being involved in bi-directional linkages on firms' goals for interacting

c) Goals of interaction					
Variables	**Weight methods**	**All firms involved in other linkages (OL)**	**OL after matching (control group)**	**Firms involved in bi-directional linkages (BiL)**	**Difference of means of BiL - OL (control group)**
		Means			**ATT**
goals_abs	Nearest Neighbour	0,3549	0,3585	0,4942	0.1357***
	Kernel (normal)	0,3549	0,3577	0,4942	0.1365***
	Radius	0,3549	0,3567	0,5000	0.1433***
	Caliper	0,3549	0,3620	0,5000	0.138***
goals_contr	Nearest Neighbour	0,3359	0,3547	0,5543	0.1996***
	Kernel (normal)	0,3359	0,3448	0,5543	0.2095***
	Radius	0,3359	0,3628	0,5500	0.1872***
	Caliper	0,3359	0,3540	0,5500	0.196***
goals_suppl	Nearest Neighbour	0,3158	0,3256	0,4787	0.1531***
	Kernel (normal)	0,3158	0,3200	0,4787	0.1586***
	Radius	0,3158	0,3244	0,4760	0.1516***
	Caliper	0,3158	0,3280	0,4760	0.148***
goals_hr	Nearest Neighbour	0,4012	0,4554	0,5669	0.1114***
	Kernel (normal)	0,4012	0,4147	0,5669	0.1522***
	Radius	0,4012	0,4200	0,5660	0.1460***
	Caliper	0,4012	0,4550	0,5660	0.111***
goals_cap	Nearest Neighbour	0,4397	0,4638	0,5963	0.1324***
	Kernel (normal)	0,4397	0,4449	0,5963	0.1514***
	Radius	0,4397	0,4580	0,5907	0.1327***
	Caliper	0,4397	0,4673	0,5907	0.1233***
goals_k	Nearest Neighbour	0,3304	0,3430	0,5349	0.1919***
	Kernel (normal)	0,3304	0,3345	0,5349	0.2004***
	Radius	0,3304	0,3361	0,5370	0.2009***
	Caliper	0,3304	0,3450	0,5370	0.192***

Source: The Survey 2006

Table 9) ATT of being involved in bi-directional linkages on whether firms' pay for achieve the goals they consider of some importance

d) Firm's payment for linking					
Variables	Weight methods	All firms involved in other linkages (OL)	OL after matching (control group)	Firms involved in bi-directional linkages (BiL)	Difference of means of BiL - OL (control group)
		Means			ATT
pay_abs	Nearest Neighbour	0,0313	0,0231	0,1231	0.1**
	Kernel (normal)	0,0313	0,0287	0,1231	0.0944***
	Radius	0,0313	0,0208	0,1270	0.1062***
	Caliper	0,0313	0,0238	0,1270	0.1032***
pay_contr	Nearest Neighbour	0,0268	0,0154	0,2615	0.2462***
	Kernel (normal)	0,0268	0,0318	0,2615	0.2297***
	Radius	0,0268	0,0383	0,2460	0.2078***
	Caliper	0,0268	0,0159	0,2460	0.2302***
pay_suppl	Nearest Neighbour	0,0357	0,0385	0,1769	0.1385***
	Kernel (normal)	0,0357	0,0407	0,1769	0.1362***
	Radius	0,0357	0,0402	0,1746	0.1344***
	Caliper	0,0357	0,0397	0,1746	0.1349***
pay_hr	Nearest Neighbour	0,1295	0,1308	0,3615	0.2308***
	Kernel (normal)	0,1295	0,1381	0,3615	0.2235***
	Radius	0,1295	0,1219	0,3571	0.2352***
	Caliper	0,1295	0,1349	0,3571	0.2222***
pay_cap	Nearest Neighbour	0,3616	0,3615	0,5385	0.1769**
	Kernel (normal)	0,3616	0,3768	0,5385	0.1617***
	Radius	0,3616	0,3994	0,5317	0.1324**
	Caliper	0,3616	0,3651	0,5317	0.1667**
pay_k	Nearest Neighbour	0,0357	0,0231	0,2692	0.2462***
	Kernel (normal)	0,0357	0,0396	0,2692	0.2296***
	Radius	0,0357	0,0398	0,2698	0.2300***
	Caliper	0,0357	0,0238	0,2698	0.2460***

Source: The Survey 2006

Appendix: Variables' definition

Variable group	Variable Name	Type of data	Variable Definition
Firms' network behaviour	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 with PRO (i.e. joined research, participation in research networks, incubators, and scientific parks)
	link_vert	Dummy	Firms that linked to suppliers or clients
	link_int	Dummy	Firms that linked to its own network (within the group or with the headquarters)
	goals_	1-4 scale normalised to 0-1	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_contr), 3) to supplement 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) (goal_hr), 5) 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 resources (i.e. technology 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 = up to 16 employees, 2 = 27, 3=40, 4=60, 5=85, 6=116, 7=156, 8=229, 9=411, 10=all bigger than 411
	skills	Ratio	Professional over total employment
Firms' 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
	patent	1-4 scale normalised to 0-1	Whether the firm obtained patents
	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)
Sector characteristics	IA_sector	Ratio	Total employment over sales for the whole sample of ENIT 2005 for 8 groups of sectors (see INDEC 2008))
	linked_act_sector	Ratio	Sum of firms that were actively connected to PRO per sector (2 digits ISIC)