Science-industry links in Latin America:
empirical evidence from National Innovation Surveys

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Introduction

The concurrence of the open economies setting, which re-shapes interactions between firms and research institutions, and the emergence of new technological paradigms, which cause a redefinition of boundaries, and hence cooperation agreements, between the scientific sector and industry in the pursuit and generation of innovative knowledge, give a new lease of life to the longstanding debate on science-industry links.

New technological paradigms entail a redefinition of tasks both for the scientific and for the industrial sector. Basic R&D increasingly leads to obtain marketable produce, even in the form of intellectual property. On the one hand, universities and research-labs are progressively more involved in production activities, and business criteria have been introduced in their management strategies; on the other, firms, especially in certain technological trajectories, are more and more concerned with basic R&D and with "scientific" research. At the same time, a generalized re-shaping in institutional arrangements, intellectual property rights, innovation laws, etc. opens up different spaces of actions (and interaction) for firms, universities and research centers. These issues concur to throw new light on science-industry links, the role of scientific inputs for industrial development, and cooperation in R&D between universities and enterprises; hence, the focusing of current policy debate in advanced economies on innovation, cooperation and public-private partnership is quite understandable.

Latin American countries are not alien to these trends. Innovation and technology are, luckily, too fashionable issues in the "era of knowledge economy" to be left out from the political discourse and from firms' and universities' concerns. However, the debate on science-industry links takes peculiar nuances in the countries of the region. Policies seems to call for a simplified version of the national innovation system view, mostly focusing on creating mechanisms to facilitate cooperation in R&D, setting aside concerns regarding increasing the capacities and capabilities to carry out R&D both in the scientific and the industrial sector.

Following the emerging literature on innovation and cooperative behavior in R&D, based on micro-data from national innovation survey (Veuguelers and Cassiman, 1999; Arundel and Hollanders, 2005; Laursen and Salter, 2005; Knell and Srholec, 2005, among others), this paper aims at contributing to understand how science-industry links work in Latin American countries. The present paper explores micro-evidence from innovation surveys of Argentina, Brazil, Colombia and Uruguay to give insights on R&D cooperation between firms and universities in local manufacturing industry, with the double purpose of, on the one hand, constructing a frame to discuss cooperative micro-behavior of firms in the specific case of Latin American countries and, on the other hand, providing empirical evidence to contribute to the current policy debate on science-industry links. We start by briefly reviewing the literature on innovation and cooperation, we sketch innovation patterns in Latin American countries to clarify the context to which the micro-data refer to; we summarize, in few words, the evolution of science and technology policies in the countries of the region, focusing on the role of science-industry links. Then we analyze micro-evidence from innovation surveys, testing the determinants of R&D cooperation with universities and research labs for firms in each of the countries object of study.

Cooperation and innovation, some introductory notes

A property by now generally acknowledged is that firms are not monads in their search for innovation. Innovation is an interactive process and firms rely upon multiple capabilities and sources in their search, generation and adoption of novelty (Shumpeter 1942; Rosenberg 1982; Kline and Rosembreg, 1986; Freeman, 1987; Dosi, 1988; Nelson and Winter, 1982; Nelson, 1993; Freeman and Soete, 1997). According to the literature on national innovation systems, innovation is an interactive process that ensues in given environments where agents (basically firms and research institutions), responding to different incentives interact and cooperate (Nelson and Winter, 1982; Freeman, 1982; Cimoli and Dosi, 1995). Framework conditions affect firms' technological behavior. Enterprises perform in settings where they are expected to interact on a continuum basis with other economic and non-economic agents like partners, competitors, universities, public institutions and civil society organizations. They mold their technological behavior also according to this set of interlinks. In the pursue of innovation and technological development firms might carry out in-house R&D and, at the same time, they might count on external sources, such as other firms (clients, suppliers, headquarters, etc.), and universities, research centers and networks. Evolutionary economics recognizes the complementarities between these strategies, and offers an interesting interpretative framework for analyzing cooperative behavior in R&D.

First, recognizing the tacit dimension of knowledge and the fact that technological capabilities are embodied, at least to some extent, in individuals, firms and institutions (Polany, 1967; Freeman, 1982; Pavitt, 1984), leads to stress the relevance of R&D capabilities of firms in the analysis of cooperative behavior; i.e. the standard approach of efficient division of labor in innovation does not apply. Cooperation in R&D cannot make up for individual capacities of firms; there are non-substitutable innovation efforts that firms must carry out in order to profit from cooperative R&D agreements. In other words, firms' absorptive capacity shapes cooperative behavior in R&D (Cohen and Levinthal, 1990), and in-house R&D efforts and external sourcing appear as complementary. To profit from cooperation with external agents firms need a certain degree of capabilities to identify potential benefits from R&D cooperation; at the same time enterprises need to dispose of technical capacities to profit from the interchange with external units.

Second, interactions between firms, institutions and the prevailing legal systems, i.e. the dynamics of national innovation systems, affect knowledge generation and diffusion paths. The codified and non-codified networks determine more or less favorable environments for knowledge generation, diffusion and accumulation, according to the density and specificity of linkages. At the same time, the environment shapes the openness of firms to external sources (Cohen and Levinthal, 1990). And, reasonably, the level of technological opportunities available in the environment molds the kind of cooperation and interaction that firms choose to be engaged in (Klevorick et al. 1995). Firms that belong to an environment offering high opportunities may be more likely to search for cooperation and be more open to external sources to gain access to key information and technologies (Laursen and Salter, 2005). On their turn, more innovative firms reshape the environment and can induce a process of increasing returns inducing universities and research centers, and other firms, to be willing to cooperate with them.

Third, sectoral technological specificities matter. R&D cooperation encompass a sector specific innovative behavior: there are sectors where innovation commonly derives from cooperative R&D projects, think for example about the role of consumers as innovators in new IT-based activities or the well-know clustering effect like the Silicon Valley one; and there are sectors that are more science-based than others, like chemical and pharmaceutical sectors or biotechnological industry, in which science-industry links are almost ordinary in the generation of innovative knowledge (Pavitt, 1984; Dosi, 1988).

Within the broader debate on cooperation and networking in R&D, the role of scientific research on industrial innovativeness and the relationship between public and private sectors in innovation has been extensively addressed. Scientific inputs are relevant for innovativeness, especially in a sectoral perspective (Nelson, 1959; Chesnais, 1986; Mansfield 1991; Pavitt 1991). In the last decades these topics have been on top of academic and policy makers discussions due to the role that science-industry links played in the industrialization of emerging economies and in their catching up. The co-evolution of research capacities and production capabilities, the flow of expertise between academies and the industrial sector in South East Asian economies are examples in this area (Pack and Westphal, 1986; Kim, 1993; 1997; 2000; Amdem, 1989) Moreover, the emergence of new technological paradigms entails a redefinition of traditional boundaries of science and business. The scientific sector is increasingly close to "producing" marketable produce, even in the form of "intangibles", i.e. intellectual property, and firms carry out research in domains that are close to the traditional conception of science (Dasgupta and David 1994; Pisano, 2006;). Profit entered the logic of scientific research and searching for discovery is not alien to firms' behavior. At the same time, firms and research institutions face new institutional settings and norms which foster, on the one hand, commercialization and diffusion of science and, on the other, the appropriability of innovation, establishing new codes –and challenges- for its diffusion (Cohen, Nelson, Walsh, 2002; Mowery et al. 2004;).

Few could argue against the fact that science-industry links, in general, positively affect firms, universities, and to broader extent countries' innovativeness; however it is less straightforward derived which are the conditions for cooperative R&D between the two to ensue, what are the standards of excellence and the structural determinants for this kind of cooperation to increase firms' (universities, and countries) performance and which is the set of incentives which best favors such cooperation.

Beyond appreciative theorizing, there is a growing body of literature providing insights on cooperative behavior in innovation using micro data from innovation surveys. These studies, mostly based on the European Community Innovation Survey (CIS), focus on different aspects of the determinants of cooperative behavior. In general, size, capacity to appropriate returns form innovation (the use of appropriability mechanisms), internal capacities in R&D (i.e. absorptive capacity) and the importance assigned to costs and risks as obstacles for innovation are among the factors that result significant in determining the probability of firms to be engaged in R&D cooperation with the scientific sector. (Arora and Gambardella, 1994; Colombo and Gerrone, 1996; Veugelers 1997; Veugelers and Cassiman, 1999; Hall, Link and Scott, 2000; Berdebos et al., 2004; Knell and Srholec, 2005; Laursen and Salter, 2005;).

For example, Veugelers and Cassiman (1999) analyze the decision to make or buy in innovation strategies. In their analysis of the Belgian manufacturing sector they find that high costs and risks and low appropriability affect firms' cooperative behavior. Small firms are more likely to choose one strategy, make or buy, while larger firms are more likely to combine different strategies. Firms that identify internal sources as relevant are more likely to mix the outsourcing with the direct carrying out of R&D. Berderbos et al. (2004) explore the determinants of different types of R&D cooperation for Dutch innovative firms; according to the authors, bigger firms are more likely to be engaged in what they call "institutional cooperation", i.e. cooperation with universities and research labs. Absorptive capacity, measured through R&D intensity, the perception of risks and costs as obstacles to innovation, and being beneficiaries of R&D subsides are additional variables influencing the likelihood of cooperating with the scientific sector.

Abravosky et al. (2005) carry out a study using the third CIS for analyzing the determinants of R&D cooperation in France, Germany, Spain and the UK. According to their findings the capacity of firms to appropriate returns from innovation (the usage of appropriability mechanisms) positively influences the probability of engaging in cooperative R&D; receiving public support also affects R&D cooperation especially with the research base. Risks and costs as obstacles to innovation, here again, are perceived as factors affecting the decision to cooperate, i.e. cooperation can be seen as a mechanism to overcome these obstacles. Laursen and Salter (2005) analyze the relevance of external sources of innovation using the UK Innovation Survey focusing on the role of appropriability mechanisms. According to their results the relationship between the degree of openness to external sources and the strength of firms' appropriability strategy takes the form of an inverted U shape, i.e. the probability of a firm to be engaged in cooperative agreements with external agents increases when the firm makes use of appropriability mechanisms, but beyond a certain threshold an aggressive appropriability strategy might reduce the willingness to cooperate with external sources. Knell and Srholec (2005) stress the relevance of innovation for countries that are willing to catch up. In their study on innovation cooperation in the Czech Republic they find that international cooperative agreements are relevant for the domestic economy, but they demonstrate that foreign ownership does not necessarily imply knowledge spillovers to the local economy.

Analyzing science-industry links in Latin America, and in developing countries in general, requires taking into account a set of features that are, obviously, different from that of industrialized countries. In general, in those economies, firms lack a technologically dynamic domestic environment that stimulates their willingness to interact, and their search for innovation through external sources. At the same time, the prevalent technologically static behavior of firms' negatively influences the (innovative) dynamisms of the environment, engendering a sort of vicious circle. Enterprises do not innovate as much, the specialization pattern is oriented toward low technology intensive sectors and the environment is not so attractive in terms of technological opportunities. And also, most of innovations are "ready-made" products, already available in foreign economies. At the same time, R&D is not a priority for regional universities, which in general suffer from budget and human resources constraints. And even though islands of excellence in R&D exist, research centers and firms are likely to search for international cooperative agreements and projects, rather than domestic ones (Cimoli, Ferraz, and Primi, 2005). In this scenario, it is quite reasonable to expect scant science-industry links. However, there can be (common or diverging) patterns in R&D cooperation of Latin American manufacturing firms with the scientific sector, which is worth identifying especially considering the relevance of this topic in current public policy priorities.

Innovation patterns in Latin American countries, an overview

In Latin America, studies have been focusing on analyzing industrial and technological development at sectoral level in the light of development and catching up theories (Reinhardt and Peres, 2000; ECLAC, 2002; Cimoli, 2005). It is acknowledged that countries show divergent production structures and specialization patterns; however, although to different extent, they all lag behind in terms of technological and production capabilities with respect to frontier and emerging economies. Latin American countries invest scant resources in R&D and the propensity of private sector to invest in R&D is lower than that of most advanced and industrializing economies. These trends are deeply related with the prevalent production specialization, basically oriented towards natural resources and labor-intensive activities that *per se* express a limited demand for knowledge, and with the set of incentives that prevail in open economies (Cimoli, 2005).

In this setting: how do national innovation systems perform? To what extent do universities and firms cooperate? The literature regarding production, innovation and networking in the countries of the region have been addressing the weaknesses in networking and articulation between firms, universities and public institutions thorough sectoral studies (Cimoli, 2000; Tigre, Cassiolato, De Souza, Szapiro, Ferraz, 2000). However, analyses at the firm level have been focusing mostly on characterizing innovativeness (De Negri et al., 2005; López and Orliki, 2005; Viotti 2006) and on exploring the determinants of innovative efforts, according to structural factors, or the effects of innovation on productivity and export performance (Benavente, 2002; 2005; Chudnovsky et al., 2006; Kuramoto and Torero, 2004; Arza, 2005; Crespi and Patel, 2006).

For example, Chudnovsky, Lopez and Pupato (2006) analyze the determinants of innovation and its effect on productivity using panel data from Argentinean innovation surveys, considering information for the period 1992-2001. According to their estimates, in-house R&D and technology acquisitions increase the probability of firms to innovate. Innovative firms are in general, more productive than non-innovative ones. Big firms are more likely to engage in innovation activities and to obtain positive results than smaller ones. Benavente (2005) estimates the impact of R&D on firm productivity in the case of Chile, finding a positive relationship; according to his estimates for each dollar received from public support and assigned to R&D, productivity rises, on average, by 5 dollars. In a cross-country comparative study, Crespi and Patel (2006) find a positive non-linear relationship between competition and innovation, which varies according to industry specific characteristics. According to their estimates, competition usually has a positive impact on innovation in sectors like information technologies, energy and aerospace; while, for example, it could hamper innovation in the case of food, chemicals, machinery and textiles. When testing for technology gap, the authors find that increasing competition may increase the rate of innovation only in frontier countries.

Following this stream of literature which aims at analyzing micro behavior of firms from a Latin American perspective, we aim at identifying the determinants of science-industry links using micro data from innovation surveys of Argentina, Brazil, Colombia and Uruguay. These countries account for more than half of regional manufacturing value added and for almost 70% of regional R&D expenditure. These economies mainly export natural resource based products[1], however they show diverse specialization patterns, technological capabilities and market size, allowing to identify cooperative behavior in R&D in different contexts. In terms of production specialization, the manufacturing sector accounts for 17% of GDP in Argentina, 22% in Brazil, 16% in Colombia and 18% in Uruguay. Within manufacturing, technology intensive sectors represent 33% of manufacturing value added in Brazil, 15% in Colombia, 13% in Argentina and 7% in Uruguay[2]. In terms of R&D expenditures, Brazil is the only country that invests in R&D more than the regional average. In 2003, Brazil spent in R&D 0.91% of GDP, Argentina 0.41%, Uruguay 0.22% and Colombia 0.18%[3].

Data from national innovation surveys give further details on innovation performance. On average, less than 50% of sampled firms in each country qualify as innovative. Bigger firms are more likely to be innovative than smaller ones; however according to estimates the relationship is not linear. There is a threshold beyond which further increases in size reduce the probability to innovate[4]. Firms with higher internal R&D capacities (R&D expenditures and personnel) are more likely to be in the innovative pool than those with less internal capabilities and innovative firms tend to concentrate in more technology intensive sectors, such as pharmaceuticals and chemical products, electronics and transport equipment.

The Latin American policy discourse on science-industry links

The origins of systematized institutional efforts in science and technology policies in Latin America trace back to the beginning of the fifties. Each country followed a

[1] Soya, crude petroleum and maize in the case of Argentina, bovine, leather, rice, wood and soya in Uruguay, crude petroleum, coal, coffee, flowers, gold in the case of Colombia. The only exception is Brazil, which includes within its major export products airplanes, in addition to crude petroleum, iron and soya.

[2] Natural resource based sectors account for 73% in Argentina, 72% in Uruguay, 60% in Colombia and 48% in Brazil. Labor-intensive activities account for 19% of total value added in Brazil, 14% in Argentina, 21% in Uruguay and 25% in Colombia. Data refer to 2003 and are authors' calculations based on the ECLAC-UN-DDPE-PADI database.

[3] Data refer to R&D expenditure as a percentage of GDP, RICYT estimates for the year 2003 or closest year available.

[4] This is coherent with findings of similar studies carried out in advanced economies. Using data form CIS some authors find that there is a positive, non-linear relationship between firm size and the probability to be innovative (Crépon et al., 1998; Veuglers and Cassiman, 1999; and Lööf et al., 2001). The relationship between firm size and innovative conduct is quite vast and controversial. It is possible to find two different stances in the same Schumpeter (1912; 1942). According to Levin and Reiss (1984) the relation between innovation and firm size is not conclusive, and although the economies of scale and scope may exists, they may be exhausted in medium-size firm

peculiar, non-lineal path, resulting in more or less formalized political and institutional arrangements to support scientific and technological development according to (varying) national and production priorities; in general, government intervention has been quite sporadic in priorities, instruments and financing.

During the import substitution phase a linear supply model of technology policy prevailed. The public sector played a major role in identifying scientific and technological priorities. Policies aimed at supporting the expansion of local production capacity and at generating the basis for the development of endogenous capabilities. Policies addressed the creation of scientific and technological infrastructure and promotion of human capital formation (Capdevielle, Casalet and Cimoli, 2000; Tigre et al. 2000). Government intervention supported the institution of main science and technology agencies, following different nuances and timing in each country[5]. Research and development activities were mainly carried out by public research institutes and universities focusing on priority areas, as agriculture, energy, mining, forestry and aeronautical, among others, and by big public enterprises operating in strategic sectors like telecommunications and transport, thus manifestly following an selective industrial approach (Cimoli, Ferraz, Primi, 2005)[6]. Innovation was supposed to follow a linear diffusion path, from science to industrial production.

With the structural reforms and the shifting to a market-oriented approach to growth and development, the policy discourse on science and technology also changed. Faith in market mechanisms resulted in neutral and horizontal policies in order to minimize state interference. This stance towards public policies meant placing knowledge and

[5] The National Council for Scientific and Technical Research (CONICET) in Argentina was created in 1958; the National Council for Scientific and Technical Development (CNPq) was instituted in Brazil in 1951; The National Council for Science and Technology (Consejo Nacional de Ciencia y Tecnología), The Colombian National Institute for Science and Technology (Colciencias) and many forums of discussion on S&T were instituted in Colombia starting in the decade of the 70s.

[6] Governments instituted public research institutes and Commissions; the National Atomic Energy Commission (CNEA) in Argentina was set up in 1954, the National Institute for Industrial Technology (INTI) and the National Institute for Agricultural Technology (INTA) in 1957. Brazil created a series of sectoral institutions. In the early fifties the Aerospace Technology Centre (CTA) was established, while almost twenty years later, in 1973, the Agricultural Research Enterprise (EMBRAPA) was created. Most public enterprises established their own research centers, like ELETROBRAS' Electrical Energy Research Centre (CEPEL) and the Leopoldo Américo M. de Mello Research and Development Centre (CENPES) run by PETROBRAS (Pacheco, 2003).

innovation on an equal footing with information accessibility. Linearity in innovation persisted, but in a reversed way: the search for innovation was supposed to spur out from firms, which were seen as main technology boosters (Cimoli and Primi, 2003). Along the lines of structural adjustments calling for a *laissez-faire* approach, science and technology policies clearly played a marginal role, and basically focused on horizontal interventions, capacity building, technology transfers, investments in quality and efficiency, and provision of technological services following a logic of “commercialization” of knowledge and technology (Casalet, 2003; Jaramillo, 2003; Pacheco, 2003; Yoguel, 2003).

After a decade of reforms, between the end of the nineties and the beginning of the new millennium, (blinded) faith in market-led (micro) adjustments vacillated; and the leading wind of science and technology policies changed again. The renewed interest in science and technology policies also derived from new technological paradigms, which clearly entail a reshaped vision of science and technology and science-industry links. Countries reorganized the scientific and technological infrastructure, bringing about modifications in the domain and in management styles of existing institutions, and creating new institutional bodies. In Argentina restructuring, principally, aimed at increasing coordination among different bodies and initiatives; in Brazil main reforms concerned the introduction of new mechanisms to finance R&D, based on coordination between the scientific sector and the industrial one, and the design of a coordinated industrial trade and innovation policy. In Colombia, most of the policy discourse has been focused on articulation of national innovation system’s agents, new instruments and institutional bodies have been designed to favor linkages within the system. In Uruguay, as well, science and technology policy re-gained space in government planning, following the lines of the new technological Development Plan, which calls for the creation of new mechanisms to support innovation in domestic firms.

Each country followed a different path; however, the renewed interest in science and technology policies is common to all of them. Beyond countries’ differences, the institutional and political reorganization in the areas of science and technology, especially in the last decade, brought about a general commitment to increase expenditures in R&D, a shifting in priorities from basic research to the provision and commercialization of technological services and a growing interest toward the need for a greater articulation and coordination between private and public sectors and science-industry links. Most schemes and financing mechanisms emphasize articulation and co-participation of supply and demand, establishing incentive schemes to foster cooperation between academies, research labs and firms. These mechanisms range from public financing to support centers of excellence, R&D consortiums, science-parks, as well as tailored capacity building initiatives, like incentives schemes favoring the connection between researchers and firms.

However, these initiatives still have to gain strength as budgets remain low and since practices are not always in accordance with effective needs of firms and universities. In effect, part of the scant result of public policies in this area, alongside reduced budgets, could depend on the asymmetry between the attention to coordination and cooperation on the one hand, and the characteristics of production specialization and scientific research on the other. How is the status of scientific research in universities and research labs in the countries of the region? How strategically planned is the R&D trajectory of firms? What are the determinants of R&D efforts at the firm level? These characteristics may shape the need and the quality of science-industry links beyond public supporting schemes for R&D cooperation.

In general terms, prevailing production and specialization patterns induce firms to express a scant demand for knowledge; at the same time domestic agents mostly seek outward oriented linkages, basically privileging foreign companies and research laboratories that already have sound reputation and worldwide widely recognized experience. At the same time, the scientific sector follows its own logic of research, and practices of cooperation and interchange between the academy and the private sector are quite rare, following usually personal rather than institutional patterns.

In a context where firms do not carry out systematic R&D strategies, where innovation is not yet at the core of firms' competitive behavior, focusing policies mainly on the networking and cooperative perspective may be misleading, if not counter productive. The contemporary discourse on innovation policies seems to be a bit too much biased towards favoring cooperation, coordination and articulation between "science" and "industry", loosing to focus on the need to create the technological and production capacities which would allow cooperation in R&D to be effective.

We are not arguing that policies should follow a liner path from capacity generation to articulation and cooperation; a certain degree of connection and cooperation between science and industry might be determinant, especially in given technological fields, for innovation generation and diffusion; however, countries should avoid embracing any kind of “getting *something* right” recipe. Regional interest in networking and linkages between public and private agents - from the mid of the nineties the word national innovation system entered with plain right into the political debate- echoes the political practices of the north (US, 2006; EU, 2006). However, this is only apparently in line with the policy discourse in developed countries. In more industrialized economies the debate on innovation policies have been focusing on the importance of networks and linkages for innovation for a long time. The role of research partnership was seen as one of the component of a successful innovation and competitive strategy rooted in highly knowledge intensive sectors (Teece, 1989; Metcalfe, 1995; Dosi et al 2005).

In Latin America networking and science-industry links entered the regional debate on the wave of the vanishing of push for structural reforms, in a context characterized by a production structure specialized in natural resources and labor intensive activities and by a strong elite concentration that resists to structural and technical change (Cimoli and Rovira, 2006). The idea of national innovation systems lost its original conception of understating the process of generation and diffusion of innovation as a non-lineal issue, and has been transformed into a sort of simplified blueprint, as “getting the national innovation system right”, which calls for cooperation and change in habits and behaviors, rather than changes in (scientific, technological and production) capacities. Willingness of powerful elites and policy pragmatism transformed the national innovation system concept in a sort of *mantra* for innovation, calling for cooperation and networking as if they were the unique issues for guaranteeing the spur of innovativeness. This simplified version of policy recommendations, also seldom implemented, endorse the common impression that policies do not work. A simple production structure, increasingly fragmented and disarticulated in terms of local capabilities, needs harder policies than a generalized call for cooperation. Disposing of a well-designed and pragmatic technology plan is not a sufficient guarantee of effectiveness in innovation and technological capabilities upgrading. Fostering innovation through science-industry links matters, but is the co-evolution between industrial transformation and technological capabilities that should be constantly searched for.

Microevidence on science-industry links

Cooperation in R&D between universities, research centers and firms is a reality in Latin American countries, at least according to national documents, plans and declared initiatives. But, to what extent science-industry links are relevant in Latin American firm's cooperative behavior? Is there a set of structural characteristics determining the probability of Latin American firms to engage in R&D with universities? Is there a difference between these factors and those affecting science-industry links in more advanced economies? We provide insights to answer to these questions through simple econometric estimations based on micro data from national innovation surveys of the manufacturing sector in Argentina, Brazil, Colombia and Uruguay.

The data

In the case of Argentina we use data from the 2005 National Survey on Innovation and Technology (ENIT), carried out by the National Statistical Office (INDEC). The survey, which is a compulsory one, aims at conveying information regarding technological conduct of manufacturing firms. The sample, which is the same as the one for the Industrial Survey, includes 2'083 firms and it is representative of the whole manufacturing sector in terms of sectoral distribution, size and geographic location. 1'717 firms answered the questionnaire, giving a response rate of 82.5%. The survey includes questions regarding innovation activities, R&D expenditures, and efforts and obstacles to innovation. The survey also gathers information regarding the relationship between different agents, but only indirectly addresses cooperation in R&D. It also includes questions regarding the quality and the training of personnel. With respect to appropriability mechanisms, this survey only allows to check for filed and obtained patents. The survey adopts the definition of innovation of the Bogotá Manual[7], thus opting for a broad definition which includes product, process, organizational and commercialization innovations.

In the case of Brazil we use data from the National Innovation Survey (PINTEC) 2003. The PINTEC, carried out by The National Statistical Office (IBGE), aims at providing relevant information for monitoring innovation activities in Brazilian manufacturing

[7] The Bogotá Manual draws its inspiration from the Oslo Manual and derives from regional efforts to account for specificities in innovation conducts in the countries of the region (RICYT, 2001)

firms. The survey maps innovation activities from 2001 to 2003. The survey measures expenditures in innovative activities, sources of financing, the impact of innovation on sales, and the characteristics of R&D personnel. At the same time, the survey allows to derive information regarding the impact of innovation on firms' performance, the relevance of different information sources, cooperative agreements, obstacles to innovation, appropriability strategies and organizational changes. The Brazilian survey follows the Oslo Manual and aims at being comparable with the Community Innovation Survey. It adopts a strict definition of innovation, i.e. a technological innovation is the introduction of a new or substantially improved product and the adoption of a new or substantially improved process. The survey includes innovative and non-innovative firms. The universe of analysis of the PINTEC 2003 includes all manufacturing firms with 10 or more employees, i.e. approximately 84'262 firms. In 2003, 11'337 firms were sampled and 10'624 answered the interview (94% of response rate). The survey is carried out through in-person interviews for firms with more than 500 employees located in federal districts with more than 15 sampled firms, and computer assisted telephone interview (CATI) in additional cases.

In the case of Colombia we use data from the Second Innovation Survey (EDIT II) implemented by the National Planning Department (DNP, Departamento Nacional de Planeacion), the Colombian Institute for Science and Technology Development (Colciencias) and the National Statistical Institute (DANE). The EDIT II conveys information regarding technological activities in Colombian manufacturing firms for the years 2003 and 2004. The Colombian survey follows the Bogotá Manual and it allows gathering information regarding innovation inputs and outputs and it includes both innovative and non-innovative firms. The survey adopts a broad definition of innovation, distinguishing between product, process, organizational and commercialization innovation, Main survey's questions include: the amount of expenditures in R&D, the identification of major barriers and obstacles to innovation, the principal sources of ideas for innovation, a sort of evaluation of public policy support, the usage of appropriability mechanisms, including patents, industrial designs, utility models and trademarks. At the same time, the survey allows to explore the relationship with external sources of ideas, like the role of participation to exhibitions and congresses and the use of technical or patent databases, as well as the relationship with different kinds of partners in R&D activities. Firms are asked about their engagement in cooperative R&D projects with different partners, like universities, research centers, innovation networks, clients, suppliers and competitors, among others. The Colombian survey is a compulsory one,

%), the questionnaire was sent to 6670 firms, of which 6172 answered the survey (response rate 92.5)[8].

For Uruguay, we use the Second Innovation Survey (Encuesta de Actividades de Innovación en la Industria), which collects information for the years 2001-2003. The survey is carried out by the Directorate for Innovation, Science and Technology for Development (DICyT) and the National Statistical Office (INE). The survey, as the Argentinean and the Colombian one, follows the Bogotá Manual. The definition of innovation is broad, including organizational and commercialization innovations. The survey aims at collecting information on efforts and results of innovation, as well as on issues that influence the environment where innovation takes place. The survey is structured in two main sections; the first one gathers information on innovation activities, financial resources and obstacles for innovation, information and communication technologies, the use of patents, and linkages of firms with other national innovation system's agents. The second section collects general information: kind of economic activity performed, origin of capital, qualification of personnel, location. University students specifically trained by the national Statistical Office carry out the survey through in-person interviews. The universe of analysis comprehends all manufacturing firms with 5 or more employees, approximately 2'910 firms. The sampling method followed a mixed approach: random selection representative for sector of activity for firms with 5 to 19 and 20 to 49 employees and automatic inclusion of firms with more than 50 employees, or with sales above 1,000,000 US$. In the 2001-2003 survey, the sample included 828 firms, of which 814 answered the questionnaire (response rate 98.3%).

Table 1 summarizes distribution of sampled firms in each country according to science-industry links and innovativeness of firms.

[8] The survey sample covers all enterprises with 10 or more employees, but firms of lower size are also included when their sales are sufficiently high. Information regarding sectoral data is classified according to the ISIC rev.3, at four digits and the sample is representative of all the Colombian territory.

Table 1. Science-industry links, overview of sampled firms

		Total Sample	Innovative firms (INNOV = 1)	Non-Innovative firms (INNOV = 0)
Argentina	Number of firms	1399	586 (41.9)	813 (58.1)
	Science coop Number of firms	167 (11.9)	141 (84.4) (24)	26 (15.6) (3.2)
Brazil	Number of firms	10200	4407 (43.2)	5793 (56.8)
	Science coop Number of firms	123 (1.2)	120 (97.6) (2.7)	3 (2.4) (0.05)
Colombia	Number of firms	2490	827 (33.2)	1663 (66.8)
	Science coop Number of firms	39 (1.6)	20 (51.3) (2.4)	19 (48.7) (1.1)
Uruguay	Number of firms	810	398 (49.9)	412 (50.8)
	Science coop Number of firms	30 (3.7)	27 (90) (6.8)	3 (10) (0.7)

Source: Authors' elaboration based on NIS

The model

To estimate the probability of a firm to engage in cooperative R&D projects with universities and public research labs, we use a Probit model, which can be written as follows:

$$P_a(science\_coop_i = 1) = f_a(X_i^{FIR}\beta + X_i^{APP}\delta + X_i^{CTRL}\gamma + \varepsilon_i) \qquad (1)$$

or

$$P_a(science\_coop_i = 0) = 1 - f_a(X_i^{FIR}\beta + X_i^{APP}\delta + X_i^{CTRL}\gamma + \varepsilon_i)$$

where: ($science\_coop_i$) is the dependent variable, P_a denotes the probability that a firm engages in cooperative R&D projects with universities and research labs, i.e. the probability that the dependent variable is equal to 1; f_a is the probit probability distribution function, X_i^{FIR}, X_i^{APP} and X_i^{CTRL} are vectors of independent variables and β, δ and γ the respective vectors of parameters to be estimated, and ε_i the standard errors.

X_i^{FIR} represents a vector of firm specific variables, like age, size, ownership of capital, exports, etc., X_i^{APP} is a vector of different appropriability mechanisms, like patents, trademarks and lead-time advantages, etc; X_i^{CTRL} is a vector of specific control variables, sectoral and regional dummies for industry specific characteristics and geographic location of firms[9].

The literature identifies some standard variables that are assumed to influence the decision of a firm to cooperate: `SIZE`, i.e. the number of employees per firm, `SIZESQUARE`, which accounts for non-linear effects, and `DOMOWNER`, which classifies firms as national or foreign. In addition to these standard firm specific variables, we also consider `AGE`, i.e. the number of years the firm has been active, to test if it affects the probability of a firm to engage in cooperative agreements, `GROUP`, to see if belonging to a group shapes science-industry links and `EXPO`. Normally exports are included as determinants of innovativeness of firms; we expect this variable to be relevant in shaping the probability of a firm to engage in cooperation with universities and R&D labs, since export-orientation might require a more strategic and planned innovation strategy. All surveys include several questions regarding obstacles that firms face to innovate. Among them, we include `COSTOB` and `RISKOB`, which respectively indicates if the firm considers the costs and the risks associated with innovation as major obstacles for its innovative conduct. Variables related with appropriability strategies are also included. The literature on appropriability and cooperative behavior follows quite different stances; however it is acknowledged that appropriability conditions might shape cooperative behavior of firms[10]. The coverage of appropriability mechanisms in Latin American surveys is quite

[9] Table 3 in Appendix gives further details on the set of independent variables included in the exercise.
[10] The relationship between cooperative behavior and appropriability strategy is, indeed, quite controversial and the analysis of these dynamics goes beyond the scope of this paper. Laursen and Salter (2005) find a positive relationship between innovativeness and the use of appropriability mechanisms in the case of UK firms. However, an excessive emphasis on appropriability can affect firms' openness to external sources. Hall, Link and Scott (2000), find that, in the US economy, intellectual property rights inhibit firms from

scant. Only Brazil conveys information regarding different kinds of mechanisms, from patents, to trademarks, trade secrets, lead-time advantages and complexity of produce, other surveys only allow to check for patents, and in some cases utility models, industrial designs and trademarks[11]. Two control variables are included: sectoral dummies to take into account industry specific characteristics and inter-sectoral differences in cooperative conducts and innovation, and a regional dummy to account for localization.

However, the decision to cooperate with the scientific sector is influenced not only by structural characteristics of firms, sectoral specificities and appropriability strategies; it is also shaped, and may on its turn influence, absorptive capacity of firms and it can be complementary or exclusive with respect to the decision of engaging in R&D cooperation with client, suppliers and other kind of non-science partners. In their search for innovation, firms may pursue different strategies inward and outward oriented, of which cooperation with the scientific sector is only one component. It is reasonable to assume that cooperation with universities coexist with other types of innovation strategies. For these reasons we include two additional explanatory variables, ABSOR and MKT_COOP, which can be proxies of alternative-complementary strategies to the decision of cooperating with universities and research centers. Hence, we extend equation (1) to include complementary cooperative choices as specified in equation (2):

$$P_b(science\_coop_i = 1) = f_b(X_i^{FIR}\beta + X_i^{APP}\delta + X_i^{CTRL}\gamma + X_i^{ALT\_COOP}\varphi + \varepsilon_i) \quad (2)$$

f_b is the new probit probability distribution function, P_b is the probability of a firm to cooperate with the scientific sector taking into account all the determinants specified in equation (1), plus a vector $X_i^{ALT\_COOP}$ of alternative or complementary cooperative strategies, which includes ABSOR and MKT_COOP, (where φ are the set of parameters to be estimated).

ABSOR refers to the absorptive capacity of firms. This variable can be a proxy of internal capabilities to innovate and it can reflect the intensity of a firm's reliance on in-house R&D efforts. Following Cohen and Levinthal (1989) we assume that firms are likely to

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partnering in research with universities rather than favoring cooperation. The focus on capturing the rents from innovation can become greater than the benefits of being open to external knowledge.

[11] The debate on appropriability clearly goes beyond the scope of this paper, for the sake of simplicity here it suffices to state that firms may appropriate the returns from R&D efforts through different legal and strategic mechanisms.

take advantage of cooperation and they whish to collaborate with external institutions, once they have autonomous technological capabilities, for which they should have developed an absorptive capacities though in-house R&D expenditures[12]. MKT_COOP refers to possible R&D projects that firms are developing in cooperation with the "market", i.e. clients and suppliers, consultants, specialized technological providers, etc. MKT_COOP represent an alternative (or complementary) strategy with respect to the dependent variable, SCIENCE_COOP, since it accounts for the decision of the firm to carry out joint R&D projects with other firms, clients suppliers and even competitors. Since both ABSOR and MKT_COOP may suffer from endogeneity, we first check for exogeneity and, when the Wald test does not allow rejecting the hypothesis of endogeneity, we proceed to estimate the model using a two-step procedure through instrumental variables.

According to data availability we instrument ABSOR, through three variables: R&D/SALES, EMPL_RD and SOUR_INT. R&D/SALES and EMPL_RD, which is the share of personnel dedicated to R&D with respect to total employment, are standard measures of internal R&D capabilities. SOUR_INT identifies the importance of internal sources of ideas for innovation and it can be used as a proxy of internal capabilities of firms. Following a similar logic, we instrument MKT_COOP with: SOUR_MKT, PERSOB and TECHTRAN. SOUR_MKT refers to the role of clients and suppliers, competitors and consultants as sources of ideas for innovation[13]. PERSOB accounts for the lack of trained personnel as a barrier to innovate and it might indicate the need to outsource R&D. TECHTRAN measures acquisitions of capital and equipment, constituting a proxy for a sort of buy-versus-make, i.e. market-mediated, innovation strategy.

In the estimation of the model we proceed as follows, country by country: first we run a probit regression of equation (1), and then we include the two additional cooperative strategies, we check for exogeneity and then we run a probit on equation (2) following the specification of the instruments for ABSOR and MKT_COOP as stated above.

[12] According to data availability we measure absorptive capacity in each of the countries as specified in table 3 in Appendix.

[13] On average, firms state that the most relevant source of information for innovation are their providers. This depends on the fact that most of their innovation efforts are adaptive in nature and basically consist of technological modernization.

The results

Table 2 summarizes the results for each country, reporting in each first column estimates according to equation (1) and in each second column estimates for equation (2).

Table2. Econometrics results of the model

Dependent variab siencecoop	Argentina		Brazil		Colombia		Uruguay	
age					-0.01 *	-0.01 *	0.009 *	0.008
					(0.006)	(0.006)	(0.005)	(0.005)
size	8.6E-04 **	6.7E-04 ***	2.0E-04 **	1.5E-04 ***	0.003 *	0.003	-0.0007	-0.001
	(0.0002)	(0.0003)	(0.00003)	(0.00004)	(0.002)	(0.002)	(0.001)	(0.001)
sizesquare	-1.9E-07 **	-1.8E-07 **	-5.9E-09 **	-4E-09 ***	-3.9E-06	-4.0E-06	5.9E-07	9.4E-07
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.000)	(0.000)
domowner	0.157	0.224	0.07	0.36 **	0.66 *	0.77 *	0.015	0.06
	(0.15)	(0.16)	(0.11)	(0.15)	(0.42)	(0.46)	(0.28)	(0.30)
group	0.171	-0.062	0.45 **	0.23 *			0.36	0.42 *
	(0.12)	(0.15)	(0.10)	(0.12)			((0.24)	(0.25)
riskob	0.107	0.043	-0.16	-0.16	0.14	0.16	-0.35	-0.26
	(0.10)	(0.11)	(0.15)	(0.16)	(0.18)	(0.18)	(0.33)	(0.37)
costob			0.42 **	0.35 **	-0.12	-0.19		
			(0.15)	(0.16)	(0.17)	(0.21)		
pat	1.035 **	0.889 ***	0.33 **	0.12	0.27	0.19	0.06	-0.42
	(0.28)	(0.30)	(0.11)	(0.12)	(0.28)	(0.29)	(0.53)	(0.61)
trademark			0.21 **	0.06	0.36 **	0.35 **		
			(0.11)	(0.12)	(0.17)	(0.17)		
estrategic			0.32 **	0.18 ***				
			(0.05)	(0.06)				
expor	0.718 **	0.653 ***	0.6 **	0.41 ***	0.35 **	0.36 **	0.58 **	0.34 *
	(0.12)	(0.13)	(0.13)	(0.14)	(0.16)	(0.18)	(0.19)	(0.21)
absorptive		1.061 ***		1.1 ***		0.08 **		1.04 ***
		(0.33)		(0.16)		(0.04)		(0.23)
mktcoo		1.089 ***		0.9 ***		0.91		0.77
		(0.30)		(0.28)		(11.3)		(0.63)
_cons	-2.207 **	-2.371 ***	-3.43 **	-3.84 ***	-2.69 ***	-2.87 ***	-2.1 **	-2.3 ***
	(0.37)	(0.39)	(0.27)	(0.32)	(0.51)	(0.56)	-0.43	(0.47)
	Obs = 1399 Pseudo R2 = 0.14		Obs = 10200 Pseudo R2 = 0.38		Obs = 2490 Pseudo R2 = 0.15		Obs = 809 Pseudo R2 = 0.09	

Sources: INDEC, IBGE, DNP and DICYT
*** significant at 1% level, ** significant at 5 %, * sigfinificant at 10% level.
Standard deviation values in brackets ()

In the case of Argentina the variables that result significant in explaining the probability of a firm to engage in R&D cooperation with the scientific sector are size, size-square, patent and exports. When checking for sectoral heterogeneity, only chemical and pharmaceutical sectors appear as relevant. Localization in main province does not seem to have any effect on the probability to engage in cooperative R&D projects. A possible interpretation is that technological proximity may be more relevant than spatial variables in affecting firms' cooperative behavior. When including alternative cooperative strategies, such as firm's internal capabilities and the cooperation with market partners, the instruments chosen for these variables are adequate, and the estimates lead to the following results: size, size-square, patents and exports are still significant, and the investment in basic R&D (absorptive capacity) and the fact that the firm is engaged in market cooperation appear as relevant in determining the probability of a firm to carry out R&D projects with the scientific sector. This might suggest that different kinds of cooperative R&D are rather complementary than alternative.

In the case of Brazil the probability of a firm to be engaged in cooperative R&D projects with the scientific sector is positively related with the size of the firm (in a non linear way, size-square is significant), it increases when the firm is part of a group and with export-orientation, and is positively correlated with the use of different kinds of appropriability mechanisms (like patents, trademarks, trade secrets, lead-time advantages or complexity of produce). Here again, localization of firm is not relevant, and controlling for sectoral effects, the pharmaceutical sector is the only one that appears as significant. When introducing the relevance of inner R&D capabilities (ABSOR) and the existence of cooperative agreements with market actors (clients, suppliers, competitors, etc.), the set of significant variables changes as follows: the probability of being engaged in cooperative R&D projects with universities and research labs increases with firm size, but in a non-linear way; the fact that a firm belongs to a group, national ownership of capital, export-orientation and the use of strategic appropriability mechanisms positively affect the probability of science-industry links. Investing in basic R&D (ABSOR) and being engaged in cooperative R&D projects with clients, suppliers or other market actors increases the probability of cooperating with universities. These results, suggest that the propensity to cooperate with the scientific sector depends upon the kind of innovation effort that firms pursue, i.e. firms that dedicate more resources to R&D, which pursue complex innovative strategies are those who value and need to cooperate with the scientific sector.

In the case of Colombia, results are slightly different. Younger firms are more likely to cooperate than firms that have been operating for more time; this can be explained by the kind of sectors (and hence innovation activities) in which younger firms are more likely to be specialized. Size, as in the other cases is still relevant, being bigger firms more likely to cooperate than smaller ones. The use of appropriability mechanisms (in this case trademark) and export orientation are also significant. Controlling for sectors does not yield any significant result[14], while instead, firms which are localized in the main province (Bogotá and Cundinamarca) are less likely to be engaged in cooperative R&D projects with the scientific sector; again this result can depend upon the kind of sectoral specialization and it can reaffirm the idea that is not concentration and spatial proximity what determines cooperation. When checking for additional firm' strategies, such as inner R&D capabilities and market cooperation but appear as non significant. However, in the case of R&D capabilities (ABSOR), the variable becomes significant when instrumented. This suggests that the variable, as it is measured in our panel, i.e. considering if the firm carried out R&D for two consecutive years, is not relevant. However, since two of the instruments are significant, SOUR_INT and R&D/SALE, we introduce them directly into the main regression as independent variables. After this correction, the model predicts that younger firms are more likely to be engaged in cooperative R&D projects with universities and research labs; at the same time export-orientation and the use of appropriability mechanisms (trademarks) positively affects the probability of science -industry links.

In the case of Uruguay, the only two significant variables are export orientation and age, which in contrary to the Colombian case, positively affects the probability to cooperate in R&D with universities; i.e. older firms are more likely to cooperate with public research labs. When including additional instrumented cooperative strategies, the probability of a firm to cooperate with the scientific sector is determined by the fact that a firm belongs to a group, by its export orientation and by the fact that it continuously carries out R&D efforts (ABSOR).

To sum up, there are five main considerations that it is worth to single out from the estimations of our model:

i. Size matters. Bigger firms are more likely to engage in R&D projects with universities and research labs, than smaller ones. But this relationship is not

[14] This is mainly because there are too few observations scoring a positive cooperative R&D project with the scientific sector, hence reducing the capacity of the model to capture any significant variations in terms of sectoral distribution; however the sectoral distribution of cooperative agreements in R&D offer interesting results as we will see at the and of this paragraph.

linear, and it is reasonable to expect that beyond a certain threshold firm' size may deter the propensity to cooperate with the scientific sector[15].

ii. Export-oriented firms are likely to cooperate with universities and research labs. This is probably due to the kind of innovative efforts that export-oriented firms carry out, which may be more structured and strategically planned than that of inward oriented firms. As in many of the studies analyzing science-industry links in advanced economies, also in our case the use of appropriability mechanisms appears as a significant determinant of the probability of firms to be engaged in cooperative R&D projects with the scientific sector.

iii. The estimates of our model also suggest some interpretations regarding alternative cooperative agreements. Firms that invest more in basic R&D (i.e. firms with higher absorptive capacity as it is measured in Argentina and Brazil) are more likely to be engaged in cooperative agreements with the scientific sector. It is reasonable to expect that cooperating in R&D with universities and research-labs would require certain level of internal capacities of the firm in order to recognize the value of that kind of cooperation and to be able to profit form it. In addition, the probability of science-industry links is also shaped by the fact that the firm is also participating in joint R&D projects with market agents, such as clients, suppliers, competitors, etc. Hence, different kinds of collaborations in R&D seem to be complementary strategies, rather than alternatives. It is more likely to carry out internal R&D effort and at the same time to simultaneously cooperate with the scientific and or the private sector, than following a unidirectional outsourcing strategy in R&D.

iv. An additional element that we consider relevant to flag is the sectoral dimension of science-industry links. Estimates only signal as significant the chemical and the pharmaceutical sector in the cases of Argentina and Brazil, i.e. firms that are in those sectors are morel likely to carry out cooperative R&D projects with universities. This, of course, depends on the specificities of the innovative search in those sectors. Regressions for Colombia and Uruguay do not yield significant results due to the reduced number of firms that actually carry out R&D

[15] This assumption is confirmed by marginal effects estimations: we obtain positive firs order effects and negative secondary order effects for size in each of the countries.

cooperation with universities; hence, the control for sectoral heterogeneity cannot extrapolate any significant result. However, the sectoral behavior of firms in terms of cooperative R&D with the scientific sector becomes evident once we look at the sectoral distribution of R&D cooperation. Chemicals and pharmaceuticals are the sectors that show, in all of the four cases, the highest relative concentration of science-industry links, followed in general by electronics, machinery and transport equipment (see graph 1 in appendix).

v. It should be noted that results appear more consistent in the cases of Argentina and Brazil, where the incidence of the phenomena object of study is higher, this is a natural consequence of the fact that in the case of Colombia and Uruguay result can suffer from zero-inflation, due to the high concentration of zero values in the panel.

Conclusions

Econometric estimates suggest that the determinants of firms' cooperative behavior in R&D with the scientific sector in Argentina, Brazil and to a lesser extent Colombia and Uruguay, are similar to those of frontier economies. Actually, bigger firms are more likely to engage in joint R&D projects with universities and research labs, even though marginal effect estimates suggest that beyond a certain threshold, increases in firm size may reduce the probability to cooperate with the scientific sector. Export-orientation also positively affects the likelihood of cooperating in R&D with universities, suggesting that export-oriented firms are more likely to have structured R&D strategies that may require cooperation with the scientific sector. Absorptive capacity, i.e. in-house R&D efforts are also critical in shaping science-industry-links, the more firms invest in R&D the more they are likely to be wiling to cooperate with universities. At the same time, cooperation with the scientific sector is usually complementary to cooperation with market agents, suggesting that the decision to cooperate follows a strategic approach to R&D rather than a way to overcoming internal obstacles. With respect to the role of the capacity to appropriate returns form innovation and the propensity to cooperate, the use of appropriability mechanisms appears as a positive determinant of the probability of being engaged in cooperative R&D projects. In the cases of Argentina and Brazil we also obtain significant results controlling for sectors; firms in the pharmaceutical and chemical sectors are more likely to cooperate with universities, than those specializing in less science-based sectors. (It is interesting to remark that ownership of capital does not yeld uniform results across countries).

Our results suggest that science-industry links are shaped by a set of structural characteristics; on the one hand, firms with more structured and complex R&D strategies, which usually are bigger in size, export-oriented, make use of appropriability mechanisms and have a higher propensity to invest in R&D, are those who are more likely to cooperate with universities, on the other hand, it is the kind of technological efforts, i.e. the sector of specialization, that explains the probability of science-industry links. Having said that, it is quite obvious that, given the poor innovation performance and the prevalent specialization pattern, firms in Argentina, Brazil, Colombia and Uruguay rarely engage in cooperative R&D projects with universities and research labs. In general terms, and beyond deep countries differences, firms specialize in traditional sectors that express a scant demand for innovation, they do not prioritize innovation as a main driver towards competitiveness and the latent demand that could pull for technological development is mainly oriented to foreign (market) partners and produce. In addition, firms carry out mostly adaptive technological development, thus reducing the need for cooperating with universities and research labs, which on their turn. are few, suffer from lack of financial resources, and are, generally, disconnected from the private sector.

This backwardness in technological capacities, the evident lack of convergence with respect to frontier economies and persistent inequality are placing a heavy burden on Latin American governments and international institutions leading them to adopt a proactive stance towards development. And, luckily, innovation and technology are too fashionable issues in the "era of the knowledge economy" to be left out from the political discourse. The need for government intervention to support innovation is out of question. A general consensus on the relevance of innovation for development already arose and innovation policy is nowadays an accepted word in the "politically correct" discourse. However, it seems that technology policies are picking the "soft" side of the national innovation system discourse, in order to be compliant with regional elites, which obviously resist to any real change in the *status quo* of the distribution of power and production resources. The renewed interest in science and technology policies have been biased towards "consensus friendly" issues like the need to foster R&D cooperation, networking and science-industry links, prioritizing these issues with respect to favoring increase in R&D expenditures and supporting scientific development.

Let us single out, that we are not calling for a linear approach to science and technology policies, assuming that public intervention should be first focusing on some issues, like fostering private R&D expenditures, and then shifting towards additional policies like those favoring science-industry links. Complex production systems require policies capable of managing complementarities between science and industry to favor the generation and the diffusion of innovative knowledge (Metcalfe, 1995; Cimoli, Dosi, Nelson and Stiglitz, 2006). Our point here is that, networking and cooperation in R&D are crucial, and in new technological paradigms spillovers and linkages between "science" and "industry" are increasingly relevant in the search and generation of innovative knowledge; however, in countries where both universities and firms lack scientific and technological capabilities, policies fostering science-industry links should be accompanied by strong interventions to favor the upgrading in those capabilities.

Complexity and cumulativeness of learning, tacit dimension of knowledge, sectoral specificities of technology, the role of interaction and cooperation among different agents, and of environment and institutions in determining firms' innovative behavior, are all factors that should be taken into account when designing policies to foster technological development (Cimoli and Dosi, 1995). A public agenda focusing primarily on public-private partnership, diverting financing from instruments to increase the (scientific and technological) capacities of those agents, would result in a wobbly strategy. The risk is to end up trapped by a (simplified) innovation *mania*, where everybody is in favor of innovation and technological development, policies foster science-industry links, but science and industry may lack the capacities, capabilities and support to carry out R&D, and hence to cooperate in R&D[16].

In this respect, we consider that evidence from innovation surveys can contribute to the understating of firms' behavior thus conveying relevant information for analysts and policy makers; monitoring what firms are doing, in which direction they are going and which kind of incentives they are facing, is a crucial step to go beyond good intentions in policy design.

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[16] This situation echoes the European paradox in innovation policy described by Dosi, Leren and Labini. (2005).

References

Abramovsky, L., Kremp, E., López, A. and Simpson, H. (2005), Understanding co-operative R&D activity: evidence from four European countries, The Institute for Fiscal Studies, Working Paper 05/23.

Amsden, A. (1989), Asia's Next Giant: South Korea and the Last Industrialization, New York, Oxford University Press

Arora, A. and Gambardella, A. (1994), Evaluating technological information and utilizing it: science knowledge, technological capability and external and external linkages in biotechnology, Journal of Economic Behavior and Organization, 91-114.

Arundel, A. and Hollanders, H. (2005), Policy, indicators and targets: measuring the impacts of innovation policies, European Trend Chard on Innovation, European Union.

Arza, Valeria (2005): “Technological Performance, Economic Performance and Behavior: A Study of Argentinean Firms during the 90s”, Innovation: Management, policy and practice, vol 7, n 2.

Benavente, J. M. (2002), The role of research and innovation in promoting productivity in Chile, Serie Documentos de Trabajo No 200, Departamento de Economía, Universiad de Chile.

Benavente, J. M. (2005), Investigación y desarrollo, innovación y productividad: un análisis econométrico a nivel del a firma, Estudios de Economía, Vol. 32 No , Junio 2005, 39-67.

Berdebos, R., Carree, M., Diederen B., Lokshin B., and Veugelers R. (2004), Heterogeneity in R&D cooperation strategies, International Journal of Industtrial Organization, 22 pp. 1237-1263.

Capdevielle, M., M. Casalet and M. Cimoli (2000), “Sistema de innovación: el caso mexicano”, Proyecto Instituciones y mercados, Comisión Económica para América Latina y el Caribe (CEPAL)/Sociedad Alemana de Cooperación Técnica (GTZ).

Casalet, M., (2003), “Políticas científicas y tecnológicas en México: evaluación e impacto”, FLACSO, sede México.

Chesnais, F. (1986), Some notes on technological cumulativeness, the appropriation of technology and technological progressiveness in concentrated market structures, OECD, Paris.

Chudnovsky, D, Lopez A. And G. Pupato (2006):”Innovation and Productivity in Developing Countries: A study of Argentinean Manufacturing Firms´ behavior”, Research Policy, n35, 2, March, 266-88.

Cimoli M. (2005), Heterogeneidad estructural, asimetrías tecnológicas y crecimiento en América Latina, CEPAL-BID, Santiago de Chile.

Cimoli M. Ferraz, J.C. and Primi, A. (2005), Science and technology policy in open economies: the case of Latin America and the Caribbean, ECLAC, DDPE Series n. 165.

Cimoli, M. (ed), (2000), "Developing innovation system: Mexico in the global context", Continuum-Pinter Publishers, New York-London.

Cimoli, M. and Dosi, G. (1995), Technological paradigms, patterns of learning and development: an introductory roadmap, Journal of Evolutionary Economics, 5, 3.

Cimoli, M. and Primi, A. (2003), Las pol'ticas tecnologicas para la creación y difusióndel conociiento en América Latina y el Caribe, mimeo, DDPE, ECLAC-United Nations, Santiago, Chile.

Cimoli, M., Dosi, G., Nelson, R. R. and Stiglitz. J. (2006),) "Institutions and policies shaping industrial development: An introductory note", LEM Papers Series 2006/02, Laboratory of Economics and Management (LEM), Sant'Anna School of Advanced Studies, Pisa, Italy.

Cimoli, M. and Rovira, S. (2006), Elites, Structural Inertia and Development: Latin American in the post-reform era. Paper presented at the Reading Conference, October, 2006. Reading, UK.

Cohen, W. and Levinthal, D. (1989), Innovation and learning: the two faces of R&D, The Economic Journal, 99, 569-596.

Cohen, W. and Levinthal, D. (1990), Absorptive capacity: a new perspective on learning and innovation, Administrative Science Quarterly, 35, 128-152.

Cohen, W., R. Nelson and J. Walsh, (2002), Links and impacts: the influence of ublic research on industrial R&D, Management Science, 48(1), p.1-23.

Colombo, M.G., and Gerrone, P. (1996), Technological cooperative agreements and firm's R&D intensity, A not causality relations, Research Policy, September 1996, 25 (6), pp. 923-932.

Crépon, B., Duguet, E. and Mairesse, J. (1998), Research, innovation and productivity: an econometric analysis at the firm level, National Bureau of Economic Research, working paper 6696.

Crespi, G. and Patel, P. (2006), Innovation and competition: the sector level evidence, Europe Innova, forthcoming.

Dasgupta, P. and P. David (1994). "Toward a New Economics of Science." Research Policy 23(5): 487 – 521.

De Negri, J.A., Salerno, M.S. and Barros de Castro, A. (2005), "Innovacoa, patrones tecnológicos e desempenho das firmas industriais brasileiras, in Innovacoa, Patrones Tecnológicos e Desempenho das Firmas Industriais Brasileiras, IPEA, pp. 5-46.

DNP-Colciencias (2006), Visión Colombia II centenario: fundamentar el crecimiento y el desarrollo social en la ciencia, la tecnología y la innovación, Bogotá, Colombia.

Dosi, G. (1982), Technological paradigms and technological trajectories: a suggested interpretation of the determinants and directions of technical change, Research Policy 11, 147-162.

Dosi, G. (1988), Sources, procedures and microeconomic effects of innovation, Journal of Economic Literature, XXVI, 3, 1120-71.

Dosi, G., Llerena, P. and Sylos Labini, M. (2005), Evaluating and comparing the innovation performance of the United States and the European Union, Expert Report, European Trend Chart on Innovation.

ECLAC (Economic Commission for Latin America and the Caribbean) (2002), Globalization and development (LC/G.2157(SES.29/3)), document prepared for the Twenty-ninth session of ECLAC (Brasilia, Brazil, 6-10 May), Santiago, Chile.

EU (2006), Putting knowledge into practice: A broad-based innovation strategy for the EU, COM(2006) 502 final, COMMISSION OF THE EUROPEAN COMMUNITIES, Brussels, 13.9.2006.

Freeman, C. (1982), The economics of industrial innovation, second ed. Pinter (first ed. Penguin, 1974).

Freeman, C. (1987), Technology policy and economic performance: lessons form Japan, Pinter, London.

Freeman, C. (1991), Networks and innovators: a synthesis of research issues, Research Policy, 499-514.

Freeman, C. and Soete, L. (1997), The economics of industrial innovation, Pinter, London.

Hall, B. H., Link, A. N., Scott, J. T. (2000), Barriers inhibiting industry from partnering with universities: evidence from the advances technology program, University of California, Berkeley.

Jaramillo Salazar, H. (2003), “Políticas científicas y tecnológicas en Colombia: evaluación e impacto durante la década de los noventa”, Trabajo realizado para la CEPAL, Bogotá, Colombia.

Kim, L. (1997), Imitation to Innovation: The Dynamics of Korea's Technological Learning, Boston: Harvard Business School Press.

Kim, L. (1993), National System of Industrial Innovation: Dynamics of Capability Building in Korea, in Richard R. Nelson (comp.), National InnovationSystems: A Comparative Analysis, Nueva York: Oxford University Press, pg.. 357-383.

Kim, L. (2000), Korea’s National Innovation System in Transition, in Linsu Kim y Richard Nelson (comps.), Technology, Learning and Innovation: The Experiences of Newly Industrialising Economies, Cambridge University Press. Cambridge, UK.

Klevorick, A. C., Levin, R. C., Nelson, R.R: and Winter, S. G. (1995), On the sources and significance of interindustry differences in technological opportunities, Research Policy 24, 185-205.

Kline, S.J. and Rosemberg, N. (1986), An overview of innovation, in R. Lindau and N. Rosemberg (eds.), The positive sum strategy, harnessing technology for economic growth, National Academy Press, Washington D.C.

Knell, M. and Srholec, M. (2005), Innovation cooperation and foreign ownership in the Czech Republic, NIFU-STEP.

Kuramoto, J. and Torero, M. (2004), Public/private research and development and innovativeness in Peru: an overview relative to other Latin American countries, Group of Analysis for Development – GRADE, Lima, 2004.

Laursen, K. and Salter, A. (2005), The paradox of openness: appropriability and the use of external sources of knowledge for innovation, Druid.

Levin, R.C. and Reiss, P.C. (1984), Test of a Schumpeterian model of R&D and market structure, in Z. Griliches (ed.), R&D, patents, and productivity, Chicago, University of Chicago Press, 1984.

Lööf, H., Heshmati, R., Asplund, S. and Nääs, S. (2001), Innovation and performance in manufacturing industries: a comparison of the Nordic countries, SSE/EFI, Working Paper Series in Economic and Finance 457.

López, A.and Orliki, E. (2006), Innovación y mecanismos de apropriabilidad en el sector privado en América Latina,, forthcoming, ECLAC- WIPO.

Mansfield, E. (1991), Academic research and Innovation, Research Policy, 20, 1-12.

Metcalfe, S. (1995), The economic foundations of technological policy, in Stoneman, P. (ed.), Handbook of the economics of innovation and technical change, Blackwell, Oxford.

Mowery, D. C. Nelson, R. R., Sampat, B. N. and Ziedonis, A. A. (2004), The ivory tower and industrial innovation: university industry technology transfer before and after the Bayh Dole Act, Standford Univerity Press, California.

Nelson, R. R. (1959), The simple economics of basic scientific research, Journal of Political Economy, 67(2), 297-306.

Nelson, R. R. (1993), National Innovation Systems: a comparative analysis, Oxford University Press.

Nelson, R. R. and Winter, S. (1982), An evolutionary theory of economic change, Belknap Press, Harward University Press.

Nelson, Richard y Rosenberg, Nathan (1993): Technical Innovation and National Systems, en Nelson, Richard (ed.) National Innovation System - A Comparative Analysis, Oxford University Press.

Pacheco, C. (2003), “As reformas da Política Nacional de Ciência Tecnologia e inovaçao no Brasil, 1999-2002”, Trabajo realizado para la CEPAL, Campinas, Brasil.

Pack, H. and Westphal, L. E (1986), Industrial Strategy and Technological Change, Journal of Development Economies, 4, 205-237.

Pavitt, K. (1984), Sectoral pattern of technical change: towards a taxonomy and a theory, Research Policy 13 (6) pp. 353-373.

Pavitt, K. (1991), What makes basic research economically useful? Research Policy, 20, 109-119.

Pisano, G. (2006), Science business: the promise, the reality and the future of biotech, Harvard Business School

Polanyi, M. (1967), The tacit dimension, Garden city, NY: Doubleday Anchor, 1967.

Reinhardt, N. and Peres, W. (2000), “Latin America’s new economic model: micro responses and economic restructuring”, World Development, 28(9).

RICYT (2001), Standarization of indicators of technological innovation in Latina American and Caribbean countries, Bogotá Manual, Red de Indicadores de Ciencia y Tecnología, RICYT.

RICYT (2004), El Estado de la Ciencia Principales Indicadores de Ciencia y Tecnología Iberoamericanos –Interamericanos, Buenos Aires.

Rosenberg, N. (1982), Inside the black box: technology and economics, Cambridge University Press.

Schumpeter, J. (1912), Theory of Economic Development, Originally published in german as Theories der Wirtschaflichen, Entwicklung, 1912.

Schumpeter, J. (1942), Capitalism, Socialism and Democracy, Harper, New York.

Teece, D. (1989), Strategic technology and public policy, Selected papers, Edward Elgar, London.

Tigre, P., Cassiolato, J. E., De Souza Szapiro, M. H. and Ferraz, J. C., (2000), “Câmbio estructural e sistemas nacionales de inovação: O caso Brasileiro”, Proyecto Instituciones y mercados, Comisión Económica para América Latina y el Caribe (CEPAL)/Sociedad Alemana de Cooperación Técnica (GTZ).

US, Domestic Policy Council, (2006), American Competitiveness Initiative, Office of Science and Technology Policy, US.

Veugelers, R. (1997), Internal R&D expenditures and external technology sourcing, Research Policy, October 1997, 26 (3), pp. 303-315.

Veugelers, R. and Cassiman, B. (1999), Make and buy in innovation strategies: evidence from Belgian manufacturing firms, Research Policy, 28, 63-80

Veugelers, R. and Cassiman, B. (2005), R&D cooperation between firms and universities, some empirical evidence from Belgian manufacturing, International Journal of Industrial Organization, 23, 355-379

Viotti, E. and Baessa, A. (2006), Innovação na indústria brasileira, Argentina e de países Europeus: una comparação de resultados de surveys de innovação, Universidade de Brasilia, forthcoming.

Wooldridge, J.M. (2001), Econometric Analysis of Cross Section and Panel Data, MIT Press, Cambridge.

Yoguel, G. (2003), “La política científica y tecnológica argentina en las últimas décadas: algunas consideraciones desde la perspectiva del desarrollo de procesos de aprendizaje”, Trabajo realizado para la CEPAL, Buenos Aires, Argentina.

Appendix

Table 3. Definition of Variables Used in the Model

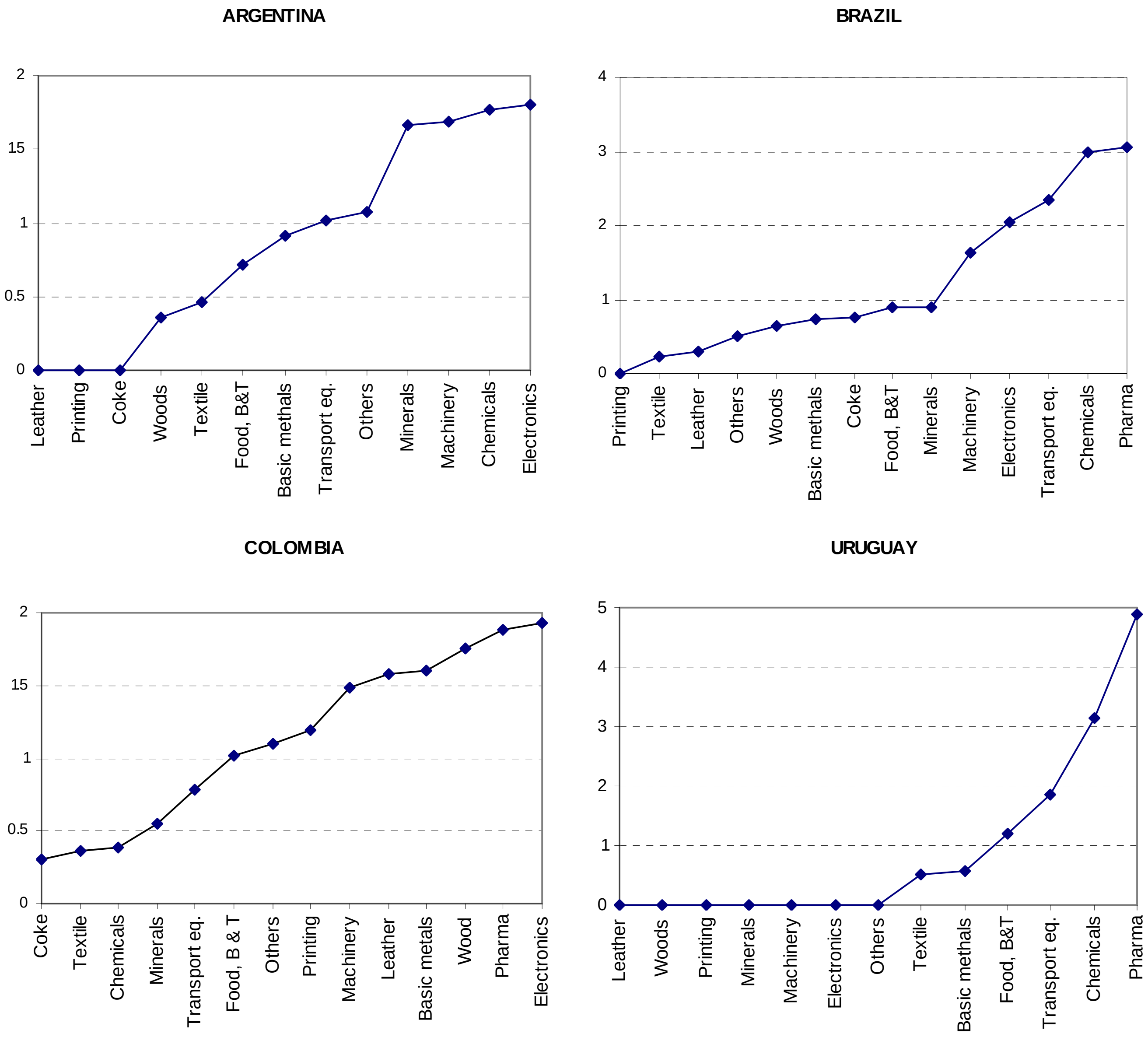
Variable	Country	Definition
science_coop	Argentina	Since there is no direct question regarding R&D science-industry link, we assing value 1, if the firm declared to spend in R&D and to be engaged in cooperation with unviersities, research labs or public innovation netowrks, 0 otherwise
	Brazil Colombia Uruguay	1, if the firm has been engaged in cooperative R&D projects with universities, research labs, or public innovation netowrks, 0 otherwise
Firm Specific Variables		
AGE		Number of years since the firm is actively operating. Not available for Argentina and Brazil
SIZE		Number of employees
SIZE_square		Square of the number of employees to account for non-linear effects
DOMOWN	Argentina Colombia Uruguay	1, if the origin of capital is national, or if national capital accounts for 10% or more of total capital.
	Brazil	1, if the origin of capital is national or when shareholder is national or the "majority shareholder" is national, 0 otherwise
GROUP		1, if the firm belongs to a group, 0 otherwise. Not available for Colombia
COSTOB		1, if the firm declared costs to be important or very important obstacles to innovate, 0 otherwise. Not available for Argentina and Uruguay.
RISKOB		1, if the firm declared risks to be important or very important obstacles to innovate, 0 otherwise
EXPO		1, if the firm exports, 0 otherwise
Approriability strategy variables		
PAT	Argentina Uruguay	1, if the firm obtained at least one patent between 2001 and 2003, 0 otherwise
	Brazil	1, if the firm obtained at least one patent, or utilitly model, or industrial desing, between 2001 and 2003, 0 otherwise
	Colombia	1, if the firm obtained at least one patent between 1996 and 2004, or one utility model or an industrial design between 2003 and 2004, 0 otherwise
TM	Argentina	Not available
	Brazil	1, if the firm registered at least one trademark between 2001 and 2003, 0 otherwise
	Colombia	1 if the firm registered at least one trademark in 2003 or 2004, 0 otherwise
	Uruguay	Not available
STRAT	Brazil	1, if the firm declared to have been using trade secret, lead-time or complexity as appropriability mechanisms, 0 otherwise
Control Variables		
SECTOR	Argentina	13 sectoral dummies, according to ISIC classification
	Brazil	15 sectoral dumimies, according to ISIC classification
	Colombia	14 sectoral dummies, accoridng to the ISIC classification
	Uruguay	13 sectoral dummies, according to ISIC classification
REGION	Argentina	1, if the firm belongs to the province of Buenos Aires, 0

		otherwise
	Brazil	1, if the firm is located in Sotuh-East region (São Paulo, Rio de Janieiro, Espiritu Santo and Minas Gerais), 0 otherwise
	Colombia	1, if the firm is located in the Bogotá or Cundinamarca region, 0 otherwise
	Uruguay	1, if the firm is located in the Montevideo Department, 0 otherwise
Additional Cooperation variables		
ABSOR	Argentina	1, if the firm declares to carry out basic R&D, 0 otherwise
	Brazil	1, if the firm declares to carry out basic R&D, 0 otherwise
	Colombia	1, if the firm declares to carry out R&D both in 2003 and 2004, 0 otherwise
	Uruguay	1, if the firm declares to carry out R&D on a continuous basis, 0 othrwise
MKT_coop	Argentina	Since there is no direct question regarding R&D cooperation we assing value 1, if the firm declared to spend in R&D and to be engaged in cooperation with clients, suppliers, competidors and other firms, 0 otherwise
	Brazil Colombia Uruguay	1, if the firm declares to cooperate in R&D with clients, suppliers, competidors and other firms, 0 otherwise
Instrumental variables for ABSOR		
R&D/sales		Expenditures in R&D over total sales
Employment_R&D		Number of R&D personnel over total employment
SOUR_INT		1, if the firm value internal sources of information as important or very important for innovation, 0 otherwise. Not available for Argentina.
Instrumental Variables for MKT_coop		
SOUR_MKT		1, if the firm value market sources of information (i.e. clients, suppliers, competidors and other firms) as important or very important for innovation, 0 otherwise
PERSOB		1, if the firm declares personnel to be an important or very important obstacle to innovate, 0 otherwise
TECHTRAN		1, if the firm declares to acquire capital goods and equipment, 0 otherwise

Table 4. Descriptive statistics of Innovation Surveys by cooperative behavior

	Argentina		Brasil		Colombia		Uruguay	
	Coop = 1	Coop = 0	Coop = 1	Coop = 0	Coop = 1	Coop = 0	Coop = 1	Coop = 0
Age	-	-	-	-	21.3	22.5	35.6	28.3
Size	376.9	206.1	2294.2	240.4	123.5	129.4	151.9	69.5
Domowner	0.81	0.88	0.67	0.92	0.97	0.91	0.83	0.91
Group	0.35	0.22	0.53	0.90	-	-	0.30	0.31
R&D/Sales	0.86	0.17	0.46	0.42	2.04	1.19	1.09	2.04
Empl in R&D	2.57	0.46	5.94	0.93	0.27	0.42	7.38	0.12
X	0.87	0.52	0.34	0.34	0.49	0.30	0.73	0.39
Patents	6.6	1.1	35.1	2.9	10.3	4.4	3.3	2.3
Trademark			51.7	9.8	33.3	18.5		
Strategic			56.6	6.8				

Graph 1. Sectoral Cooperative Intensity Index within countries



Source: Authors' elaboration from National Innovation Surveys

Note: The graphs portrays the sectoral cooperative intensity index (SCII) defined as folloews:

$$\text{SCII} = \frac{X_i / \sum_i X_i}{Y_i / \sum_i Y_i}$$

being X_i the number of firms with cooperative agreements in the *i-th* sector and Y_i the number of firms in the same sector.

Table 5. Sectoral cooperative behavior within countries

			ARGENTINA	
	SCIENCE-INDUSTRY LINKS	**TOTAL**	**Innovative (INNOV = 1)**	**Non Innovative (INNOV = 0)**
	(% of firms engaged in R&D projects with universities, R&D labs and innovation networks in each sector)	11.9	24	3.2
D.1	Manufacture of food products, beverage and tobacco	9.8	4.1	0.6
D.2	Manufacture of textile and textile products	5.2	1.2	0.2
D.3	Manufacture of leather and leather products	18.4	0.9	0.2
D.4	Manufacture of wood and wood products (except furniture) and pulp, paper and paper products	6.8	0.9	0.0
D.5	Publishing, printing and recorded media	0.0	0.0	0.0
D.6	Manufacture of coke, refined petroleum products and nuclear fuel and of rubber and plastic products	8.3	0.2	0.0
D.7	Manufacture of chemicals and chemicals products (except pharmaceuticals)	26.1	5.1	0.6
D.8	Manufacture of pharmaceuticals, medicinal chemicals and botanical products	-	-	-
D.9	Manufacture of other non-metallic mineral products	15.4	3.1	0.5
D.10	Manufacture of basic metals and fabricated metal products (except machinery and equipment)	10.3	1.9	0.1
D.11	Manufacture of machinery and equipment n.e.c.	17.6	3.2	0.4
D.12	Manufacture of electrical and optical equipment	15.9	2.2	0.1
D.13	Manufacture of transport equipment	10.3	1.0	0.2
D.14	Manufacturing n.e.c	6.1	0.3	0.1

	BRAZIL			
	SCIENCE-INDUSTRY LINKS (% of firms engaged in R&D projects with universities, R&D labs and innovation networks in each sector)	**TOTAL** 1.21	**Innovative (INNOV = 1)** 2.73	**Non Innovative (INNOV = 0)** 0.05
D.1	Manufacture of food products, beverage and tobacco	0.16	0.36	0.00
D.2	Manufacture of textile and textile products	0.04	0.09	0.00
D.3	Manufacture of leather and leather products	0.02	0.02	0.02
D.4	Manufacture of wood and wood products (except furniture) and pulp, paper and paper products	0.06	0.14	0.00
D.5	Publishing, printing and recorded media	0.00	0.00	0.00
D.6	Manufacture of coke, refined petroleum products and nuclear fuel and of rubber and plastic products	0.01	0.02	0.00
D.7	Manufacture of chemicals and chemicals products (except pharmaceuticals)	0.17	0.36	0.02
D.8	Manufacture of pharmaceuticals, medicinal chemicals and botanical products	0.06	0.14	0.00
D.9	Manufacure of rubber and plastics products	0.04	0.09	0.00
D.10	Manufacture of other non-metallic mineral products	0.10	0.23	0.00
D.11	Manufacture of basic metals and fabricated metal products (except machinery and equipment)	0.09	0.20	0.00
D.12	Manufacture of machinery and equipment n.e.c.	0.11	0.25	0.00
D.13	Manufacture of electrical and optical equipment	0.19	0.43	0.00
D.14	Manufacture of transport equipment	0.14	0.29	0.02
D.15	Manufacturing n.e.c	0.04	0.09	0.00

	SCIENCE-INDUSTRY LINKS (% of firms engaged in R&D projects with universities, R&D labs and innovation networks in each sector)	TOTAL	COLOMBIA Innovative (INNOV = 1)	Non Innovative (INNOV = 0)
D.1	Manufacture of food products, beverage and tobacco	1.6	2.3	1.2
D.2	Manufacture of textile and textile products	0.6	1	0.4
D.3	Manufacture of leather and leather products	2.5	5.6	1.2
D.4	Manufacture of wood and wood products (except furniture) and pulp, paper and paper products	2.8	2.6	2.8
D.5	Publishing, printing and recorded media	1.9	4.7	0.8
D.6	Manufacture of coke, refined petroleum products and nuclear fuel and of rubber and plastic products	0.5	0	0.7
D.7	Manufacture of chemicals and chemicals products (except pharmaceuticals)	0.6	1.6	0
D.8	Manufacture of pharmaceuticals, medicinal chemicals and botanical products	2.9	3.2	2.7
D.9	Manufacture of other non-metallic mineral products	0.9	0	1.4
D.10	Manufacture of basic metals and fabricated metal products (except machinery and equipment)	2.5	3.6	2.1
D.11	Manufacture of machinery and equipment n.e.c.	2.3	2.5	2.2
D.12	Manufacture of electrical and optical equipment	3.0	4.8	1.8
D.13	Manufacture of transport equipment	1.2	2.6	0
D.14	Manufacturing n.e.c	1.7	4.3	0.8

	URUGUAY			
	SCIENCE-INDUSTRY LINKS	**TOTAL**	**Innovative (INNOV = 1)**	**Non Innovative (INNOV = 0)**
	(% of firms engaged in R&D projects with universities, R&D labs and innovation networks in each sector)	3.7	6.8	0.7
D.1	Manufacture of food products, beverage and tobacco	1.48	2.5	0.5
D.2	Manufacture of textile and textile products	0.2	0.5	0.0
D.3	Manufacture of leather and leather products	0.0	0.0	0.0
D.4	Manufacture of wood and wood products (except furniture) and pulp, paper and paper products	0.0	0.0	0.0
D.5	Publishing, printing and recorded media	0.0	0.0	0.0
D.6	Manufacture of coke, refined petroleum products and nuclear fuel and of rubber and plastic products			
D.7	Manufacture of chemicals and chemicals products (except pharmaceuticals)	0.9	1.8	0.0
D.8	Manufacture of pharmaceuticals, medicinal chemicals and botanical products	0.7	1.3	0.2
D.9	Manufacture of other non-metallic mineral products	0.0	0.0	0.0
D.10	Manufacture of basic metals and fabricated metal products (except machinery and equipment)	0.1	0.3	0.0
D.11	Manufacture of machinery and equipment n.e.c.	0.0	0.0	0.0
D.12	Manufacture of electrical and optical equipment	0.0	0.0	0.0
D.13	Manufacture of transport equipment	0.2	0.5	0.0
D.14	Manufacturing n.e.c	0.0	0.0	0.0