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Firms' linkages with universities and public research institutes in Argentina: factors driving the selection of different channels

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Knowledge flows between public research organisations (PROs) and firms may occur through various channels. Channel selection may have different drivers and effects. Although much research has been carried out on the drivers of firms and researchers to connect with each other, less attention has been paid to the determinants of the selection of different channels of interaction. This research analysis factors driving firms' selection of different channels of interactions with public research organisations (PROs), both public research institutes (PRIs) and universities (UNIs). The paper estimates bi-variate probit models with sample selection using micro data for 2007 from a representative survey of Argentinean firms. The classification of channels is based on previous research for Latin America and includes four types according to the main goals that firms and public research organisations seek when interacting: traditional, service, commercial and bi-directional channels. We find that factors driving the selection of the bi-directional channel are different from those driving selection of the others. In particular, firms choosing this channel employ a more skilled workforce and generally interact with PRIs and UNIs in order to benefit their own innovative activities. Thus, this commitment to knowledge capabilities and innovation when firms use the bi-directional channel may enhance the potential of PRO–firm interactions to upgrade the national innovation system (NIS).

Introduction

Innovation occurs primarily within firms. However, it is clear that firms do not innovate in isolation. Their innovative activities (IA) are heavily dependent on their environment since learning and innovation are interactive processes that require intensive communication among different actors. The literature on national innovation systems (NISs) (Lundvall, 1992; Nelson, 1993) argues that the possibilities for innovation in an economy depend not only on the performance of specific organisations, such as firms or public research organisations (PROs), but also on their interaction and the characteristics of channels they use for interacting (Gregersen and Johnson, 1997). Therefore, linkages between PROs and firms and their features have received growing attention in both the literature and public policy.

PRO–firm linkages are not just knowledge transactions, but represent an institutionalised form of learning that contributes to the national stock of knowledge. Unlike orthodox assumptions in economic theory, the NIS approach holds that

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actors' behaviour depends not only on the overall structure of incentives, but also on institutional arrangements built up over time. In particular, PRO–firm linkages are the result of historical processes and are influenced by the set of routines and practices that shape the behaviour of actors within the NIS and also by public policy in science and technology (S&T). Ever since the early 1990s, governments from many countries have attempted to increase linkages between PROs and firms (Dasgupta and David, 1994; Slaughter and Leslie, 1997; Nelson, 2004; Etzkowitz *et al*., 2005). The policy expectation was to strengthen innovation through knowledge interaction among actors of the NIS. In the case of Latin America, the boost to PRO–firm linkages came together with the imperative of increasing and diversifying sources of financing for PROs, which faced deep budget cuts at the time (Arocena and Sutz, 2005).

PRO–firm interactions may occur through a variety of modes, such as training, personnel exchanges, contract research, informal communication, joint R&D, consultancy, and so on (Cohen *et al*., 2002). Many authors have investigated the modes preferred by firms and PROs (e.g. Meyer-Krahmer and Schmoch, 1998; D'Este and Patel, 2007; Bekkers and Freitas, 2008). However, few studies compare the innovative results obtained by using different channels (see Adams *et al*., 2003; Arvanitis *et al*., 2008a, 2008b; Eom and Lee, 2009) and in general there has not been much effort to associate modes systematically with types of outcome. A series of papers published recently in a special issue of *Science and Public Policy*[1] pursued this goal by analysing the cases of four countries (Argentina, Brazil, Costa Rica and Mexico) with a common taxonomy of modes and outcomes of interaction. One important result from all the country studies was that modes of interaction that involved a bi-directional flow of knowledge (from firms to PROs and *vice versa*) were the most effective at driving firms' innovative outcomes. This paper attempts to build upon past research by analysing Argentinean firms' determinants for choosing different modes of interactions with public research institutes (PRIs) and universities (UNIs), named jointly as PROs in the literature.

In Argentina, there are very few academic studies that look explicitly at PRO–firm collaboration. The majority of these papers are based on case studies, which either study the impact of linkages on firms' innovative capabilities (e.g. Moori-Koenig and Yoguel, 1998; Yoguel and López, 2000; Lugones and Lugones, 2004), or analyse the interaction dynamics from the point of view of the PROs (e.g. García de Fanelli, 1993; Bisang *et al*., 1995; Estébanez, 1996; Llomovatte *et al*., 2006; Riquelme, 2008). To the best of our knowledge, there are only two studies on PRO–firm linkages based on survey information and econometric techniques in Argentina: Arza and López (2011), which analysed firms' determinants for linking to PROs; and Arza and Vazquez (2010), which investigated the benefits for firms and PROs of interaction when using different channels. This paper adds to this research by tackling an original topic: we compare firms' drivers for the selection of different channels of interactions with the PRIs and the UNIs. We use an original and representative database of Argentinean manufacturing firms. We estimate selection models to assess simultaneously: (i) factors driving firms to interact with PROs; and (ii) firm characteristics and behaviours that drive the selection of different channels of interactions with PRIs and UNIs. This is of paramount importance for policy purposes since it will help to develop tools related to the use of specific channels of interactions with the PRO related to a particular firm's profile.

The paper has five more sections besides this introduction. The next section briefly discusses patterns of PRO–firm interaction in Latin America and in Argentina in particular. The following section analyses the literature on drivers of PRO–firm interaction, with strong emphasis on those studies that attempt to distinguish different channels of interactions. Then comes a presentation of the data and the methodology, and finally a discussion of empirical results and our conclusions.

Patterns of PRO–firm linkages in Argentina and Latin America

Weak linkages, but historical importance of PRO research for firms' performance

There are some production activities where PRO–firm linkages have worked with satisfactory results in terms of product innovation in many Latin American countries (e.g. agricultural biotechnology in Argentina, aerospace in Brazil, coffee in Costa Rica and the chemical industry in Mexico). However, the general perception is that the production and dissemination of scientific and technological knowledge, by both firms and PROs, are rather limited in these countries when compared with the international benchmark. Yet, judged by their achievements, PROs have been historically more successful than firms.[2] Further, there is widespread agreement in the literature that linkages between both actors are very weak (Arocena and Sutz, 2000; Cimoli, 2000; Cassiolato *et al*., 2003; López, 2007; Dutrénit *et al*., 2010a). However, since the mid-1990s there has been an increase in the policy promotion of interaction activities and in the number of linkages. These changes have generally responded to budgetary pressures on the PROs and to the dissemination of ideas that challenge the role of the state as the main pillar of scientific production (Dasgupta and David, 1994; Slaughter and Leslie, 1997; Nelson, 2004; Etzkowitz *et al.*, 2005). They are also the result of advances in the literature on innovation studies emphasising the importance of strengthening interactions as a necessary condition for the development of the NIS.

It is worth noting that, although PRO–firm linkages have traditionally been scarce, the research carried out by the PROs was key to the success story of many productive activities in many Latin American countries. For example, Gutiérrez (1991) and León and Losada (2002) highlight the outstanding performance of INTA (the National Institute of Agricultural Technology) as an important factor driving early Argentinean agricultural development; Suzigan and Albuquerque (2009) discuss the importance of university research in the development of aeronautics, steel and agriculture in Brazil; and Casas *et al*., (2000) emphasise the role of PROs in successful experiences in chemical and other process industries in Mexico.

Broadly speaking, knowledge produced by Latin American PROs traditionally reached firms though specific modes, primarily related to human resource training, service provision in testing, and quality monitoring or outreach activities for transferring technological information.[3] More complex channels involving a two-way flow of knowledge, such as joint R&D, or the commercialisation of PRO research outputs in incubators and spin-off companies, were hardly present prior to the active promotion that began in the mid-1990s.

Historical evolution of PRO–firm linkages in Argentina

Although Argentinean universities grew steadily throughout the early twentieth century, it was only in the 1950s that they reached the so-called golden age, when research activities gained dynamism. The spirit of this period reflected the ideas of

the linear model of innovation that spread around the world after World War II. It was believed that scientific knowledge was a necessary condition for economic development and public action was focussed on creating and supporting scientific and technological institutions rather than on promoting interactions between them and the private sector. Most public research institutes – specialised institutes for agriculture (INTA), industry (INTI), atomic energy (CNEA) and the National Research Council (CONICET) – were created then. Consequently, public spending on S&T manifestly increased, although this did not go hand-in-hand with private sector spending. Imports continued to be the main source of technological knowledge for the private sector. This period finished violently with the Onganía military coup in 1966.

In the late 1960s and early 1970s, a group of intellectuals (e.g. Sábato and Varsavsky)[4] – soon recognised as referents for S&T thinking in Latin America – criticised the predominant scientism of S&T policies and insisted on a more active and direct role for the state and public institutions in technology development. The problem of development was then viewed as the result of technological dependency. These voices were influential in policy and specific measures were created to regulate technology flows from abroad and to channel investment in S&T towards strategic targeted sectors. However, probably because of the prevailing macroeconomic instability, these measures were not sustained and were, therefore, ineffective. As a matter of fact, after the military coup of 1976, there was a reversal in S&T policy. The S&T complex was virtually dismantled, the activities and knowledge outputs from PROs declined – with the exception of CNEA, because of its links with military technology.

The 1990s marked a period of liberalisation policies in Argentina. It was believed that trade liberalisation would promote technological innovation because of an increase in foreign competition and cheaper imported capital goods. Policies during this period also relied on foreign direct investment as a mechanism for successful technology transfer from abroad. S&T policies, especially after the creation of the National Agency for the Promotion of S&T (ANPCyT) in 1996, prioritised the private sector by providing subsidies to private R&D and by supporting PRO–firm linkages. Meanwhile, PROs, and especially UNIs, developed a regulatory framework to promote interaction with the private sector. As an example, Figure 1 shows the evolution of approved collaboration agreements at the University of Buenos Aires (UBA), by far the largest university in the country. As can be clearly seen, agreements with the private sector grew exponentially during the 1990s.

More recently there seems to have been a turn in S&T policy orientation towards higher emphasis on public initiative. For example, a Ministry of Science Technology and Innovation was created in 2007 and there was an overall increase in the budget on S&T policies. CONICET has systematically increased the number of scholarships and the salary of researchers since 2003. Finally, in comparison with the late 1990s, in the late 2000s, PROs augmented their interactions with other actors beyond the private sector (see Figure 1, for the UBA case). In summary, the Argentinean experience reflected the international trends in S&T policy. A general support of the linear model of innovation in the 1950s as a strategy for economic development was later supplanted by the prerogative that PROs should be more directly linked to productive needs. This translated into wider support for PRO–firm interactions, especially from the 1990s onwards. However, S&T indicators for Argentina[5] suggest that none of these strategies successfully upgraded the NIS.

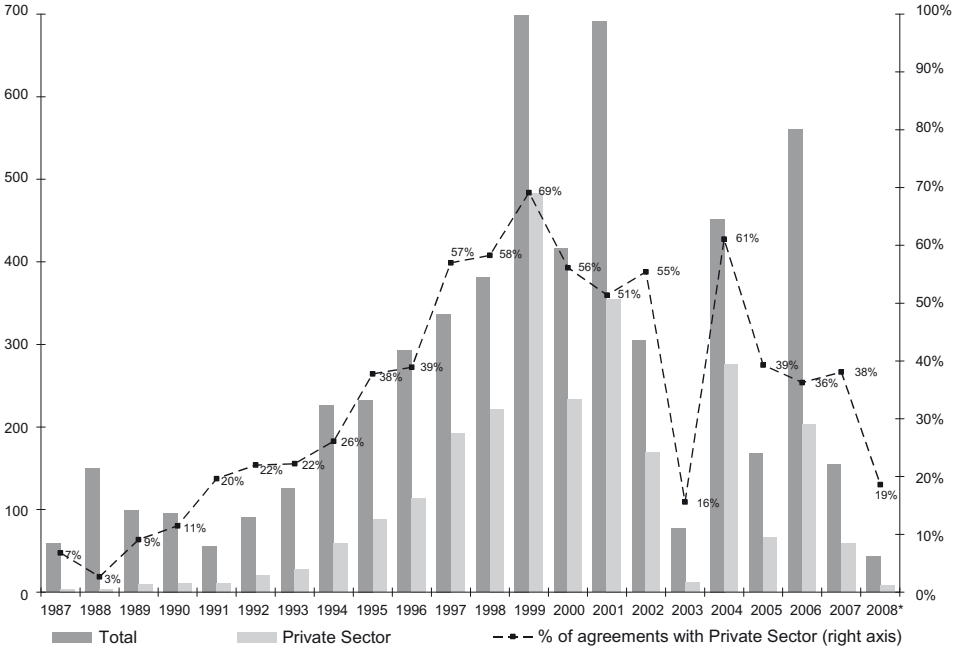

Figure 1. Approved collaboration agreements at UBA (1987–2008)
Source: Secretary of Science and Technology of the University of Buenos Aires (UBA).

S&T policy still needs to design more precise tools to make better use of existing capacities in the NIS. We believe this research could contribute to that aim.

Drivers for selection of channel interaction

The literature on modes of interactions

There are various benefits for firms that may result from their interactions with PROs. For example, firms benefit from new laboratory instruments and analytic methodologies that constitute a fundamental input for testing and monitoring activities in their industry (Rosenberg, 1992). PROs widen the capacity of firms to solve concrete problems, thus aiding incremental innovations. Some problems demand a combination of technologies that no single firm could develop on its own, but which could nevertheless be achieved using the knowledge stock available in PROs (Patel and Pavitt, 1995). In some cases, such knowledge flows may even increase the likelihood of generating radical innovations. Similarly, PROs may obtain intellectual rewards by interacting with industry because such relationships inspire many fields of research (Rosenberg and Nelson, 1994; Rosenberg, 1996; Nelson, 2004). This is particularly the case for those fields of research located in the 'Pasteur quadrant' (Stokes, 1997), which engage in basic and applied research simultaneously (e.g. all types of engineering, biotechnology, metallurgy, computer science). Moreover, linkages also allow PROs to gain access to new sources of funding for their research (Geuna, 2001).

The literature on PRO–firm linkages can be divided into two types. First, there are studies, mainly descriptive in nature, exploring how interactions work, the role

of liaison offices, the goals of the interactions, the macro and micro performance of science parks or other types of networks, etc. (e.g. Meyer-Krahmer and Schmoch, 1998; Cohen *et al*., 2002; Acworth, 2008; Kodama, 2008; Lockett, Kerr, and Robinson, 2008; Wright *et al*., 2008). Within this group, there has been an attempt to pinpoint various modes of knowledge transfer and to identify the most preferred ones. In developing countries in particular, consultancy was usually seen as the most common form of PRO–firm interaction (Ojewale *et al*., 2001; Arocena and Sutz, 2005; Kruss, 2006; Vega-Jurado, Fernández de Lucio, and Huanca-López, 2007), probably because there was no demand from industry for more sophisticated modes.

These studies normally built taxonomies to organise modes of interaction according to a common criterion. For example, modes were classified by the degree of formality in the contractual arrangements (e.g. Bonaccorsi and Piccaluga, 1994; Vedovello, 1997; Vedovello, 1998; Schartinger *et al*., 2002; Romero, 2007; Eun, 2009), by the level of articulation and personal communication among stakeholders (e.g. Fritsch and Schwirten, 1999; Santoro and Saparito, 2003; Perkmann and Walsh, 2007), by the relative potential for transmission of novelty (e.g. Romero, 2007; Wright *et al*., 2008), and by the main goals that firms and PROs seek to achieve when interacting (e.g. Kruss, 2006; Arza, 2010). In this research we identify channels of interactions as modes organised according to specific criteria.

A second group of studies, mainly but not exclusively based on survey data, attempted to analyse causal effects. They studied either firm (and/or PRO) characteristics that work as drivers for forming linkages (e.g. Veugelers and Cassiman, 2005; Fontana *et al*., 2006; Landry *et al*., 2007; Giuliani *et al*., 2010), or they assessed the effect of linkages in terms of benefits received by PROs and/or firms (e.g. Monjon and Waelbroeck, 2003; Owen-Smith and Powell, 2003; Rothaermel and Thursby, 2005; Defazio, Lockett, and Wright, 2009).

The two streams of literature fed each other, especially by means of identifying firm (and/or PRO) characteristics that were important drivers of linking or mediating factors for successful interactions. However, until recently, causal studies did not pay much attention to previous contributions looking at multiple modes of interaction. There are very few studies that analyse either the determinants or the relative effectiveness of different modes of interaction, despite abundant reasons to suppose that drivers and effects systematically differ across modes of interaction.

Among papers analysing drivers of different modes/channels of interaction some analysed whether their use is sector, field and/or technology specific (e.g. Meyer-Krahmer and Schmoch, 1998; McMillan *et al*., 2000; Schartinger *et al*., 2002; Cohen *et al*., 2002; Landry *et al*., 2007; Bekkers and Freitas, 2008). Other studies attempted to identify characteristics of researchers (mostly reputation and experience) driving the selection of different modes/channels of interaction (e.g. Schartinger *et al*., 2002; Fukugawa, 2005; D'Este and Patel, 2007; Bekkers and Freitas, 2008), and finally some other papers analysed firm characteristics (mostly firm size, proximity and innovative behaviour) as drivers of different modes/channels of interaction (Vedovello, 1997; Vedovello, 1998; Schartinger *et al*., 2002; Bekkers and Freitas, 2008).

Fewer studies offered insights into the relationship between modes/channels of interaction and the benefits they potentially trigger. Some have focused on the relationship between channels of interactions and firms' innovative inputs (e.g. Cohen *et al*., 2002; Adams *et al*., 2003; Arvanitis *et al*., 2008b), and some on firms'

innovative outcomes (e.g. Arvanitis *et al*., 2008a; Eom and Lee, 2009). Until recently, there has been little work on systematically comparing benefits obtained by using different types of modes/channels. An attempt to fill this gap was undertaken by a series of papers published in a special issue of *Science and Public Policy*,[6] which compared the relative effectiveness of different channels of interaction in producing certain types of benefits for firms and PROs in four Latin American countries. All papers in this collection use a single taxonomy to classify modes of interaction, based on the goals that firms and PROs pursue when interacting. Interestingly, results across countries were similar in terms of the characteristics of benefits triggered by each type of channel.[7] Having proved to be a successful taxonomy for analysing the benefits of PRO–firm interaction in Latin America, this paper builds on such research to examine what prompts firms' drivers to choose the various channels in the taxonomy.

Taxonomy of modes of interaction and previous findings

The taxonomy, fully described and justified in Arza (2010), classifies modes into four main types of channels of interaction.

- *Traditional*. This is the result of conventional missions of PROs (teaching and research) and is the way firms have historically benefited from the activities of the PROs (e.g. hiring new graduates, or obtaining information through conferences, publications, etc.). For PROs, the main motivation to use this channel is intellectual: for firms, it is to acquire knowledge. Knowledge, therefore, flows mainly from PROs to firms. Personal interaction is not necessary.
- *Services*. This channel includes the provision of scientific and technological services in exchange for money (e.g. consultancies, use of PRO equipment for quality control or testing, training firms' staff, etc.). Motivation for use of this channel is similar to motivation to use the traditional channel – to get to know what is already known by other actors in the NIS. For PROs, the main motivation is to raise new funds. Knowledge flows mainly from PROs to firms. Personal interaction may or may not exist. Personal interaction lasts only as long as the provision of service takes (i.e. usually for short periods).
- *Commercial*. This channel allows PROs to market their research results (e.g. patents, technology licenses, spin-offs, incubators, etc.). For PROs, the main motivation is to market their research outputs and obtain funds. For firms, it is to be involved in innovation activities, creating new products or processes. Depending on the characteristics of the contractual agreement and the extent to which researchers engage in business activities or support, knowledge may flow in both directions. Personal contact is established at the beginning of the relationship and may continue afterwards, depending on the specific features of the agreement.
- *Bi-directional*. This channel allows knowledge to flow both ways, strengthening the potential for joint learning. Interactions using this channel are generally motivated by the scientific and academic ambitions of researchers (e.g. to generate new knowledge, to apply theoretical knowledge, etc.) and by firms' innovation strategies. This channel includes such modes of interactions as joint R&D, participation in networks, science and technology parks, etc.

Personal contact is usually involved. In general, the relationships are formalised in agreements for long-term cooperation.

Main and specific research goals

Our main research goal is to compare firms' selection of four channels of interaction (traditional, service, commercial and bi-directional) with UNIs and PRIs.[8] Previous results suggest that the traditional and bi-directional channels generate most types of benefits for firms most effectively in all countries analysed. The bi-directional channel is particularly important as a determinant of firms' innovation benefits (Arza and Vazquez, 2010). It was also found that firms that invest more heavily in in-house innovative activities obtained larger benefits when using the bi-directional and traditional channels. This is to be expected since firms with greater absorbing capabilities will be better able to benefit from the external environment (Cohen and Levinthal, 1990).

The importance of firm capability as a mediating factor for achieving successful outputs through direct interactions has been highlighted in the literature (Meyer-Krahmer and Schmoch, 1998; Vedovello, 1998; Laursen and Salter, 2004; Hanel and St-Pierre, 2006; Wright *et al*., 2008; Lee and Wong, 2009). Moreover, both the bi-directional and the commercial channels explicitly require involvement of firms' knowledge assets for successful results (Arza, 2010). Building from this research, our specific goals here are to compare drivers related to capabilities and proactive behaviour across channels with particular focus on the bi-directional channel. We ask:

(1) Are firms' capabilities an important driver for choosing channels?
(2) Does innovation affect the selection of channel?
(3) Is the selection of channels field-specific? Do research fields affect the selection of channel differently for interactions with PRIs or with UNIs?
(4) What are the goals followed by firms choosing the bi-directional channel? Are they different from the goals followed by firms when they choose other channels?

Data, descriptive statistics and methodology

Data collection

The database of firms consists of a subsample of the National Survey of Technological Innovation (ENIT) conducted in December 2007 by the National Institute of Statistic and Censuses (INDEC) to gather data for 2006. In the ENIT for the previous year (with data for 2005), firms were asked whether they had links with UNIs or PRIs.[9] Then, in the 2007 survey, a questionnaire was sent to the 590 firms that declared links with these institutions in 2005. The response rate of the questionnaire was 60% (355 firms). A questionnaire was sent to a control group of 384 firms that did not have linkages with UNIs or PRIs that year.[10] In this case, the response rate was 62% (238 firms). Thus, our sample yields a total of 592 firms, both linked and not linked with PROs. All data in this paper refer to the year 2005.

Main characteristics of the firms in the sample

This section compares linked and unlinked firms for some key variables (Table 1). The main differences are as follows.

- *Firm characteristics*. Linked firms are bigger than unlinked firms.[11] The average linked firm belongs to the 6.6 decile of employment of the ENIT (around 150 employees) and the average unlinked firm to the 5.8 decile (around 110 employees). However, the workforce is similar in terms of skills; in both cases around 12% are professionals. Finally, firms with links to PROs are more prone to networking with the private sector (i.e. headquarters, other firms in the group, customers and suppliers).
- *Innovative performance*. Linked firms seem to be more successful in innovation in products (40%), processes (31%) and both (21%), against 27%, 20% and 9%, respectively, for unlinked firms. Moreover, 5% of linked firms obtained a patent compared with only 2% of unlinked firms.
- *Investment in innovation*. Although being more innovative in terms of outputs, linked firms do not seem to invest significantly more in innovation activities. This could be related to the fact that firms may connect to PROs either to complement or to substitute for their investments in-house. By calculating mean values, we mix strategies characterised by opposite behaviours related to investment in innovation activities.
- *Use of PRO research outputs*. Firms may use research outputs produced by PROs independently of whether they were directly linked to PROs. However, in general, those that linked to PROs tend to use the research outputs that PROs produce more intensively.[12] This is particularly the case with new techniques, tools and use of laboratory equipment.
- *Expected roles for PROs*. In the survey, there was a question aimed at identifying firms' beliefs about the roles of PROs in society. Firms had to assess four roles: education, research, social and entrepreneurial. All firms value the traditional roles of PROs (related to education and research). The entrepreneurial role is the least valued by all firms. Linked firms value the research activities of PROs more than unlinked firms, while the latter value the entrepreneurial role more highly.

Classification of modes of interactions

Table 2 presents statistics about the importance of different modes of interaction with UNIs and PRIs as stated by linked firms. The options presented in Table 2 comprise all options available in the questionnaire. As can be seen, the most common mode of interaction, both with UNIs and PRIs, is information exchange, followed closely by publications and conferences. For UNIs, hiring graduates is a relatively important mode of interaction. All the other modes are much less common. Modes of interaction were re-arranged into the four channels identified by the taxonomy presented above.

The *traditional channel* implies PRO diffusion of their research outputs, thus among modes of interaction in Table 2 we include publication, conferences and hiring graduates. This is the most highly valued channel among firms. The *service channel* includes consultancies, personnel exchange and information exchange. There is controversy over whether or not personnel and information exchange

Table 1. Descriptive statistics

	Linked 355	Unlinked 238	Linked=Unlinked
Firm characteristics and networking			
Size (deciles employment)	6.63	5.84	***
Skills (professionals over total employment, %)	11.60	11.94	
Networking with private sector (%)	0.82	0.52	***
Innovative performance (proportion)			
New product	0.40	0.27	***
New process	0.31	0.20	***
New product & new process	0.21	0.09	***
Patents obtained	0.05	0.02	**
Investment in innovation over sales (%)			
In-house R&D	0.68	0.39	
External R&D	0.04	0.06	
Machinery and equipment	1.51	1.37	
Hardware	0.11	0.07	
Technology licenses	0.07	0.06	
Training	0.05	0.05	
Industrial design and engineering	0.23	0.12	
Consulting	0.06	0.03	
Total investment in innovation	2.80	2.24	
Use of research results (0.25–1 scale)			
Publications, documents, etc.	0.62	0.58	**
Prototypes	0.50	0.48	
New techniques and tools	0.66	0.56	***
Laboratories/metrology	0.63	0.53	***
Expected roles for UNIs and PRIs (0.25–1 scale)			
Education	0.75	0.77	
Research	0.70	0.66	**
Social	0.58	0.62	*
Entrepreneurial	0.53	0.57	**

Notes: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.
Source: Secretary of Science and Technology of the University of Buenos Aires (UBA).

should be considered a service rather than a traditional flow of knowledge from PRO to firm. This paper includes them within the service channel because, in the case of personnel exchange, they are mostly internships in which students are hired on medium-low salaries. They are a sort of cheap consultancy. It is more doubtful whether information exchange was always a mode of interaction that implies a payment contribution, as the service channel implies. We keep it in this channel to be consistent with previous research. Firms rate this the second most important channel.

The *commercial channel* comprises tools for the commercialisation of research outputs already produced (e.g. spin-off firms, university-owned firms, incubators, licences and patents). This is the least important channel according to surveyed firms (less than 25% considered any of the modes in this channel even moderately important). Although studies for other countries also found that modes included in this channel are not as important as other modes, in the Argentinean case there are big differences in preferences, which may be a manifestation of the poor entrepreneurial performance of the PROs.

Table 2. Modes of interaction (% of linked firms with at least moderate importance)

	UNIs	PRIs
Traditional channel	62%	59%
Publications	46%	49%
Conferences	45%	46%
Hiring graduates	33%	17%
Service channel	57%	57%
Information exchange	50%	52%
Consultancies	26%	24%
Personnel exchange	13%	7%
Commercial channel	24%	23%
Patents	15%	14%
Science parks	13%	12%
Incubators	6%	4%
University-owned firms	2%	2%
Spin off	2%	2%
Licences	15%	16%
Bi-directional channel	36%	32%
Research contracts	25%	22%
Joint R&D	24%	23%
Networks	15%	14%

The *bi-directional channel* comprises joint research, research networks, science parks and contract research. While the first two evidently imply knowledge flowing in both directions, a few words will be said to justify the latter two. In Argentina, public support for the creation of science parks consists of incentives for moving technically-aware firms near to PROs so as to increase the likelihood of knowledge spillovers. Although the literature tends to associate science parks with incubators, in Argentina the concepts are different. Secondly, contract research could be classified as part of the service channel, since it sometimes involves activities related to the use of PRO infrastructure, such as laboratory instruments for testing and monitoring. However, we hold that there would normally be a two-way flow of knowledge since this interaction implies the discussion of specific problems or technological challenges faced by firms. A good few firms value the bi-directional channel, especially in relation to interactions with UNIs. All in all, the traditional and the service channels are the most preferred by firms interacting with PROs.

Methodology

Our research goal is to estimate and compare the effect of factors responsible for the selection of the channels of interaction with UNIs and PRIs. A basic selection problem arises because only those firms that claimed in 2006 to have had linkages with PROs in 2005 answered the questionnaire in 2007. This may create a selection bias since factors driving firms to interact with PROs in the first place could also affect the probability of them choosing one specific channel of interaction instead of others. We therefore need to control for selection bias. For this reason, we estimate a probit model with selection, which is the equivalent of Heckman's model, except that both the selection and the regression equations have dichotomous

Table 3. Marginal coefficients on the probability of linking to PROs, evaluated at different points

	(I) At means	(II) At means except for innovative=1 & network=1
Network	0.3104***	0.2707***
Sector	0.002***	0.0013***
Size	0.0227***	0.015***
Skills	−0.001	−0.0007
Innovative	0.1821***	0.159***
In house IA over sales	0.0184	0.0121
Public financing	0.3023***	0.152***
Diagnosis indicators for the probit model		
Number of observations	592	
Pseudo-*R*-squared	0.117	
Chi-squared	93.74***	
Log likelihood	−352.0	
Log likelihood, constant-only model	−398.9	

Notes: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

dependent variables. The former is a dummy variable that adopts the value 1 for firms linked to PROs, the latter is a dummy variable that takes the value 1 when the firm chooses a specific channel of interaction with a PRI or UNI.[13] Nevertheless, in the Appendix (Table A.1) we present the marginal effect for Heckman models for which the dependent variable in the regression equation is the average importance of modes of interaction of each channel. Results are similar for both methodological strategies.

The definition of all variables is presented in Table A.2 in the Appendix. Our selection of explanatory variables is based on the literature and our research goals. For the selection equation (factors driving interactions with PROs), the determinants most often investigated are firm size (e.g. Piergiovanni *et al*., 1997; Santoro and Chakrabarti, 1999; Ojewale *et al*., 2001; Cohen *et al*., 2002; Rodriguez-Pose and Refolo, 2003; Simonin, 2004; Fukugawa, 2005; Godfrey, 2005; Fontana *et al*., 2006; Segarra-Blasco and Arauzo-Carod, 2008), industry or technology characteristics (e.g. Jaffe, 1989; Anselin, Varga, and Acs, 2000; Leydesdorff *et al*., 2006; Segarra-Blasco and Arauzo-Carod, 2008; Garcia-Aracil and de Lucio, 2008), network related characteristics (e.g. Fontes, 2001; MacPherson, 2002; Pittaway *et al*., 2004; van Rijnsoever *et al*., 2008), public policy promotion (e.g. Ballesteros and Rico, 2001; Hayashi, 2003; Mendoza, 2007), firm knowledge bases (e.g. Santoro and Chakrabarti, 1999; Schartinger *et al*., 2002; Fischer and Varga, 2002; MacPherson, 2002; Arundel and Geuna, 2004) and geographical proximity (e.g. Vedovello, 1997; Fritsch and Schwirten, 1999; Abramovsky *et al*., 2007). In our model of firm determinants for linking, we include proxies for all these variables with the exception of proximity (because of lack of information). For the regression equation (factors driving the selection of channels of interactions with PRIs or with UNIs), we include explanatory variables so as to be able to address our four specific research goals. Thus, explanatory variables were related to firm skills, firm innovativeness (both in terms of

Table 4. Marginal effects evaluated at the means on the probability of using different channels of interactions

	Traditional		Services		Commercial		Bi-directional	
	UNIs	PRIs	UNIs	PRIs	UNIs	PRIs	UNIs	PRIs
Size	0.0277**	0.0143	0.0243**	0.0113	−0.0039	−0.0084	0.0312***	0.0223∗
Skills	0.0041∗∗	0.0014	0.0016	0.0005	0.0003	0.0001	0.0042**	0.0045**
Innovative	−0.1216	0.0517	−0.0012	0.0197	0.0501	0.0238	−0.0617	−0.0309
In-house IA over sales	0.0287	−0.0029	0.0184	0.0025	0.006	0.0014	0.0295	0.0045
Research field	1.7828***	1.8677***	1.4775***	1.3027***	0.6522**	0.5820**	1.1004***	0.8931***
Goals								
Goal (a): Technological consultancy to solve production problems	0.0359	0.0778	0.1705	0.195	0.0995	0.1267	0.1301	0.1237
Goal (b): Using available resources	0.2439*	0.2403	0.2425*	−0.0149	0.1043	0.0083	0.4824***	0.0456
Goal (c): Assist in quality control	0.2746**	−0.0032	0.1052	0.1443	−0.0352	0.0351	0.1094	0.1715
Goal (d): Contract research to collaborate with the IA of the firm	0.0759	0.2152	0.0625	0.3403**	0.2452**	0.3035**	0.4775***	0.6356***
Diagnosis indicators for the bi-variate probit model estimated with sample selection								
Number of observations	645	645	645	645	645	645	645	645
Number of censored observations	292	292	292	292	292	292	292	292
Rho	−0.158	0.108	0.699***	0.28	−0.0256	−0.04	−0.0591	−0.504*
Log likelihood	−581	−599.2	−594.6	−606.1	−569	−562.7	−564.4	−563

Notes: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

input and output), fields of research and goals of the interaction. We also controlled by firm size.

Econometric results

We estimated eight bi-variate probit models with sample selection, since there are four channels of interaction (traditional, service, commercial and bi-directional) with two institutions (UNIs and PRIs). The selection equation is specified identically in all cases. Consequently, results for this equation are very similar in all models. Therefore, to save space the results for the selection equation are presented just once.[14] The next subsection discusses the results and the following focuses on the main conclusions of the paper: the discussion of factors responsible for the selection of channels.

Results from the selection equation

Table 3 presents the marginal effects on the probability of linking to PROs: evaluated at the means of independent variables (column I) and when dummy variables for both *network* and *innovative* take the value 1 – with all other variables evaluated at the mean (column II). Size differences persist in both samples;[15] we find that size has a positive impact on the probability of connecting to PROs. This may be explained by biases in the response rate. As expected for construction, the sectoral variable is significant (i.e. it measures the intensity of linking across sectors, especially designed to control for sector). More interesting, we find that the greater the connections with other actors in the NIS (*network*), the greater the probability that the firm interacts with PROs. In other words, as others have found (e.g. MacPherson, 2002), networking capabilities matter. Moreover, we find that innovative firms are more likely to connect to PROs. Similarly, we find that public support for R&D increases the probability of connecting to PROs. This is expected since some policy programmes designed by the ANPCyT offering R&D subsidies stimulate interactions with PROs.

Finally, reading from column II, the use of public financing has a lower impact on the probability of linking – although still significant – when the firm is innovative and has connections with other actors. In other words, public support for R&D is especially helpful in encouraging firms with low networking and innovative capabilities to interact with PROs. This was expected since it is more likely that firms strong in both capabilities are already connected to PROs (as shown by the positive and significant coefficient of these two variables in column I). However, the finding is nevertheless interesting since it confirms that R&D subsidies are effective in encouraging new PRO–firm interactions.

Results of the regression equation

This focuses on our specific research goals. Table 4 presents the marginal effects evaluated at the mean for the regression equation of the bi-variate probit models with sample selection for UNIs and PRIs. As mentioned above, Heckman estimations are presented in the Appendix (Table A.1). While results in Table 4 are interpreted as factors affecting the probability of choosing a channel, results in the Appendix should be interpreted as factors affecting the intensity of use of a chan-

nel. We believe the former interpretation is more intuitive, since the scale for the intensity of use was originally qualitative,[16] and only later converted into a continuous variable for the sake of estimation. In any case, the main results relevant to our research goals are very similar in both approaches.

The rho coefficients, which estimate the correlation coefficient between unobservable factors affecting the probability of linking and unobservable factors affecting the selection of channels, is very low and not significant in most cases (with the exception of the services channel in the case of UNIs, and the bi-directional channel in the case of PRIs). This means that we would have obtained very similar results for most estimations had we used standard probit models (without controlling for selection). Similarly, in Heckman estimations presented in the Appendix, the rho coefficients are not significant (except for the services channel in the case of UNIs).

In general, we can say that drivers differ much more across channels of interaction within UNIs than within PRIs. In other words, systematic differences across firms are clearer with firms that select different channels in the case of interaction with UNIs than with firms interacting with PRIs. However, drivers of the bi-directional channel are similar in both cases (with UNIs and with PRIs) and differ from the drivers of the other channels.

Firm size is an important determinant for three of the four channels in the case of UNIs, while it is only a significant driver of bi-directional channel use in the case of PRIs. On the one hand, the different effect of size for interaction with UNIs and PRIs may be related to the fact that the former tend to be much more bureaucratic than the latter in Argentina.[17] Thus, interactions with UNIs may demand more of a firm's resources. Moreover, this may also be related to the fact that some PRIs have collaboration programmes specifically targeting small firms. On the other hand, the bi-directional channel may be more demanding since, to use that channel, firms must be committed to research activities. Since research activities are usually scale dependent, this may explain why size affects the selection of this channel so intensively.

Firm capabilities measured by workforce formal training are an important incentive for using the traditional channel with UNIs and the bi-directional channel with PRIs and UNIs. This is an important finding which answers our first research question. Firms that use these channels are among those most prepared to take advantage of the knowledge opportunities opened up by these channels. On the one hand, absorptive capacity is necessary to use the information transferred through the traditional channel (especially via publications and conferences). The fact that these skills are driving factors for the connection with UNIs but not with PRIs may be explained by UNIs tending to produce more blue sky research – and therefore being more demanding of absorptive capacity – than PRIs. On the other hand, highly developed skills are always necessary to interact using the bi-directional channel, especially if one expects learning to occur at both ends. Thus, it is an encouraging finding that firms that connect to both PRIs and UNIs using the bi-directional channel are particularly skilled.

Firms' innovativeness does not seem to be a determinant of choosing between channels, which answers our second research question. Although we find that innovative firms are more likely to link with PROs, we find differences across channels neither for this variable nor for investment in in-house innovative activities. With *innovative* we wanted to capture firms that were among the most innovative in

terms of their past experience. However, because of data restrictions, this dummy variable accounts for firms that achieved successful innovation in product and process in 2005 (i.e. contemporaneously with the interaction with PROs). In other words, it would have been better to use longer history indicators. With *in-house* we attempted to measure firm commitment to innovation. However, firms may interact with PROs to complement or substitute their investment in-house – especially when using the bi-directional or the service channel. Therefore one effect may compensate for the other.

The field of research is an important driver for all channel types. However, to answer our third research question we must say that in most channels the applicability of the research field has a greater effect on interactions with UNIs than with PRIs. Moreover, it is also more relevant when using the traditional channel than any of the others.[18] Our indicator of field of research accounts for the degree of applicability of the knowledge field inspired by Stokes (1997). It weights the most heavily those fields of research that belong to the Pasteur quadrant (see Table A.2 in the Appendix). This factor would be expected to be less important when knowledge interactions are more customised (i.e. when knowledge flows are adapted to the specific needs of the firms). In such a case, any field of research, even those far away from the Pasteur quadrant could be applicable to industrial use. This explains why this factor is more important for interactions with UNIs and when using the traditional channel. In both cases knowledge outputs are less customised. Thus firms would choose such channels especially when knowledge/research fields are, by nature, more applied (i.e. when they belong to the Pasteur quadrant).

Regarding the goals for interacting (the fourth research question) we included four different goals in the regression: (a) consultancy or advice to solve concrete problems; (b) using PRO resources; (c) quality control; and (d) contracting research to collaborate on innovative activities of the firm. Somehow, we wanted to account for two types of firms' attitudes: using PRO resources to contribute to firms' production activities [goals (a), (b) and (c)] or creating something new in collaboration with a PRO [goal (d)]. Generally speaking this may be interpreted as the two main types of goals that justify the intensification of linkages within the NIS (i.e. sharing resources for more efficient production and sharing knowledge to create new knowledge resources).

Goal (d) is a significant goal driving firms to select different channels, with the exception of the traditional channel (for PRIs and UNIs) and the service channel (for UNIs). This is good news since it may imply low opportunity costs of interactions for researchers (i.e. in terms of research not done while pursuing collaboration agreements), since an attitude towards creation dominates the interaction across the majority of channels. Moreover, the conceptual framework predicts that the selection of the traditional and (in the case of UNIs) the service channel are not driven by the intention to innovate (Arza, 2010). These channels are usually chosen for short-term production related purposes. In turn, when firms aimed at innovation [i.e. when they seek goal (d)] they normally choose channels through which knowledge flows both ways.

Finally, in the case of UNIs, goal (b) was a significant driver for the traditional, the service and, particularly, the bi-directional channel. This goal was not significant for driving interactions with PRIs. This may be related to the fact that UNI research resources are larger and more diversified than those in PRIs. Moreover, UNIs clearly opened up their infrastructure for the use of the private sector via collabora-

tion agreements only in the late 1990s. Thus, in recent years a wide array of new and sophisticate resources became 'available' at UNIs to firms that established collaboration agreements with them. This may also explain the significance of this goal especially regarding the bi-directional channel – which involves, usually, long-term agreements. This finding raises some concerns; it would be advisable not to overused resources available in UNIs indiscriminately in the private sector. Project assessment should be pursued to evaluate the social impact of such private use of public resources.

Concluding remarks

Empirical research has been carried out worldwide to identify firms' and researchers' preferences for different modes or channels of interaction. Less research was pursued concerning the relative effectiveness of the use of different channels.

Building from past research, this paper uses a taxonomy that groups different modes of interaction into four channels: traditional, service, commercial and bi-directional. Past research for Argentina argues that firms and researchers tend to use the former pair more often than the latter. This paper confirms that this is true for firms, even when PROs are separated into PRIs and UNIs. However, it has been shown elsewhere (Arza and Vazquez, 2010) that only the bi-directional channel drives long-term benefits for firms and for PROs. In the former case, long-term benefits are related to innovation rather than to production, and in the latter case they are knowledge outcomes rather than financial outcomes. This paper aims at identifying the firm characteristics that drive the selection of different channels of interactions with PRIs and UNIs. This is important because it could help policymakers to develop tools to promote the use of specific channels; for example, those used infrequently (in Argentina, the commercial and the bi-directional) or those with better potential in terms of long-term impacts (bi-directional).

Two main findings can be drawn from this research. First, factors driving the selection of different channels are not the same for interactions with UNIs and with PRIs – with the exception of the bi-directional channel, which tends to be selected by similar firms in both cases. Secondly, certain firm characteristics and behaviours drive the selection of specific channels. In particular, sharp differences can be identified in factors driving the bi-directional channel in contrast to the rest. In general, size is a determinant for the selection of channels of interactions with UNIs, but it is not a significant driver for choosing channels of interaction with PRIs. This may be explained by higher bureaucracy at UNIs and also by specific programmes designed at PRIs to target small firms. Similarly, the degree of applicability of the research fields is a more important determinant of interactions with UNIs than with PRIs. The explanation may be that knowledge produced by UNIs tends to be more generic than that produced by PRIs, which, by definition, attempts to provide technological support to firms.

Drivers of the bi-directional channel are different from drivers of the other channels, but similar for interactions with UNIs and PRIs. In particular, firm size has a larger effect on the selection of the bi-directional channel than on the selection of the other channels. Moreover, firms choosing this channel employ a highly skilled workforce. Probably, the reason for size and skills being especially relevant for the selection of the bi-directional channel is that firms commit their own knowledge resources when using this channel. Firms that interact to collaborate with their own

innovative activities tend to prefer the bi-directional channel above and beyond other channels. All in all, these findings suggest that firms choosing the bi-directional channel are those able and willing to invest their knowledge resources in the interaction. This is an interesting finding since a virtuous circle of PRO–firm learning may occur when they interact using this channel. It would be interesting to replicate this study for other Latin American countries with similar data since the bi-directional channel was more conducive to innovation and intellectual benefits (Dutrénit and Arza, 2010). In other words, interaction using this channel may be rewarding for all actors involved. Consequently, there would be low opportunity costs if use of this channel were intensified.

However, we also found that firms tend to choose the bi-directional channel with UNIs when they are interested in using UNI resources, though 'UNI resources' is a very broad concept. However, if public resources become overused by private interests, some important social goals may be ignored in public research. This is one important concern for those who distrust the promotion of PRO–firm linkages. Our contention is that if PRO–firm interactions are to be supported, the use of the bi-directional channel should be intensified. This conclusion is consistent with former research on Latin America. Nevertheless, we believe that more research is required into the opportunity costs of PRO–firm interactions in general, and when using the bi-directional channel in particular.

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Notes

1. See Arza and Vazquez (2010) for the Argentinean study, Fernandes *et al*. (2010) for Brazil, Orozco and Ruiz (2010) for Costa Rica and Dutrénit *et al*. (2010b) for the Mexican case study.
2. For example, three Argentinean scientists working in Argentinean PROs won Nobel Prizes in Science and a Mexican graduate of a Mexican public university won the Nobel Prize in Chemistry for research at MIT. Similarly, the share of publications by authors from these countries in total world publications indexed in the ISI Web of Science is much higher than the share of these countries in the patents database USPTO (United States Patent and Trademark Office). Moreover, the increase of scientific production observed in the last decade has not been accompanied by an increase in patent applications.
3. Recent research indicates that these modes continue to be preferred by some Latin American countries (Dutrénit and Arza, 2010).
4. Varsavsky (1973) proposed what López (2007) called a linear model but 'the other way around': he argued that society had to set the productive priorities, from which technological needs were to be derived. These needs should be satisfied by S&T. In turn, Sábato (1973) developed the triangle model to emphasise the need for public policies to integrate the three vertexes – the state, the productive sector and the scientific sector. Sábato's ideas set a precedent for the triple helix notion of Etzkowitz and Leydesdorff (1997).
5. Notably, private sector investments in R&D are low (Thorn, 2005). In 2007, for example, firms participated in less than 30% of total expenditures in innovative activities, a share lower than that in Brazil (45.5%), Chile (45.8%) and México (41.5%) (http://www.ricyt.org/).

6. See Arza and Vazquez (2010) for the Argentinean study, Fernandes *et al*. (2010) for Brazil, Orozco and Ruiz (2010) for Costa Rica, and Dutrénit *et al*. (2010b) for the Mexican case study.
7. Kruss (2012) uses the same taxonomy to relate channel with benefit and also with risk of interactions for the biotechnology sector in South Africa.
8. UNIs and PRIs differ in their mission within the NIS. Consequently, we analyse results separately for these types of institutions.
9. PRIs included INTA, INTI and ANPCyT.
10. This group was built to resemble as closely as possible the linked group in size and sector affiliation.
11. Despite the sampling methods for the unlinked group, non-responses created a significant difference in the average size of both subsamples.
12. Firms had to assess research outputs on a four-point Likert scale (1–4). Table 1 rescales original values by dividing them by 4, thereby creating a 0.25–1 scale.
13. For the sake of precision, we consider choosing a channel of interaction to be when the firm assessed any of the modes which comprised the channel as at least moderately important (i.e. a value >0.5 in the 0.25–1 scale).
14. Results correspond to a probit model on the probability of connecting to PROs. The estimates for the selection equations of all the models, whose regression equation is presented in Table A.1, are very similar and are available upon request.
15. It is important to remind the reader that the group of unlinked firms that was included in *The Survey 2006* was selected to resemble the size and sector characteristics of linked firms. Thus, size and sectoral affiliation are somehow already controlled for and we would not expect strong differences in size and sectoral variables between linked and unlinked firms just because of the way the sample was constructed.
16. Not important, of little importance, moderately important and very important for each of the modes of the channel.
17. R&D managers informed us, in personal interviews, that collaboration with PRIs is always easier and smoother than with UNIs, because of the complicated bureaucratic procedures involved, especially among the bigger UNIs (such as UBA).
18. Although in this case the effect is larger for PRI interactions.

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Appendix

Table A.1. Marginal effects evaluated at the means for the importance of different channels of interactions: regression equation of a Heckman model

	Traditional		Services		Commercial		Bi-directional	
	UNIs	PRIs	UNIs	PRIs	UNIs	PRIs	UNIs	PRIs
Size	0.0237**	0.0118	0.0215**	0.001	−0.0046	−0.0087	0.0205**	0.0157*
Skills	0.0035**	0.0012	0.0019	0.0005	0.0004	0.0002	0.0032**	0.0037**
Innovative	−0.085	0.0483	−0.0155	0.0106	0.044	0.0282	−0.043	−0.0152
In-house IA over sales	0.0056	−0.0026	0.0082	0.002	0.0084	0.0016	0.0084	0.0034
Research field	1.3906***	1.5013***	1.3851***	1.0790***	0.654**	0.5836**	0.8576***	0.6847***
Goal (a): Technological consultancy in order to solve production problems	0.028	0.0669	0.1807*	0.184*	0.092	0.1229	0.1175	0.1012
Goal (b): Using available resources	0.1685	0.2045	0.2238*	−0.014	0.1122	0.014	0.3955***	0.0297
Goal (c): Assist in quality control	0.2728***	−0.004	0.1052	0.1291	−0.044	0.0167	0.0809	0.1244
Goal (d): Contract research to collaborate with the IA of the firm	0.0654	0.1744	0.0718	0.294**	0.2681**	0.3344***	0.4228***	0.5998***
Diagnosis indicators for the estimation of the Heckman model								
Number of observations	645	645	645	645	645	645	645	645
Number of censored observations	292	292	292	292	292	292	292	292
Rho	−0.1097	0.0654	0.4621**	0.1912	−0.0546	−0.0512	−0.0686	−0.3278
log likelihood	−286.6	−773.7	−228.0	−702.2	−124.1	−615.2	−239.6	−734.9

Notes: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table A.2. Variable definitions

Concept	Variable name	Type of data	Definition
Traditional channel	*Traditional*	Dummy	1=if one or more of the modes of interaction included in the traditional channel was considered at least as 'moderately important' by the firm
Service channel	*Service*	Dummy	1=if one or more of the modes of interaction included in the service channel was considered at least as 'moderately important' by the firm
Commercial channel	*Commercial*	Dummy	1=if one or more of the modes of interaction included in the commercial channel was considered at least as 'moderately important' by the firm
Bi-directional channel	*Bi-directional*	Dummy	1=if one or more of the modes of interaction included in the bi-directional channel was considered at least as 'moderately important' by the firm
Size	*Size*	Ordinal	Deciles based on employment for the full sample (ENIT)
Skills	*Skills*	Continuous	Professionals over employment
Innovativeness	*Innovative*	Dummy	1=the firm obtained a new product and a new process
	In-house IA over sales	Continuous	Expenditures in R&D and Design and Engineering over sales
Degree of applicability of research fields that are important for firms' IA	*Research field*	Continuous	Weighted average of importance of research fields (1–4 rescaled 0.25–1) for firms' innovative activities (according to firms themselves). The weights are: 0.2=Physics and Math 0.4=Chemistry and Biology; 0.6=Medicine; 0.8=Biotechnology and Agronomy; 1=Engineering and Design
Goals of the collaboration with PROs	*Technological advice or consultancy in order to solve production problems*	Ordinal	Importance (1–4 rescaled 0.25–1) of this goal as stated by firms

(*Continued*)

Table A.2. (*Continued*)

Concept	Variable name	Type of data	Definition
	Using available resources	Ordinal	Importance (1–4 rescaled 0.25–1) of this goal as stated by firms
	Assist in quality control	Ordinal	Importance (1–4 rescaled 0.25–1) of this goal as stated by firms
	Contract research to collaborate with the IA of the firm	Ordinal	Importance (1–4 rescaled 0.25–1) of this goal as stated by firms
Networking capabilities	*Network*	Dummy	1=the firm links to private actors within the NIS to co-operate actively or to exchange information
Public support	*Public financing*	Dummy	1=the firm receives public funds to finance its investment in R&D
Sectoral specificities	*Sector*	Continuous	Sum of firms that were actively connected to PROs by sector (two digits)