Academy-Industry interactions at three different stages of the linking process: Micro evidence from the perspective of both agents

Dr Gabriela **Dutrénit**[1]
Dr Claudia **De Fuentes**[2]

Abstract

Academy-industry linkages can play an important role for economic development. Both agents can benefit from interaction, but they have a different perspective regarding the reasons to interact, the main knowledge flows and the benefits derived from the interaction. The main aim of this paper is to analyze these interactions from both perspectives during three different stages of the linking process: i) main reasons to interact; ii) knowledge flows during the interaction; and iii) main results derived from interaction. This study is based on original data collected by two surveys carried out in Mexico during 2008, to R&D and product development managers of firms and to academic researchers; 341 innovative firms and 451 academic researchers answered the questionnaire.[3] We performed descriptive statistics and multivariate analysis techniques to analyze the data. Main characteristics of academy-industry in Mexico are: academy is not the main but an important source of knowledge for firms; human resources mobility is an important knowledge flow mechanism from firms´ perspective; academy-industry interaction is more intense for 'radical innovation' than for incremental innovation; and researchers oriented to applied science and technological development are those who interact more with firms, but basic science researchers also interact. Concerning to the stages of the linking process, for the first stage we found that firms' main reasons to interact are to increase their basic/intermediate technological capabilities and to complement them. The main barrier to interaction from both perspectives is the lack of knowledge of each one of the agents regarding the activities of the other. An additional barrier for firms is their belief that they have enough in-house capabilities, which may reveal a limited concern to absorb external knowledge. For the second stage, we found that researchers and firms have different perspectives regarding the importance of knowledge flows; firms value more knowledge flows from human resources, while researchers find more important collaborative R&D and consultancy as knowledge flows mechanisms. For the third stage, we identified the main benefits from interaction analyzing both perspectives, even though the interactions are not broadly spread in Mexico, those researchers and firms engaged in collaboration categorize them as successful, benefiting from the use of installations, publications, prototypes, etc. However, differences in the perception of benefits from both agents limit interactions and thus the possibility to initiate virtuous circles in the production and diffusion of knowledge.

[1] Professor of the Master and PhD programs in Economics and Management of Innovation, Universidad Autónoma Metropolitana-Xochimilco, Mexico City, Calzada del Hueso 1100, col. Villa Quietud Coyoacán, CP 04960, Fax (5255) 5483 7235. gdutrenit@laneta.apc.org; Visiting felllow at UNU-MERIT.

[2] Postdoctoral Fellow at the Master and PhD programs in Economics and Management of Innovation, Universidad Autónoma Metropolitana-Xochimilco, Mexico City, Calzada del Hueso 1100, col. Villa Quietud Coyoacán, CP 04960, Fax (5255) 5483 7235. Postdoctoral Fellow University of Ottawa, Faculty of Social Sciences, Department of Economics.

[3] This study is based on an international research project sponsored by the IDRC (Canada). The main objective of the project is to identify new forms of Academy-industry interaction, analyze differences according to countries' level of development and propose policies to strengthen collaboration. Twelve countries from Latin America, Asia and Africa are participating within the framework of this project, which is part of the "Catching up project".

1 *Introduction*

The role of universities and public research centres (PRC), hereafter academy, is evolving along time, from the formation of human resources and knowledge generation to a more oriented focus to solving problems and attending social needs. Interactions between academy and industry are increasing in many developing countries; they shape the formation of human resources and are a source of ideas for basic and applied research; both activities can promote economic and social development.

The modes of academy-industry interaction vary across sectors (Cohen, Nelson and Walsh, 2002) and there are differences according to countries' development level (Arocena and Sutz, 2005). In many developing countries, such as Mexico, those interactions are not as common to strengthen the National System of Innovation (NSI) (Cimoli 2000; FCCT 2006; Lorentzen 2009; Cassiolato, Lastres and Maciel, 2003; Lall and Pietrobelli, 2002; Muchie, Gammeltoft and Lundvall, 2003; Oyelaran-Oyeyinka, 2006). On one hand, firms do not see academy as a primary source of knowledge or as a primary partner for innovation activities, on the other, academic researchers are more likely to generate basic research than technology development and interact with the industry.

Even though there is an increasing literature regarding academy-industry interactions, most of the studies focus either on academy (Melin, 2000; Bozeman and Corley, 2004) or on firms perspective (Laursen and Salter, 2004; Hanel and St-Pierre, 2006; Fontana, Geuna and Matt, 2006; Mathews and Mei-Chih, 2007; Ayadi, Rahmouni and Yildizoglu, 2009) and analyse interactions from one agent perception. Few studies have tackled the analysis of interactions from both perspectives (Carayol, 2004; Bekkers and Bodas Freitas, 2008; Bittencourt, *et al*, 2008; and Intarakumnerd and Schiller, 2008), but they have not explored the specificities of the three stages of the linking process. This paper built on the previous literature to analyze academy-industry interactions from both perspectives and discuss differences in the nature of their interactions across the three stages of the linking process: main reasons to interact, knowledge flows during the interaction, and results derived from interaction.

This study is based on original data collected by two surveys to analyze academy-industry interactions carried out in Mexico during 2008. One focuses on R&D and product development managers of firms and the other on researchers at universities/public research centres (PRC); 387 firms and 461 academic researchers answered the questionnaire. For the specific aim of this study we focused on 341 innovative firms and 451 researchers. We performed descriptive statistics, two regression models and multivariate analysis techniques to analyze the data.

This paper is divided as follows; after this introduction, the second section reviews different bodies of literature that approach the issues discussed here. Section three describes the strategy for data gathering and methodology of analysis. Section four presents and discusses the empirical evidence. Finally section five concludes.

2 *Conceptual framework: Academy-industry interactions*

It is broadly recognized the role that academy-industry interactions play to develop a strong NSI, as it can promote virtuous circles in the production and diffusion of knowledge (Albuquerque et al, 2008). Rosenberg and Nelson (1994) found that such circles are sector dependent and can be more critical in some sectors and knowledge fields. They found that universities played a critical role in chemical engineering, aeronautical engineering, computer engineering and biotechnology. Several studies have approached these interactions from different bodies of literature focusing on different issues and using different unit of analysis.

Most of the studies analyze such interactions from the firms´ perspective (Laursen and Salter, 2004; Hanel and St-Pierre, 2006; Fontana, Geuna and Matt, 2006) using available data from the National Innovation Surveys. Other studies, which are based on *ad hoc* surveys, analyze interactions focusing on academics´ perspective (Melin, 2000; Bozeman and Corley, 2004) and some few analyze both sides of the interaction (Carayol, 2004; Bekkers and Bodas Freitas, 2008; Bittencourt *et al*, 2008; and Intarakumnerd and Schiller, 2008).

We have conceptualized academy-industry interactions at three different stages of the linking process: main reasons to interact, knowledge flows during the interaction, and results derived from interaction. Different studies have made important contributions to each one of these stages individually; the most important for our analysis are reviewed below.

2.1 *Why do academy and firms collaborate?*

It is widely recognized that academy-industry interactions represent an important driver for innovation and technology development (Cohen, Nelson and Walsh, 2002). Some authors argue that interactions change as the country develops, and reflect a co-evolution of factors (Mowery and Sampat, 2005; Albuquerque *et al*, 2008), which depend on the context, incentives structure and agents' specificities, particularly their absorptive capacities and embedded culture. Worldwide, and also in developing countries, innovation policy has recently focused on fostering academy-industry interactions, without clearly recognising that both agents respond to different incentives, academic researchers function within an academic logic, while firms' depend on business logic. In fact, academy and firms collaborate for different reasons. On one hand, academy can get different sources of founding and new ideas for research, and interactions can increase the mobility of researchers and knowledge production and diffusion; on the other hand, firms interact with academy to identify potential employees and access sources of knowledge, which can lead to important industrial applications (Hanel and St-Pierre, 2006). In this sense, differences between both perspectives are important to understand the evolution of academy-industry interactions and promote specific policies to strengthen such interactions.

Some works use National Innovation Surveys to analyze main drivers of interaction from the firms´ perspective (Laursen and Salter, 2004; Hanel and St-Pierre, 2006; Arza and López, 2008; Eom and Lee, 2008). Based on UK firms, Laursen and Salter (2004) argue that management factors, such as firms´ strategy to rely on different types of knowledge sources, and structural factors, such as R&D intensity, firm size, and industrial environment, are important drivers to collaborate and get the benefits from academy. Hanel and St-Pierre (2006) analyze the probability of Canadian firms to collaborate with Universities, and found that industrial sector, firms' size, engagement in R&D, and location are determinants for interaction. Arza and López (2008) found that Argentinean firms interact with academy to contribute to their innovative activities and to recruit students, but they couldn't find evidence that firms´ knowledge base is an important driver for collaboration. They also analyzed the barriers for interaction at firm level, identifying the lack of information about how academy can contribute to the innovative activities of firms as the most important one.

Based on *ad hoc* surveys other works have focused their analysis on collaboration drivers from the firms´ perspective (Cohen, Nelson and Walsh, 2002; Giuliani and Arza, 2009). Cohen, Nelson and Walsh (2002) performed a cross-sectoral analysis and found that firms interact with academy to generate new ideas and complete existing projects. Giuliani and Arza (2009) compare academy-industry linkages in the wine sector in two different countries, focusing on both sides of the linkages. They found that knowledge bases are an important determinant for interaction. They also found that scientific quality of university departments and firms´ experimentation intensity can be an important driver for interaction regarding the context specificities.[4] They conclude that some linkages are more valuable than others and some linkages are more selective in terms of knowledge specificities.

The Mexican case suggests the existence of two main types of reasons to be engaged in collaboration for firms: to increase firms´ technological capabilities and to complement them. These capabilities are largely basic/intermediate technological capabilities, with weak absorptive capacity of external knowledge.

2.2 *Which is the main knowledge flows from interaction?*

Moving forward in the linking process, during academy-industry interaction knowledge flows may occur in both directions, benefiting both agents and creating a virtual cycle in the production of knowledge. However, most of the studies focus on knowledge flows from academy to industry, analyzing either the academy or industry perspectives (Narin, et al, 1997; Swann, 2002; Cohen, Nelson and Walsh, 2002; Laursen and Salter, 2004; Mowery and Sampat, 2005; Fontana, Geuna and Matt, 2006; Intarakumnerd and Schiller, 2008; Bekkers and Bodas Freitas, 2008). The most frequently recognized are: human resources mobility -students and academics; networking; information diffusion in journals, reports, conferences and Internet; training and consultancy; collaborative R&D projects; incubators; property rights; and spin offs (Cohen, Nelson and Walsh, 2002; Narin et al, 1997; Bekkers and Bodas Freitas, 2008; Intarakumnerd and Schiller, 2008). Mowery and Sampat (2005) assert that human resources mobility can be a powerful mechanism for the diffusion of scientific research and can strengthen the links between the academic research agenda and the society needs.

From the industry perspective, some authors argue that information diffusion, property rights, human resources, collaborative R&D projects, and networking are the most important channels of knowledge flows (Swann, 2002; Cohen, Nelson and Walsh, 2002; Narin, et al, 1997). From the academic perspective, Meyer-Krahmer and Schmoch (1998) found that the most important knowledge flows from the industry in four fields come through collaborative R&D. Albuquerque et al (2008) identified that for Brazilian researchers the most important knowledge flows are collaborative research, information diffusion, networking and training, which are related to the main roles of university.

Several studies go further into the analysis and show that knowledge flows are sector and technology specific (Cohen, Nelson and Walsh, 2002; Laursen and Salter, 2004; Mowery and Sampat, 2005; Hanel and St-Pierre, 2006; Fontana, Geuna and Matt, 2006; Arza and López, 2008; Intarakumnerd and Schiller, 2008); as different sectors have different knowledge bases and innovation patterns (Pavitt, 1984), they also have different ways to interact with the academy and other sources of knowledge. For biotechnology and pharmaceuticals, Cohen, Nelson and Walsh (2002) found that knowledge transfer by publications is more important. For chemical, different knowledge flows are found important, such as patents (Levin, 1988), collaborative research and human resources mobility (Schartinger, et al, 2002), and scientific output, informal contacts and students (Bekkers and Bodas Freitas, 2008). For electronics, the

[4] They found that in one of the countries low quality academic deparments tend to interact more with firms, while in the other high quality academic departments tent to interact more with firms.

most important is human resources, especially students (Balconi and Laboranti, 2006; Schartinger, et al, 2002).

Some authors have analyzed other factors that make influence knowledge flows, arguing that context, characteristics of institutions and specificities of knowledge also shape knowledge flows. McKelvey's (2008) suggests that context is an efficient mechanism to strengthen academy-industry interaction. Bekkers and Bodas Freitas (2008) analyze both sides of the interaction based and identified 23 knowledge transfer channels; they found that academy and industry perception does not show a major mismatch. According to them, sector specificities explains to some extend different types of knowledge flows, but disciplinary origin, knowledge characteristics, individual researchers´ characteristics, and the environment in which knowledge is produced and used (institutional features) are more important determinants.

From the academic side Friedman and Silverman (2003) and Bekkers and Bodas Freitas (2008) found that individual characteristics of researchers influence knowledge flows. In this line, researchers with more collaborative experience, a higher number of patents and more entrepreneurial skills tend to support more knowledge flows to industry. In addition, researchers focused on applied research tend to favour the use of patents, human resources mobility, and collaborative research, while those involved in basic research favour publications and conferences.

Based on the Mexican case, we suggest that knowledge flows are sector specific, as their technology level shapes the amount and level knowledge flows from academy to industry.
Based on the Mexican case, we suggest that knowledge flows are sector specific, but they reflect both sector characteristics and the level of technological capacities and absorptive capacities of the firms.

2.3 *Which are the main benefits from the interaction?*

There are several benefits from academy-industry interactions broadly recognized by several studies; for instance firms get a different perspective for the solution of problems and in some cases they perform product or process innovation that without interaction could not have been possible (Rosenberg and Nelson, 1994). According to Mansfield (1991), around 10% of new products in American industry between 1986 and 1994 could not have happened without academic research. Firms also benefits from highly skilled research team, new human resources, and access to different approaches for problem-solving (Rosenberg and Nelson, 1994). According to Hanel and St-Pierre (2006), academy also get benefits, such as a new perspective to approach industry problems and the possibility to shape the knowledge that is being produced at the academy, as well as other sources for research.

Most of the studies that analyze benefits from collaboration focus on the firms' perspective (Cohen, Nelson and Walsh, 2002; Mansfield, 1990; Monjon and Waelbroeck, 2003), however some others have explored the academy perspective (Albuquerque et al, 2008; Welsh et al, 2008).

From the firms' perspective, Cohen, Nelson and Walsh (2002) found that academic research has a double benefit for firms, suggests new R&D projects and contributes to the completion of existing projects. Monjon and Waelbroeck (2003) found that getting the benefits from collaboration is firm specific; for instance higly innovative firms tend to collaborate more with foreign institutions, but they get marginal benefits from collaboration. From the academy perspective, Albuquerque et al (2008) found that the most important benefits from collaboration are new research projects, human resources, thesis and dissertations, and publications and scientific discoveries. Welsh *et al* (2008) found that for the agricultural-biotechnology sector, academy-industry collaboration has many positive impacts, but also represents some hazards. On one hand, they increase contact between researchers and farmers, but on the other, working with industry can restrict communication among researchers. They conclude that to maximize the benefits of academic research requires the development of policies that increase interaction, and protects the autonomy and freedom of researchers.

Some works have not found a direct link between academy-industry collaboration and innovation (Mansfield, 1990). Recently Eom and Lee (2008) found that firms´ size have an effect on innovation and patenting, while they did not find effects of collaboration on innovation performance. However, these authors found that the impact of collaboration can be observed through patents, and it may have an influence on the selection or direction of firms' research projects. Brimble and Doner (2007) found that interactions in Thailand are short-term duration, low-tech diffusion, and in most cases only individual agents are involved, which suggest that benefit are quite limited.

Other works have identified some disadvantages of academy-industry interaction. They mention that a greater involvement with industry can corrupt academic research and teaching, keeping away the attention from fundamental research. It can destroy the openness of communication among academic researchers and put restrictions on publishing, which is an essential component of academic research (Rosenberg and Nelson, 1994; Welsh et al, 2008).

The positive and negative aspects of interaction have brought some debate about the new role of academy regarding the increasing interaction with industry. Rosenberg and Nelson (1994) argue that, on one hand, universities can and should play a larger and more direct role in assisting industry (mostly firms´ view); while in the other hand, some researchers see these developments as a threat to the integrity of academic research (mostly academics´ view). This discussion is relevant for developing countries, as universities could play an important role for development, which require more orientation towards economic and social needs.

Based on the Mexican case, we suggest that differences in the perception of benefits from both agents limit interactions and thus the possibility to initiate virtuous circles in the production and diffusion of knowledge.

3 *Methodology*

This paper contributes to the discussion of academy-industry interactions from the perspective of both agents along three stages of the linking process: i) main reasons to interact; ii) knowledge flows during the interaction; and iii) main results derived from interaction.

3.1 *Data gathering*

This study is based on original data collected by two surveys on academy-industry interactions carried out in Mexico during 2008. R&D and product development managers of firms answered the firms' survey, and the academic researchers survey was conformed by researchers working at universities/PRC; the unit of analysis in both cases is individuals. Data is conformed by 387 questionnaires coming from firms and 461 coming from academic researchers. For this analysis we used 341 innovative firms and 451 researchers affiliated to national institutions.

The original firms’ database was integrated by 1200 firms, some benefited from public funds to foster R&D and innovation activities, such as the R&D fiscal incentives program and competitive funds to foster innovation from CONACYT,[5] and others do not receive public funds. The percentage of answer was 32.3%. The distribution of firms by size, sectors and regions obtained in the received questionnaires are consistent to the sample. The academic researchers’ database was built from researchers listed at the National Researchers System from CONACYT;[6] researchers from six specific fields of knowledge related to the industry were included (Physics, Mathematics and Earth Sciences; Biology and Chemistry; Medicine and Health Sciences; some disciplines of Social Sciences; Biotechnology and Agriculture; and Engineering). Some researchers not recognized by this National Researchers System were also included to broad the sample and allow comparability between fields. 5,880 researchers integrated the sample. The percentage of answer was 8%. All the knowledge fields are represented in the received questionnaires.

3.2 *Analysis of the information*

To analyze the information we performed descriptive statistics as a first step to understand each one of the three stages. We built two regression models to determine the effects of the reasons to get involved in interaction, the main knowledge flows and the main benefits of interaction. To build the regression models we also performed multivariate analysis techniques to build three factors for firms and two factors for academy. The three factors for firms are associated with main reasons to interact, knowledge flows, and benefits from interaction. The two factors for academy are associated with knowledge flows and benefits from interaction.

For the first stage, we performed descriptive statistics to analyze the main reasons to interact from the firms’ perspective. We did not have enough information to compare these results with academics´ perspective. However, we identified and compared the main barriers to interact from both perspectives.

For the second stage, we performed descriptive statistics to identify the main knowledge channels from academy to industry from both perspectives. During the questionnaire construction we designed 18 variables for each one of the agents. The variables are associated with human resources mobility -students and academics; networking; information diffusion; training and consultancy; collaborative R&D projects; incubators; installations; property rights; and spin-offs. From the industry side we analyzed sector specificities to identify modes of knowledge flows in different sectors. We focused on the following 9 sectors: Food and beverage; Leather product; Chemical; Fabricated metal; Machinery; Electrical equipment, appliance and component; Medical, measuring and control instruments; Transportation equipment; and ICT

For the third stage, we analyzed the main impacts derived from collaboration for firms´ innovation and for academy’s research. In the case of firms, we performed descriptive statistics at general and sectoral level to identify the importance of collaboration on publication and reports, prototypes, development of new techniques and instruments, and use of laboratories. For academy, we identified 17 variables associated with product and process development, formation of human resources, scientific discoveries, publications, and spin-offs.

---

[5] Mexican National Research Council for Science and Technology.

[6] The National Researchers System was created in 1984 and its main objectives include the promotion of formation, development and consolidation of a critical mass of high level researchers, mainly inside the public system. It grants pecuniary incentives (monthly compensation) and non-pecuniary (status and recognition) to researchers based on their productivity and quality of their research.

We built two probit regression models to analyze the characteristics of the three stages from the firms´ and academics´ perspective. The dependent variable in both cases is collaboration. For the firms´ perspective the independent variables are product and process innovation (NPDI and NPSI), R&D investment (R&D), FACTOR 1 associated with the main reasons to interact, FACTOR 2 associated with the main knowledge flows, and FACTOR 3 associated with the main benefits from interaction. For the academy perspective the independent variables are the type of organization (TO), research activity (RA), and institutional and personal economic benefits (IEB and PEB), FACTOR 4 associated with knowledge flows, and FACTOR 5 associated with benefits from interaction. We built the factors using factor analysis techniques to reach an optimal solution. Table 1 describes the variables related to each factor.

Table 1 Variables related to factors

Factor	Associated variables
Firms´ perspective	
FACTOR 1. Main reasons to interact	To get technological advice or consultancy to solve production problems To use university/PRC´s installations To identify and hire outstanding students To test products or processes
FACTOR 2. Main knowledge flows	Hiring recent university graduates Internships Training Contract research with universities Joint R&D projects Scientific publications and reports Public conferences and meetings
FACTOR 3. Main benefits from the interaction	Publications and reports Prototypes New techniques and instruments Labs/Metrology
Academics´ perspective	
FACTOR 4. Main knowledge flows	Contract research Consultancy Joint R&D projects Meetings
FACTOR 5. Main benefits from the interaction	New research projects New products Process improvement Thesis and dissertations Publications

Source: Authors´ own

The PROBIT regression model for firms´ can be described as follows:

$$\text{Prob[COLL=1]} = f(\text{NPDI, NPSI, R\&D, F1, F2, F3})$$

The PROBIT regression model for academics´ can be described as follows:

$$\text{Prob[COLL=1]} = f(\text{TO, RA, IEB, PEB, F4, F5})$$

At some specific points of analysis it is possible to compare the results with those obtained by other countries participating in the project, this comparative analysis help us to dimension the results obtained for Mexico.

4 *Main characteristics of academy-industry interaction*

To analyze academy-industry interactions in Mexico we focused on 341 manufacturing innovative firms and on 451 academic researchers affiliated to a national institution. From the analysis we can highlight the following main general findings:

- Academy is not the main but an important source of knowledge for firms.
- Human resources mobility is an important knowledge flow mechanism from firms´ perspective.
- Academy-industry interaction is more intense for ‘radical innovation’ than for incremental innovation.
- Researchers oriented to applied science and technological developments are those who interact more with firms, but basic science researchers also interact.

Academy is not the main but an important source of knowledge for firms

Firms have several knowledge sources for technology development and innovation, 91% of the surveyed firms have mentioned different types of knowledge sources. Customers and suppliers play a key role as knowledge sources; academy represents a less but still important knowledge source. This pattern is similar for most of the sectors across countries. For the specific case of Mexico, customers (63.8%), internet (56.8%), conferences (51.9%) and firms´ operation departments (48.8%) are the most important knowledge sources for technology development and new projects, while academy is located slightly below 30%. In the case of South Africa, customers (34.5%) represent the most important knowledge source, while universities (5.2%) and PRC (3.4%) are less important (Petersen and Rumbelow, 2008).

We focus on innovative firms in Mexico to analyze academy-industry interaction. There are some differences between firms that interact with industry and firms that do not interact - collaborative and non-collaborative firms (See Table A.12). In terms of R&D activity we found an important gap between these groups. Collaborative firms spend 32% more on R&D than non-collaborative firms. In terms of human resources, collaborative firms have larger R&D departments and employ 85% more highly skilled human resources to perform R&D activities than non-collaborative firms. Firms that interact with academy tend to use other knowledge sources more extensively than non-collaborative firms, for instance, the use of consulting firms. For both types of firms, customers are the most important type of knowledge source (See figure Figure A.2).

The importance of knowledge sources is sector and technology specific. Manufacturing sectors with more interaction with academy are Medical, measuring and control instruments; Leather product; Food and beverage; Chemical; and Fabricated metal (See Table A.14).

Regarding collaborative partnerships we observed a similar behaviour in other countries, both developed and developing. For South Africa (Petersen and Rumbelow, 2008), Thailand, (Intarakumnerd and Schiller, 2008), and Korea (Eom and Lee, 2008), the most important partners are customers and suppliers, while collaboration with academy is not very intense. Similar results were found for the case of UK firms (Laursen and Salter, 2004).

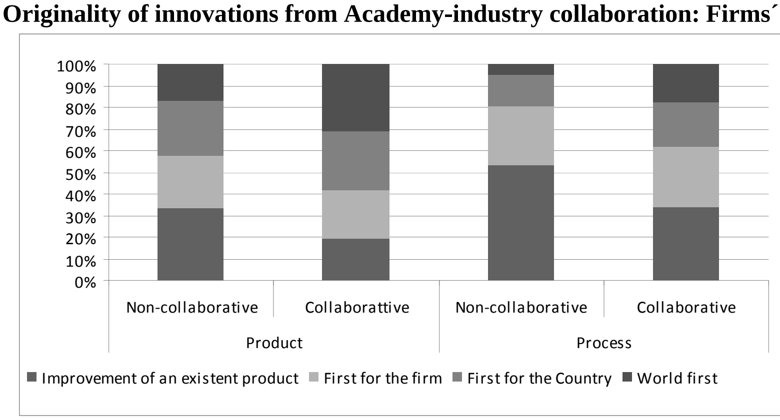
Human resources mobility is an important knowledge flow mechanism from firms´ perspective

There are several types of knowledge flows from academy-industry interaction. From the firms´ perspective the most important is human resources mobility. Firms identify the importance of knowledge embedded in students recently graduated or in students that are performing internships in the firm. For students recently graduated, sectors that rely the most on this type of knowledge flow are Leather product; Medical, measuring and control instruments; and ICT. For internships, sectors that rely more on this knowledge flow are Leather product; Fabricated metal; Machinery; and Medical, measuring and control instruments (See Table A.15). According to Mowery and Sampat (2005), human resources mobility can be a powerful mechanism for the diffusion of scientific research and can strengthen the links between the academic research agenda and the needs of society. However, other types of human resources mobility, such as staff mobility programs are not quite extended in Mexico. We can observe a mismatch between firms´ and academy perspectives, as for academics human resources mobility do not represent an important knowledge flow mechanism (See Table 4).

Academy-industry interaction is more important for 'radical innovation' than for incremental innovation

Academy-industry interactions are becoming more important in knowledge-based economies; different studies have analyzed the importance of those interactions (Etzkowitz and Leydesdorff, 2000; Rosenberg and Nelson, 1994). For the case of Mexico we observe that for process innovations, interactions usually focus on incremental innovations, while for product innovations the most important interactions are for 'radical innovations' (world first).[7] Higher levels of collaboration for radical product innovations suggest that collaboration with academy has a positive impact on the originality of innovations, while for the development of incremental innovations firms can rely mostly on their own sources or other knowledge sources, mainly clients' suggestions (Figure 1).

Figure 1. Originality of innovations from Academy-industry collaboration: Firms´ perspective



Source: Authors´ own.
Sample: 341 innovative firms.
Note: Firms were asked to assess the novelty of their innovations (100% total innovations). We analyzed both collaborative and non-collaborative firms

Researchers oriented to applied science and technological development are those who interact more with firms, but basic science researchers also interact.

Academic researchers whose research line is oriented towards applied science or technological development tend to interact more with industry than those concentrated on basic research (See Table A.13). According to our sample, 25% of researchers focus on basic science, 55% on

[7] In this study we use world first innovations as a proxy for 'radical innovations'.

applied sciences, and 20% on technology development. As in the case of firms, we have classified researchers as collaborative and non-collaborative; 33% of those researchers oriented to basic sciences, 74% of those focused on applied sciences and 90% of those focused on technology development interact with industry (collaborative). It means that there are no sharp divisions of labour between researchers; many of those who concentrate on basic research also interact with industry, allowing a dialogue between these two different arenas. Also 38% of researchers point that academy-industry interaction represents a source of ideas for new projects and open new research areas, confirming results obtained from other authors (Hanel and St-Pierre, 2006; Albuquerque et al, 2008; Welsh *et al* 2008). Data about researchers' productivity in terms of patents and software shows that collaborative researchers have much more productivity in terms of applied research related products than non-collaborative (See Table A.13). However, they have almost the same productivity in terms of publications in ISI journals, which suggest that interaction has not been affecting academic results of Mexican researchers.[8]

In terms of financed projects by other institutions, collaborative researchers are engaged in more financed projects than non-collaborative. This result suggests that collaborative researchers have access to more ideas for research projects, they are more active in research activities or there are more funds for applied research.

5 *Three stages of the linking process: the perspective of firms and academic researchers*

The linking process can be analysed through three different stages: i) main reasons to interact; ii) knowledge flows during the interaction; and iii) main results derived from interaction. Evidence form the Mexican case is discussed below.

5.1 *Stage 1: Why universities/PRC and firms interact?*

Universities act as producers and custodians of knowledge; their main roles are the formation of highly skilled human resources, the development of basic and applied research (Rickne, 2001), mostly basic, and the contribution to economic development through collaboration with other agents, like business sector (Sutz and Arocena, 2005; Etzkowitz and Leydesdorff, 2000). PRC play the same roles but with different accent, in general they are more oriented to knowledge generation, mostly applied science, and less to human resources formation. Their contribution to technological development in some sectors is remarkable.

At this first stage we focused on firms´ perspective to analyze the main reasons to interact with academy. We also identified the main barriers for interaction and compared both perspectives. We focused on collaborative firms and explored 10 reasons to interact. From Table 2 we can observe that the main reasons for firms to interact with academy are related to identify and hire students, get technological advice to solve production problems, test products/processes, and use the university/PRC´s installations. The main reasons are then related to activities that increase firms' capabilities (i.e. human resources) or complement firms' capabilities (i.e. get

[8] National Research System evaluate researchers according to academic results, mostly publications in ISI journals, this incentive could contribute to explain that collaborative researchers have almost the same productivity than non-collaborative ones. See Rivera et al (2009) about research productivity of Mexican agricultural researchers.

technological advice to solve production problems, test products/processes and use the installations). This last suggests that firms largely have basic/intermediate technological capabilities, but with weaknesses in the external linkages technical function.[9] This later limit firms to get benefit from knowledge generated in academy. Arza and López (2008) found similar results for Argentinean firms, they cooperate mainly to test products/processes, contribute to quality control, and get technological advice. For both countries the least important reason for interaction is to contract R&D.

Table 2 Firms´ main reasons for interaction. Collaborative firms´ perspective

	Average	**Percent of highest importance**
Technology transfer from university/PRC	2.12	24.6%
To get technological advice or consultancy to solve production problems	2.38	28.7%
Increase the firm's ability to find and absorb technology information	2.13	24.0%
To get information from engineers or scientist and tendencies on R&D	1.91	22.2%
To contract research focused on the firm's innovation activities (complementary research)	2.06	23.4%
To contract research that the firm can not perform	2.13	22.5%
To identify and hire students	2.44	26.0%
To use the university/PRC´s installations	2.25	25.4%
To test products or processes	2.35	26.3%
For quality control	2.00	21.6%

Sample: 172 collaborative/innovative firms
Note: Firms were asked to assess the main reasons in a 1-4 likert scale (1=not important, 4=very important)

Even though firms expressed several reasons to interact with academy, there are several barriers that impede academy-industry interaction. We analyzed both perspectives to identify the specific barriers for each agent; we focused on non-collaborative firms and non-collaborative researchers (Table 3).

Table 3 Main barriers to interaction: the perspectives of firms and academic researchers

	Firms Non-collaborative	**Academy Non- collaborative**
The firm has enough capacities for in-house R&D	32.3%	
Universities are not familiar with the firm's operations	29.4%	29.5%
PRC are not familiar with the firm's operations	26.0%	29.5%
It is time consuming to establish contractual agreements	21.3%	
Lack of trust or confidentiality problems	11.0%	10.9%
Low research quality	12.6%	
Universities are too focused on basic research	16.8%	
Geographic distance	3.6%	8.6%
Hard to establish a dialogue	6.3%	
IP structure	14.1%	9.7%
Firms are not familiar with university/PRC´s activities		41.5%
Lack of economic incentives for researchers to establish cooperation		34.1%
Bureaucracy in academic institutions		29.5%
High research cost		27.8%
Lack of human resources at the university technology transfer offices		25.0%
Different priorities and objectives		24.4%
Lack of human resources at the firm to establish contact with academy		22.2%
The university considers inappropriate to trade with public		17.6%

[9] Bell and Pavitt (1995).

knowledge	
Financial institution’s bureaucracy	15.3%
Different research deadlines	14.2%
Firm’s bureaucracy	13.1%

Source: Authors´ own.
Sample: 169 Non-collaborative firms, and 149 non-collaborative researchers
Note: Firms and researchers were asked to assess the main barriers in a 1-4 likert scale (1=not important, 4=very important); percent of firms and researchers that answered 3-4.

From the table above we observe that one of the main barriers for interaction from both sides is the lack of knowledge of the potential partners’ activities. Firms perceive that academics are not familiar with their operations, while academics perceive that firms are not familiar with their activities. The most important barrier from firms´ perspective is that they believe they have enough capacities for in-house R&D, either internal or within their group. This may reveal a limited concern with absorbing external knowledge, or limited absorptive capacities to identify and use this type of external knowledge. Academic researchers mentioned that two other important barriers for interaction are the lack of economic incentives to establish cooperation and bureaucracy in academic institutions. IP structure and geographic distance are not important barriers for interaction from neither of both perspectives in the Mexican case. The former illustrates their low patenting activity (Aboites, Dominguez y Beltran, 2004).

Studies in other developing countries found similar results. The main three barriers for interaction in Argentina are firms perception that they do not need to interact because their in-house R&D is enough, especially for large firms; the second barrier is that academy do not have a proper understanding of firms´ operations; and finally the difficulty in establishing contractual agreements with academy (Arza and López, 2008).

Both firms’ reasons and barriers for interaction suggest they have basic/intermediate technological capabilities but low absorptive capacities; they carry out R&D activities and even develop ‘radical innovation’ (world first), but they do not benefit from external knowledge sources, at least coming from academy.[10] Overall we can argue the existence of two main types of reasons to collaborate for Mexican firms: to increase their basic/intermediate technological capabilities and to complement them.

5.2 *Stage 2: Which is the main knowledge flows from academy-industry interactions?*

During academy-industry interaction knowledge may flow in both directions and may benefit both agents creating a virtual cycle in the production and diffusion of knowledge (Albuquerque et al, 2008). Evidence coming from different studies suggests that knowledge flows are sector and technology specific, which determine the dynamics of interaction (Laursen and Salter, 2004; Mowery and Sampat, 2005; Hanel and St-Pierre, 2006; Fontana, Geuna and Matt, 2006; Arza and López, 2008; Intarakumnerd and Schiller, 2008). At this stage we analyze the main knowledge flows from academy to firms from both perspectives, differentiating knowledge flows from university and PRC, as they can present variations due to their specific functions. We also identify the specificities of knowledge flows in the 9 sectors mentioned above.[11]

[10] Following Cohen and Levinthal (1989), R&D activities are considered a main indicator of absorptive capacity. However, several authors use a broad set of variables to characterise absorptive capacities, including human resources, linkages, etc. (see Criscuolo and Narula, 2002; Giuliani, 2005; Lorentzen, 2005).
[11] Food and beverage; Leather product; Chemical; Fabricated metal; Machinery; Electrical equipment, appliance and component; Medical, measuring and control instruments; Transportation equipment; and ICT.

In the literature, the most important knowledge channels are related to information diffusion, consultancy, human resources, networking, collaborative R&D projects, property rights, and spin-offs (Swann, 2002; Cohen, Nelson and Walsh, 2002; Narin et al, 1997). According to our evidence (Table 4), at a general level, the most important knowledge channels from universities are related to human resources (first of all internships), collaborative R&D in the form of contract research and training. These channels are ranked of the highest importance by a larger porcentaje of firms. Firms like better to contract research from HEIs instead of working together to solve problems. In contrast, the most important knowledge channels from PRC are related to collaborative R&D projects (both contract research and joint projects), information diffusion (scientific publications and reports) and training. These types of knowledge flows, and the importance assigned to them, reflect firms´ perception about the main roles of universities and PRC. Firms perceive that the main role of universities is the formation of human resources, and the main function of PRC is to solve problems by means of R&D. There are certain consensus bewteen firms, as the standard deviation observes quite low levels.

Table 4 Knowledge flows from academy-industry interaction from both perspectives

	Collaborative firms´ perspective						Collaborative academic researchers´ perspective		
	Regarding universities			Regarding PRC					
	Average imp.	% of highest importance	Std. Dev.	Average imp.	% of highest importance	Std. Dev.	Average imp.	% of highest importance	Std. Dev.
Scientific publications and reports	2.3	25.1%	1.3	2.5	32.0%	1.3	1.8	16.1%	2.6
Public conferences and meetings	2.3	22.2%	1.2	2.4	22.7%	1.3	2.2	26.0%	2.4
Networks that include universities	2.1	21.6%	1.2	2.0	21.6%	1.3	2.0	25.7%	2.8
Informal information from personal contacts	2.3	19.3%	1.2	2.3	20.9%	1.2	2.0	16.2%	2.5
Meetings between researchers and entrepreneurs	---	---	---	---	---	---	2.6	38.9%	2.3
Hiring students recently graduated	2.5	28.1%	1.3	1.9	13.5%	1.2	1.7	14.5%	2.6
Internships	2.7	36.3%	1.2	2.1	20.5%	1.3	---	---	---
Temporal staff exchange (staff mobility programs)	1.8	7.0%	1.1	1.7	9.9%	1.1	1.5	13.9&	2.8
Training	2.5	32.2%	1.4	2.4	30.8%	1.3	2.1	23.3%	2.6
Consultancy by academics	2.3	25.7%	1.3	2.2	26.3%	1.3	2.4	26.0%	2.4
Contract research with universities	2.4	32.7%	1.3	2.4	35.7%	1.4	2.4	33.4%	2.5
Joint R&D projects	2.4	18.6%	1.3	2.4	34.5%	1.4	2.5	36.6%	2.5
Technology licenses	1.9	14.6%	1.2	1.8	14.6%	1.2	1.4	12.8%	2.8
Patents	2.0	20.5%	1.2	1.9	21.6%	1.3	1.3	15.2%	2.8
Incubators	1.8	11.7%	1.1	1.7	9.9%	1.2	1.6	16.6%	2.8
Science and technology parks	1.9	15.2%	1.2	1.8	14.0%	1.2	1.4	16.2%	2.9
The firm is owned by the university	1.3	3.5%	0.8	1.4	5.3%	1.0	---	---	---
Spin-off	1.4	6.4%	0.9	1.4	6.4%	1.0	1.4	13.6%	3.0

Source: Authors´ own.
Sample: 172 collaborative firms, 302 collaborative researchers.
Note: Firms and researchers were asked to assess the importance in a 1-4 likert scale (1=not important, 4=very important)

According to the academy side, networking (meetings) and collaborative research (contract research and joint projects) are the most important knowledge channels. These are the three channels that are ranked of highest importance by a larger percentage of firms. However, researchers have different individual perceptions about the importance of the knowledge flows, as revealed by the quite high standard deviation. In other words, there is a sort of consensus about the main knowledge flows between firms, while researchers have different individual perception about it.

Similar results were observed for Brazil (Albuquerque et al, 2008), where from the academic perspective, the most important knowledge flows from academy to industry is contract R&D; property rights, networking, and spin-offs are not very relevant knowledge flows. For the case of Korea (Eom and Lee, 2008), the most important knowledge channels are property rights and consultancy, revealing a greater patenting activity. For the case of Thailand (Intarakumnerd and Schiller, 2008), academy perceives that the most important knowledge channels are consultancy and networking, and the least important is collaborative R&D. These differences in the perception about the knowledge flows reflect that differences in technological capability accumulation, sectors, and incentives matter to explain the way firms can benefit from knowledge located at the academy.

Several studies indicate the importance of spin-offs as a knowledge flow mechanism, but in the Mexican case spin-offs are not considered an important knowledge channel neither for academic researchers nor for firms. There are several barriers for the success of spin-offs especially in developing countries. In the case of South Africa, Kruss (2008) found the same results and the study concluded that even though the capacities of universities, the entrepreneurial activity and the favourable policy and funding context, is extremely difficult and complex to sustain a competitive knowledge-intensive university's spin-off firm in South Africa.[12]

To explore more in details knowledge flows from academy to industry we focused on 9 sectors to identify the specificities of knowledge flows (see Table A.15). Sectors that rank with higher importance different types of knowledge flows are 2 medium-low tech sectors: Leather product, and Food and beverage; and one medium-high tech sector: Medical, measuring and control instruments. We can also observe differences in terms of the most important types of knowledge flows. For Food and beverage, the most important knowledge flows are related to information diffusion and collaborative R&D. Leather product benefits more from information diffusion, networking and intellectual property. The most important knowledge flows for Chemical come from information diffusion, which support the findings by Bekkers and Bodas Freitas (2008). Human resources (internships) and training are very important for Fabricated metal, Machinery and Electrical equipment, appliance and component. Training is the most important knowledge flow for Medical, measuring and control instruments and Transportation equipment. ICT gets more benefits from collaborative projects.

These results reflect different perspectives regarding the importance of knowledge flows from academy to firms. From the firms´ perception, universities above all contribute with

[12] Collaborative research between university and industry can be successful in South Africa, but not necessarily end up in commercialization, such as the software case study, where the main problem was due to a lack of interactive capability and the absence of networks between the university and the industrial sector, and between the industrial sector and government support agencies (Kruss, 2008). The genomic sector is successful because the government facilitated networks between the university and the biotechnology sector. The government has a critical role for the success of public-private interactions, but also firm strategy has to play a strategic role for the success of interactions.

human resources and PRC are valuable as they diffuse information to technology development. Collaborative R&D is less important. There are at least two explanations for this behaviour, either firms do not have advanced technological capabilities and absorptive capacities, and thus the capabilities to interact with academy, or they do have these capabilities but they consider that domestic universities and PRC are not their appropriate partners, and then prefer other partners (either other firms or foreign academy). This result supports the findings by Monjon and Waelbroeck (2003). From the academic researchers' perspective, the role of research is more important than the role of human resources formation to diffuse knowledge to firms.

The Mexican case suggests that knowledge flows are sector specific, and reflect sectors' characteristics and level of firms' absorptive capacities and technological capabilities. The evidence shows that medium-low tech sectors, such as Leather products are also eager to interact with academy, and there are knowledge flows from these interactions.

5.3 *Stage 3: Main benefits from academy-industry interactions*

As during academy-industry interaction, knowledge flows in two directions, both agents may get the benefits of such interactions (Hanel and St-Pierre, 2006). Previous research argues that academy gets other types of income, has access to firms' equipment, and gets ideas for future research. Firms benefit from knowledge available in academy, highly skilled research teams and new human resources (Rosenberg and Nelson, 1994; Hanel and St-Pierre, 2006). However, academy-industry cooperation may not directly increase the innovation probability of firms. Eom and Lee (2008) found that a large part of the knowledge from university is intangible with imprecise impact, and academy-industry cooperation does not determine the firms' success in technological innovation. It is widely recognized that academy-industry interactions and thus their contributions to innovation activities differ according to the type of technology and sector (Petersen and Rumbelow, 2008; Intarakumnerd and Schiller, 2008; Kruss, 2008; Bittencourt, et al, 2008).

For the case of Mexico, if firms are engaged in academy-industry interactions, they rank them as successful, especially for interactions older than 2 years. 60% of firms consider that linkages with academy were successful or have success expectations in terms of their goals, and 11% of firms have unsuccessful linkages or low expectations for success. Similar results were found for Argentinean firms, where 88% of firms consider or expect successful linkages, while only 12% of firms have low expectations for success (Arza, 2008).

Table 5 and 6 presents the impact of different collaborative results, such as publications and reports, prototypes, new techniques and instruments, and the use of laboratories and metrology on firms´ innovation activities.

Table 5 Impact of different collaborative results on firms´ innovation activities (Collaborative firms)

	Average of importance	Percent of highest importance
Labs/Metrology	3.2	57.6%
New techniques and instruments	3.0	48.8%
Publications and reports	2.9	42.4%
Prototypes	2.7	39.5%

Source: Authors´ own.
Sample: 172 collaborative firms.
Note: Firms were asked to assess the impact in a 1-4 likert scale (1=not important, 4=very important)

Table 6 Impact of different collaborative results on firms´ innovation activities differentiated by sector

	Share of highest importance				
	Publications and reports	**Prototypes**	**New techniques and instruments**	**Labs/Metro logy**	**Total of firms**
Food manufacturing and beverage	45.1%	21.6%	41.2%	56.9%	51
Leather and allied product manufacturing	33.3%	33.3%	44.4%	55.6%	9
Chemical manufacturing	54.2%	33.9%	44.1%	47.5%	59
Fabricated metal manufacturing	26.7%	40.0%	20.0%	40.0%	15
Machinery manufacturing	41.7%	45.8%	41.7%	50.0%	24
Electrical equipment, appliance and component manufacturing	31.8%	45.5%	59.1%	50.0%	22
Medical, measuring and control instruments manufacturing	33.3%	44.4%	33.3%	22.2%	9
Transportation equipment manufacturing	29.8%	38.3%	40.4%	42.6%	47
ICT	14.3%	7.1%	21.4%	14.3%	16
Total	37.4%	34.2%	43.3%	46.5%	172

Source: Authors´ own.
Sample: 172 collaborative firms.
Note: Firms were asked to assess the impact in a 1-4 likert scale (1=not important, 4=very important)

The most important benefit from collaboration according to firms´ perception is the use of laboratories (3.2 average of importance and 57.6% of firms ranked it highest importance). Again, this suggests that firms interact with universities and PRC for complementing their basic/intermediate innovative capabilities. Prototypes, which suggest a more dynamic interaction is the least important benefit for firms (2.7 average of importance and 39.5% of firms ranked it highest importance). Sector differences matter, we can observe 4 different types of benefits that suggest different collaborative levels. In the case of Food and beverage, Leather and allied product, Fabricated metal, Machinery, and Transportation equipment the use of labs and metrology are the main benefits from interaction; these sectors interact with academy to complement their in-house capabilities and to reach customer demands. For Chemical manufacturing, publications and reports are the most important benefits, which suggest a more research-oriented collaboration. Prototypes are the most important for Fabricated metal, and Medical, measuring and control instruments manufacturing; this suggests higher academy-industry interaction, and more intense knowledge flows. Finally, new techniques and instruments are the most relevant for Electrical equipment, appliance and component manufacturing, which reveals also a more intense use of knowledge than others.

Table 7 below lists the collaboration benefits from the academy perspective. Academic researchers consider that the most important benefit is to generate new research projects, an academic product, followed by other academic and industrial results, such as publications, thesis and dissertations, and new products and process improvement. It means that researchers recognises that collaboration brings positive results for both agents. In addition, as analysed in the case of the innovation novelty (see figure 1), the academic view confirms the firms' perspective that collaboration contributes to 'radical innovation' (new products that are world first) and process improvement.

Table 7 Main benefits for academic researchers derived from collaboration with firms

	Average	Percent of highest importance
Formation of human resources		
Bachelor	1.6	23.8%
Master	1.5	20.2%
PhD	1.2	14.6%
Thesis and dissertations	1.7	22.8%
Scientific discoveries	1.3	13.2%
New research projects	2.4	37.7%
Publications	1.9	25.8%
Patents	0.9	11.3%
Designs	1.0	12.6%
Software	0.8	7.3%
New products	1.8	26.2%
New industrial processes	1.4	16.2%
Product improvement	1.6	18.2%
Process improvement	1.7	18.5%
Spin-offs	0.9	7.9%
Start-Ups	0.7	6.3%

Source: Authors´ own.
Sample: 302 collaborative researchers.
Note: Researchers were asked to assess the benefits in a 1-4 likert scale (1=not important, 4=very important)

Firms and academic researchers respond to different logics. Firms respond to a business logic, while academic researchers respond to a knowledge production and diffusion logic. From the firms' perspective, the most important results from collaboration are tools to improve product quality and respond to specific norms and demands from clients and the market. From the academic researchers´ perspective, the most important result is set of ideas for new research projects; formation of human resources and publications, and also product and process innovation are important results from interaction. Quite similar results were obtained for Brazil (Albuquerque et al, 2008); the most important benefits for PRC are new research projects, formation of human resources, dissertations and publications. Some research groups in Brazil also ranked the access to different types of financing sources and access to material and equipment as important benefits from collaboration.

Academy-industry collaboration brings positive impacts to firms´ innovative activities, as it is revealed by the novelty of the innovation (see Fig 1.), and to academy's research and infrastructure. However, those benefits are reported by a small percent of firms and academic researchers, which suggest a low level of linkages. When academic researchers and firms engage in collaboration, they usually rank it as successful or with success expectations. The benefits reported from collaboration are sector specific; sectors that reported the highest percent of benefits are Food and beverage, and Chemical manufacturing. The former benefits more from the use of labs, while the later benefits more from publications. Those differences reflect the interaction level and certain characteristics of those sectors in Mexico.

5.4 *Collaboration models: academy and firms´ perspectives*

We built two regression models to identify the impact of each one of the different stages on academy-industry collaboration. The model for firms explores the effect of different elements for collaboration.

Table 8 presents the regression results from the firms' perspective. We also performed a probit regression model to analyze the academic researchers´ perspective. We observed the effect of different elements for collaboration, the importance of knowledge flows and collaboration benefits.

Probit regression model for firms can be described as follows:

$$\text{Prob[COLL=1]} = f(\text{NPDI, NPSI, R\&D, F1, F2, F3})$$

We explored the impact of product innovation, process innovation, R&D expenditure, reasons for collaboration, knowledge flows, and benefits on collaboration with academy. From the descriptive statistics analysis, we included in the model the most important variables for reasons for collaboration, knowledge flows and reasons to interact. The first and second models also integrate sectors´ technology level and each one of the important variables from the three stages of the linking process (Table 8). However, these models did not reach an optimal solution. To build the third and fourth models we did not consider the impact of sectors´ technology level, we reduced the variables related to the different stages of the linking process and we built three factors. Factor 1 is associated with reasons to interact. Factor 2 is associated with knowledge flows and Factor 3 is associated with benefits from interaction. Model 3 integrates in one factor knowledge flows from universities and knowledge flows from PRC, while Model 4 analyzes each one in separate factors. Model 4 brings the best results to analyze the effect of different elements on collaboration with academy.

Table 8 Firms´ Rotated component matrix

		Component	
	FACTOR 1. Main reasons to interact	FACTOR 2. Main knowledge flows	FACTOR 3. Main benefits from the interaction
To get technological advice or consultancy to solve production problems	.078	.884	.142
To identify and hire outstanding students	.067	.923	.086
To use university/PRC´s installations	.081	.964	.037
To test products or processes	.051	.956	.038
Scientific publications and reports	.796	.111	-.030
Public conferences and meetings	.835	.093	-.005
Hiring recent university graduates	.609	-.004	.038
Internships	.425	-.067	.094
Training	.790	.047	.045
Contract research with universities	.793	.083	.038
Joint R&D projects	.765	.150	.063
Publications and reports	.092	.099	.866
Prototypes	-.002	.070	.909
New techniques and instruments	.079	.067	.922
Labs/Metrology	.061	.053	.884

Extraction method: Principal component analysis
Rotation method: Varimax with Kaiser normalization
Rotation converged in 5 iterations
Explained variance: 70.4%

Table 9 Researchers´ Rotated component matrix

	FACTOR 4. Main knowledge flows	FACTOR 5. Main benefits from the interaction
Contract research	.074	.876
Consultancy	.139	.845
Joint R&D projects	.099	.862
Meetings	.055	.822
New research projects	.929	.098
New products	.957	.118
New process improvement	.909	.114
Thesis and dissertations	.891	.086
Publications	.602	.050

Extraction method: Principal component analysis
Rotation method: Varimax with Kaiser normalization
Rotation converged in 3 iterations
Explained variance: 74.9%

Table 10 Probit regression models for firms

	Model 1		Model 2		Model 3		Model 4	
Parameter	Estimate	Z	Estimate	Z	Estimate	Z	Estimate	Z
Product innovation	-.010	-.109	-.011	-.115	.013	.156	.020	.244
Process innovation	.059	.590*	.016	.158	.071	.796*	.079	.896*
R&D investment as % of profits	.006	1.106*	.004	.778*	.002	.515*	.003	.632*
Sector	-.013	-1.510*	.000	.000				
Factor 1. Reasons					-.850	-5.301***	-.852	-5.252***
To get technological advice or consultancy	-.002	-.022	-.001	-.016				
To use university/PRC´s installations	.000	.000	.052	.500*				
To hire students	-.229	-2.707***	-.291	-3.199***				
To test products or processes	-.055	-.635*	-.066	-.678*				
Knowledge flows (Factor 2. Academy)					.436	3.807***		
Knowledge flows (Factor 2.1. Universities)							.366	3.029***
Knowledge flows (Factor 2.2. PRC)							.074	.633*
Hiring recent university graduates	-.007	-.064	.007	.067*				
Internships	-.051	-.507*	-.053	-.516**				
Training	-.239	-1.945**	-.269	-2.187***				
Contract research with universities	.368	2.390***	.460	2.922				
Joint R&D projects	.067	.482*	.011	.076*				
Scientific publications and reports	-.169	-1.288*	-.170	-1.271*				
Public conferences and meetings	.090	.634*	.098	.681*				
Training	.179	1.356*	.175	1.320*				
Contract research with universities	.111	.819*	.037	.276*				
Joint R&D projects	-.038	-.281*	.035	.254*				
Factor 3. Benefits					.060	.512	.062	.525*
Publications and reports	-.054	-.445*	-.071	-.585*				
Prototypes	-.067	-.599*	-.087	-.748*				
New techniques and instruments	.038	.262*	.051	.344*				
Labs/Metrology	.147	1.148*	.186	1.426*				
Intercept	.524	.960	.333	.667	-.203	-.623	-.265	-.809
Pearson Goodness-of-Fit Test								
Chi-Square	172.340		180.985		207.8		205.6	
dfa	190		190.000		205		204	
Sig.	.816		.668		0.43		0.454	
N	212		212.000		212		212	
Iterations	20		20.000		18		18	

*p ‹ 0.1; **p ‹ 0.05; ***p ‹ 0.01

The probit regression model for academy can be described as follows:

$$Prob[COLL=1] = f(TO, RA, IEB, PEB, F4, F5)$$

For the academy probit regression model we explored the impact of type of organization, research activity, institutional economic benefits, personal economic benefits, knowledge flows and benefits from interaction on collaboration with firms. We considered all the important variables from the descriptive analysis for knowledge flows and benefits from interaction. For the first model we analyzed each one of the different variables, but we did not reach an optimal solution. To build the second model we reduced those variables in 2 factors, one is associated with knowledge flows and the other associated with benefits from interaction. Although we reached an optimal solution for the second model, the model is not significant.

Table 11. Probit regression models for academic researchers

	Model 1		Model 2	
Parameter	Estimate	Z	Estimate	Z
Type of organization	-.355	-2.309**	-.350	-2.477***
Research activity	.436	4.964***	.494	5.883***
Institutional economic benefits	-.122	-2.130*	-.053	-1.121*
Personal economic benefits	.059	.835*	-.009	-.157
Factor 4. Knowledge flows			-.103	-1.579*
Contract research	-.045	-1.070*		
Consultancy	.108	2.553***		
Joint R&D projects	-.041	-.975*		
Meetings	-.064	-1.534**		
Factor 5. Benefits			.415	4.077***
New research projects	-.010	-.842*		
New products	.022	1.064		
Process improvement	-.001	-.068*		
Thesis and dissertations	-.023	-2.225***		
Publications	.269	7.151***		
Intercept	.390	1.106	.179	.580
Pearson Goodness-of-Fit Test				
Chi-Square	17813.897		21238.021	
Dfa	437		444	
Sig.	.000		.000	
N	451		451	
Iterations	20		15	

*p ‹ 0.1; **p ‹ 0.05; ***p ‹ 0.01

From the firms´ regression model we observe a high correlation between product and process innovation and collaboration with academic researchers. However, R&D expenditures do not imply a high level of collaboration with academy. Industry sector does not result an important determinant for collaboration. We found that knowledge flows and benefits from collaboration have a positive effect on collaboration with academy. For the specific case of universities, human resources and collaborative R&D, is the most important type of knowledge flows. For the specific case of PRC, the most important is training, followed by networking and collaborative research. Regarding benefits, we found that use of laboratories and metrology instruments, and development of new techniques and instruments are the most important benefits from collaboration. These two types of benefits from interaction are associated with the firms´ interest to increase product quality to satisfy market and customers´ demands, and show their interest to increase their level of technological capabilities. However, academy-industry interaction needs to go further to get more benefits associated with the development of prototypes, as they are related to higher level of interactions.

From the academy regression model we found that the type of organization is not an important determinant for collaboration; however, the type of research activity has an important effect on collaboration, researchers that perform applied research and technology development collaborate more with firms than researchers that perform basic research. Referring to economic benefits, they are not important determinants for collaboration; however, personal economic benefits have a stronger impact on collaboration than institutional economic benefits. In general, knowledge flows from academy to industry does not have a strong impact on collaboration, on the other hand, benefits has a positive impact on collaboration with firms, which suggest that academy focus more on benefits that can get from interaction than on knowledge flows to firms. Regarding benefits from interaction, academic researchers rank publications as the most important benefit for two reasons, interaction with firms is a source for new research ideas, which can be diffused to increase the stock of knowledge, and the National Researches Systems in Mexico values publications as a productivity measure for academy.

6 *Conclusions*

Academy-industry interaction is a controversial issue that is perceived in a different way by the agents involved. Interaction may bring several benefits for academic researchers and firms by the generation of knowledge flows and increasing knowledge dynamics. This paper contributes to the understanding of three different stages of the interaction process analyzing both the perspectives of both agents.

Four features characterises academy-industry in Mexico. First, academy is not the main source of knowledge for firms. Second, human resources mobility is an important knowledge flow mechanism from firms´ perspective. Third, 'radical innovations' (defined as world level novelty) are associated with more interaction with academy. Fourth, there is not a sharp division of labour between researchers, thus researchers oriented to applied science and technological development are those who interact more with firms, but basic science researchers also interact. Collaborative researchers are more productive in terms of patents and software, but they have almost the same productivity in terms of publications. This suggests that collaboration increases knowledge flows from both agents and creates virtuous cycles to generate ideas and important projects that can be financed by different institutions.

Focusing on the first stage of interaction, the Mexican case shows that there are two main reasons to interact: activities that increase firms' capabilities (mostly related to identifying and hiring human resources) and activities that complement firms' capabilities (mostly related to getting technological advice to solve production problems, testing products/processes, and using of the university/PRC´s installations). These results are line with Arza and López (2008)'s findings that Argentinean firms collaborate to contribute to their innovative activities. They also confirm the results by Laursen and Salter (2004) that one of the most important reasons for interaction is firms´ strategy. From the empirical evidence we identified that firms that invest more in R&D and are product and process innovators interact more with academy, which confirm the results obtained by Laursen and Salter (2004) and Hanel and St-Pierre (2006).

We found that one of the main barriers for interaction from both sides is the lack of knowledge of the potential partners' activities, which suggest that much more have to be done to simple knit the minimum links related to information diffusion and trust. In addition, the most important barrier from firms´ perspective is their perception of having enough capacities for in-house R&D. These results confirm those obtained by Arza and López (2008). It also suggests that collaboration for these firms is perceived as complementary more than substitute to their capabilities.

Concerning with knowledge flows, firms follow business logics and perceive that universities above all contribute with human resources and PRC are valuable as they diffuse information to technology development. Collaborative R&D is less important from firms´ perspective. These results confirm those obtained by Mowery and Sampat (2005), that one of the most important knowledge flows are human resources; and those results by Swann (2002) and Narin et al (1997) that human resources is one of the most important channels of knowledge flows. In contrast, from the academic researchers' perspective, knowledge creation plays a more important role than human resources formation for the firms; however, they have not found appropriate schemes to engage in more advanced levels of interaction with firms. Our results from academy perspective confirm those results by Meyer-Krahmer and Schmoch (1998) and Albuquerque et al (2008) that the most important knowledge flows come from collaborative research.

As it was found in several countries, our results in terms of the knowledge flows show they are sector specific. Traditional and low-medium technology sectors, such as Leather product gets important knowledge flows from academy in the form of patents, which can be associated with the existence of an important leather cluster in the City of León and its regional and sector dynamic. For the case of Chemical, we found that publications (Cohen, Nelson and Walsh, 2002; Bekkers and Bodas Freitas, 2008), collaborative research, human resources mobility (Schartinger, et al, 2002), informal contacts and networking (Bekkers and Bodas Freitas, 2008) play an important role as knowledge flows. On the other hand, we did not find that patents are important knowledge flows for Chemical (Levin, 1988).

Although academy-industry interactions are not wide extended in Mexico, we observed that 50% of the sample of innovative firms interacts in different ways with academy. Both agents get several benefits from interactions, which increase during long-term interaction. Those benefits respond to different interests and are sector and knowledge specific. Even though collaborative firms report different benefits from interaction, such benefits are associated with the use of installations and metrology equipment. These activities are focused on increasing and satisfying quality standards of specific products. But activities that could involve more interaction to develop prototypes are not quite extended. Even though public funds to foster innovation and interaction are generating some results, they are not reaching their main objective that is the increase of industrial R&D. From the academy side, the evidence suggests that academic researchers have not created specific schemes to "market" themselves as an important source for knowledge production and as an important partner for collaborative research. From academy perspective we confirm the results by Albuquerque et al (2008) that new research projects, human resources, thesis and dissertations, and publications are important benefits from collaboration; however in the Mexican case new products and process improvement are also of great importance. This reveals a researchers' concern on the role of universities/PRC to problem solving in the business sector.

The analysis made along the three stages of the linking process suggest that Mexican innovative firms have in general basic/intermediate technological capabilities and low absorptive capacities, as they do not identify and benefit from external knowledge from academy in a greater extent. However, there are differences between innovative firms. In terms of R&D activity we found an important gap between innovative firms that interact with academy versus those that do not interact. Collaborative firms spend more on R&D, have larger R&D departments, and employing more highly skilled human resources to perform these activities than non-collaborative firms. These results suggest that collaborative firms have higher technological capabilities and absorptive capacities than non-collaborative firms. Differences in the perception along these three stages from both agents limit interactions and thus the possibility to initiate virtuous circles in the production and diffusion of knowledge.

The results from this paper suggest the following policy implications. First, barriers for collaboration are mostly associated with the lack of knowledge that each one has in relation to the potential partners' activities. This suggests the importance of creating and strengthening bridge organizations, which in the case of academy could be located internally. Second, the most important sources of knowledge from the firms' perspective are those related to the formation of human resources (students recently graduated and internships), which suggest the importance to create schemes to engage students to participate in different projects with industry, joint master programs with the industry, and programs to foster the hiring of PhD in the industry. Third, firms and academy engaged in collaboration perceive important benefits and rank such interactions as successful, which suggests the need to diffuse successful experiences to foster these linkages between broader ranges of firms and generate new incentives to stimulate linkages between academy and industry.

This paper did not discriminate the behaviour of researchers regarding knowledge fields. According to previous studies, knowledge fields can impact the type of knowledge diffused to firms. In addition, there are other factors that can impact firms' behaviour, such as the geographical location. Further researcher could discriminate and identify the impact of knowledge field and geography on the three stages of the linking process. Further study can also focus on the impact of public fund on innovation and collaboration with academy to analyse the effectiveness of public funding.

Annex

Table A.12. Profile of the total Sample, collaborative and non-collaborative firms

	Non-collaborative	**Collaborative**	**Total Sample**
Firm characteristics			
Firm size (no. of firms, total)	169 (49.%)	172 (50.4%)	341
Micro (1-9)	2 (16.7%)	10 (83.3%)	12
Small (10-99)	40 (44.4%)	50 (55.6%)	90
Medium (100-249)	49 (57.0%)	37 (43.0%)	86
Large (+ 250)	78 (51.0%)	75 (49.0%)	153
Total manufacturing of which			
Low technology	45 (45.0%)	55 (55.0%)	100
Medium-low technology	30 (53.6%)	26 (46.4%)	56
Medium-high technology	74 (53.6%)	64 (46.4%)	138
High technology	9 (29.0%)	22 (71.0%)	31
ICT	11 (68.8%)	5 (31.3%)	16
Sector (no. of firms)			
Food and beverage	16 (31.4%)	35 (68.6%)	51
Leather product	3 (33.3%)	6 (66.7%)	9
Chemical	21 (35.6%)	38 (64.4%)	59
Fabricated metal	6 (40.0%)	9 (60.0%)	15
Machinery	14 (58.3%)	10 (41.7%)	24
Electrical equipment, appliance and component	11 (50%)	11 (50%)	22
Medical, measuring and control instruments	3 (33.3%)	6 (66.7%)	9
Transportation equipment	30 (63.8%)	17 (36.3%)	47
ICT	11 (68.8%)	5 (31.3%)	16
R&D activity			
Mean R&D expenditure as % of profits	10.4	15.3	13.4
Mean of HR in R&D	7.9	30.7	19.4
Mean of HSHR in R&D	1.0	7.3	4.2
Innovative firms	169 (49.5%)	172 (50.4%)	341
Type of innovation			
Product innovation	158	159	317
Improvement of an existent product	53 (33.5%)	31 (19.4%)	84
First for the firm	38 (24.0%)	36 (22.6%)	74
First for the Country	40 (25.3%)	43 (27.8%)	83
World first	27 (17.0%)	49 (30.8%)	76
Process innovation	159	163	322
Improvement of an existent process	85 (53.4%)	55 (33.7%)	140
First for the firm	43 (27.0%)	46 (28.2%)	89
First for the Country	23 (14.4%)	33 (20.2%)	56
World first	8 (5.0%)	29 (17.7%)	37

Source: Authors´ own.
Sample: 341 innovative firms.

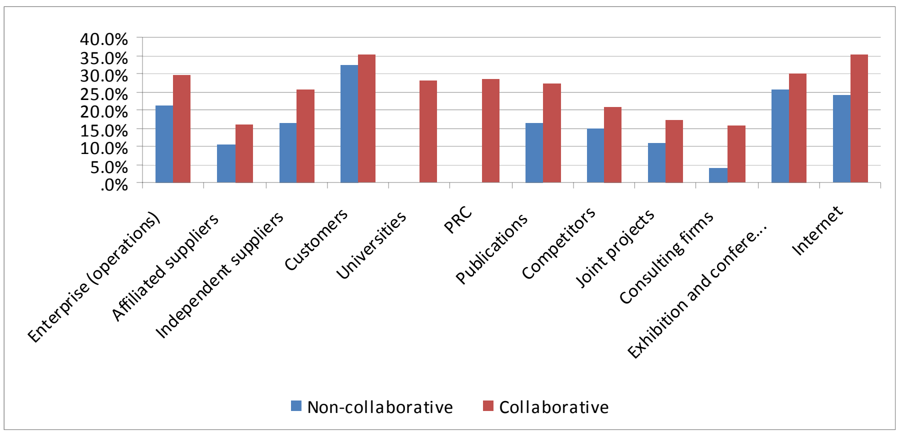
Table A.13. Profile of the total Sample, collaborative and non-collaborative academic researchers

	Non-collaborative	**Collaborative**	**Total Sample**
Researchers			
Type of research organization	149 (33%)	302 (67%)	451
University	113 (39%)	177 (61%)	290
Public Research Centre	36 (22.4%)	125 (77.6%)	161
Research activity orientation	149 (33%)	302 (67%)	451
Basic Science	75 (66.4%)	38 (33.6%)	113
Applied Science	64 (26%)	182 (74%)	246
Technology development	9 (10.2%)	79 (89.8%)	88
Other	1 (25%)	3 (75%)	4

	Non-collaborative	Collaborative	Total Sample
Main results, productivity per researcher			
Applied patents			
National	0.2	0.7	0.5
International	0	0.1	0.1
Granted patents			
National	0.1	0.4	0.3
International	0	0	0
Software	0.1	0.4	0.2
Published papers in ISI	8.8	8.1	8.3
Who financed projects			
Academy	96 (37.6%)	159 (62.4%)	255
Firm		146 (100%)	146
Angel capital		14 (100%)	14
National institutions	105 (34.7%)	197 (65.2%)	302
Private financing	4 (17.4%)	19 (82.6%)	23
International institutions	20 (32.8%)	41 (67.2%)	61
Economic benefits			
Institutional economic benefits	65 (24.2%)	204 (75.8%)	269
Personal economic benefits	26 (22%)	92 (78%)	118

Source: Authors´ own.
Sample: 451 researchers.

Figure A.2 Innovative firms´ main knowledge sources for technology development



Source: Authors´ own.
Sample. 341 innovative firms.

Table A.14 Interaction by sector: firms´ perspective

	Academy	Universities	PRC	No. of firms
Food and beverage	64.7%	41.2%	47.1%	51
Leather product	66.7%	33.3%	55.6%	9
Chemical	59.3%	50.8%	42.4%	59
Fabricated metal	53.3%	46.7%	26.7%	15
Machinery	37.5%	29.2%	20.8%	24
Electrical equipment, appliance and component	50.0%	36.4%	36.4%	22
Medical, measuring and control instruments	66.7%	66.7%	44.4%	9
Transportation equipment	34.0%	14.9%	25.5%	47
ICT	28.6%	28.6%	14.3%	16
Total	49.0%	33.9%	31.9%	341

Source: Authors´ own.
Sample: 341 innovative firms.

Table A.15 Knowledge flows by type of sector

	Food and beverage	Leather product	Chemical	Fabricated metal	Machinery	Electrical equipment, appliance and component	Medical, measuring and control instruments	Transportation equipment	ICT
Scientific publications and reports	2.6	2.9	2.6	2.4	1.9	2.2	2.1	1.9	2.5
Public conferences and meetings	2.5	2.9	2.4	2.3	1.9	2.0	2.3	1.9	2.4
Informal information from personal contacts	2.3	2.3	2.1	2.1	2.1	2.1	2.3	1.9	2.1
Networks that include universities	2.3	2.6	1.9	1.8	1.7	1.8	2.2	1.7	2.2
Hiring students recently graduated	2.2	2.6	2.2	2.1	2.1	2.1	2.5	2.0	2.4
Internships	2.4	2.6	2.3	2.6	2.5	2.3	2.6	2.2	2.3
Temporal staff exchange (staff mobility programs)	1.9	2.3	1.7	1.9	1.6	1.4	1.9	1.6	1.7
Consultancy by PRO staff members	2.5	2.7	2.2	2.2	1.6	1.8	2.3	1.7	2.5
Training	2.5	3.1	2.4	2.6	2.0	2.4	2.9	2.2	2.5
Contract research with universities	2.4	2.6	2.1	2.0	1.8	1.9	2.4	1.6	2.3
Joint R&D projects	2.6	2.7	2.3	2.6	2.0	2.0	2.4	1.9	2.6
Technology licenses	2.0	2.9	1.8	1.8	1.8	1.6	1.8	1.6	2.2
Patents	2.1	2.9	2.1	1.9	1.7	1.7	2.2	1.7	1.7
Incubators	2.0	2.8	1.6	1.6	1.8	1.5	1.9	1.4	2.1
Science and technology parks	1.9	2.7	1.7	1.9	1.8	1.7	1.8	1.6	2.1
The firm is owned by the university	1.4	1.5	1.3	1.2	1.2	1.3	1.5	1.2	1.4
Spin-off	1.5	1.5	1.3	1.2	1.3	1.3	1.5	1.3	1.4
Average per sector	2.2	2.6	2.0	2.0	1.8	1.8	2.2	1.7	2.1
Total of firms	51	9	59	15	24	22	9	47	14

Source: Authors´ own.
Sample: 250 firms

References

Aboites Aguilar, J., J.M. Domínguez and T. Beltrán Oviedo (2004), *La tríada innovadora: investigación y desarrollo en catálisis: la experiencia del Instituto Mexicano del Petróleo*, México: Siglo XXI.

Albuquerque, E., W. Suzigan, S. Cário, A. Fernandes, W. Shima, J. Britt et al. (2008), "An investigation on the contribution of universities and research institutes for maturing the Brazilian innovation system: Preliminary Results", paper presented at the *Globelics Conference*, Mexico City.

Arocena, R. and J. Sutz (2005), "Latin American Universities: From an original revolution to an uncertain transition", *Higher Education*, 50, 573-592.

Arza, V. and López, A. (2008), “Characteristics of university-industry linkages in the Argentinean Industrial Sector”, paper presented at the *Globelics Conference*, Mexico City.
Balconi, M. and A. Laboranti (2006), University-industry interactions in applied research: the case of microelectronics, *Research Policy*, 35 (10), 1616-1630.
Bekkers, R., and I.M. Bodas Freitas (2008), “Analysing knowledge transfer channels between universities and industry: To what degree do sectors also matter?”, *Research Policy, 37*, 1837-1853.
Bell, M. and K. Pavitt (1995), "The Development of Technological Capabilities", in I.u. Haque (ed.), *Trade, Technology and International Competitiveness*, pp. 69-101, Washington, The World Bank.
Bozeman, B. and Corley E. (2004), “Scientists’ collaboration strategies: Implications for scientific and technical human capital”, *Research Policy, 33*, 599–616.
Brimble, P. and R. Doner (2007), “University–Industry Linkages and Economic Development: The Case of Thailand”, *World Development*, *35* (6), 1021-1036.
Bruce, C. (2004), *Technology transfer at Canadian Universities: Fiscal Year 2002 update.* Canada: Report for the Canada Foundation for Innovation.
Carayol, N. (2004), “Objectives, agreements and matching in science–industry collaborations: reassembling the pieces of the puzzle”, *Research Policy, 32*, 887–908.
Cassiolato, J.E., H.M.M. Lastres and M.L. Maciel (ed) (2003), *Systems of Innovation and Development. Evidence from Brazil*, Edward Elgar: Cheltenham.
Cimoli, M. (ed.), *Developing Innovation Systems, Mexico in the Global Context*, London: Pinter Publisher.
Cohen, W. and Levinthal, D. (1989), “Innovation and Learning: The two faces of R&D”, *The Economic Journal*, 99, 569-596.
Cohen, W., R. Nelson and J. Walsh (2002), “Links and Impacts: The influence of public research on industrial RandD”, *Management Science* , *48* (1), 1-23.
Criscuolo, P. and Narula, R. (2002), “A novel approach to national technological accumulation and absorptive capacity: aggregating Cohen and Levinthal”, Paper presentado en DRUID.
Díaz, C. and R. Arechavala (2008), “The Role of Public Research Institutes in Innovation Networks”, paper presented at the *Globelics Conference*, Mexico City.
Doutriaux, J., and A. Soronodo (2005), “University-Industry Cooperation: Comparing the Canadian and Uruguayan experiences”, *Working paper # 05-44, School of Management* .
Eom, B., and K. Lee (2008), “The Determinants of industry-university/GRI linkages and their impacts on firm performance: The case of Korea”, paper presented at the *Globelics Conference*, Mexico City.
Etzkowitz, H., and L. Leydesdorff (2000), “The dynamics of innovation: From National Systems and "Mode 2" to a Triple Helix of university-industry-government relations”, *Research Policy*, *29*, 109-123.
Fontana, R.; A. Geuna and M. Matt (2006), “Factors affecting university–industry R&D projects: The importance of searching, screening and signaling”, *Research Policy, 35*, 309–323.
Friedman, J., and J. Silberman (2003), “University technology transfer: Do incentives, management, and location matter?”, *Journal of Technology Transfer*, *28* (1), 17-30.
Giuliani, E. (2005), “Cluster Absorptive Capacity: Why do some firms forge ahead and others lag behind?”, *European Urban and Regional Studies*, Vol. 12 (3), 269-288.
Hanel, P., and M. St-Pierre (2006), “Industry-University Collaboration by Canadian Manufacturing Firms”, *Journal of Technology Transfer* , *31*, 485-499.
Intarakumnerd, P. and M. Schiller (2008), “University-Industry Linkages in Thailand: Successes, Failures and Lessons Learned for other Developing Countries”, paper presented at the *Globelics Conference*, Mexico City.
Kodama, T. (2008), “The role of intermediation and absorptive capacity in facilitating university-industry linkages- An empirical study of TAMA in Japan”, *Research Policy, 37*, 1224-1240.
Kruss, G. (2008) “Knowledge-intensive university spin-off firms in South Africa: Fragile network alignment?”, paper presented at the *Globelics Conference*, Mexico City.

Lall, S. and C. Pietrobelli (2002), *Failing to Compete. Technology development and technology systems in Africa*, Edward Elgar.

Laursen, K., Salter, A. (2004), Searching high and low: what types of firms use universities as a source of innovation?. *Research Policy,* 33, 1201-1215

Lawton, H. (2006) *Universities, Innovation and the Economy.* Oxon, Great Britain: Routledge.

Levin, R. (1988), "Appropriability, R&D spending and technological performance", The American Economic Review, 78 (2), 424-428.

Lorentzen, J. (2005), "The Absorptive Capacities of South African Automotive Component Suppliers", *World Development*, Vol. 33 (7), 1153-1182.

Lundvall, B. and S. Borrás (2005), "Science, Technology and Innovation Policy", in J. Fagerberg, D. Mowery, and R. Nelson (Eds), *The Oxford Handbook of Innovation* (p. 656). Oxford: Oxford University Press.

Mani, S. (2004), "Government, innovation and technology policy: an international comparative analysis", *International Journal of Technology and Globalisation*, Vol. 1 (1), 29-44.

Mansfield, E. (1991), "Academic research and industrial innovation", *Research Policy, 20*, 1-12.

Melin, G. (2000) "Pragmatism and self-organization Research collaboration on the individual level", *Research Policy, 29*, 31–40

Meyer-Krahmer and Schmoch (1998), "Science-based technologies: university-industry interactions in four fields", *Research Policy*, Vol. 27 (8), 835-851.

Monjon, S. and P. Waelbroeck (2003), "Assessing spillovers from universities to firms: Evidence from French firm-level data", *International Journal of Industrial Organization, 21*, 1255-1270.

Motohashi, K. (2005) "University-industry collaborations in Japan: The role of new technology-based firms in transforming the National Innovation System", *Research Policy, 34*, 583-594.

Mowery, D. and B. Sampat (2005), "Universities in National Innovation Systems", in J. Fagerberg, D. Mowery, and R. Nelson (Eds), *The Oxford Handbook of Innovation*, Oxford: Oxford University Press.

Muchie, M., P. Gammeltoft and B.A. Lundvall (eds), (2003), *Putting Africa First. The making of African innovation systems,* Aalborg University Press.

OECD. (2002). *Benchmarking Industry-Science Relationships.* Paris: OECD.

Oyelaran-Oyeyinka, B. (2006), *Learning to Compete in African Industry. Institutions and Technology in Development*, Aldershot: Ashgate.

Pavitt, K., (1984), "Sectoral patterns of technical change: Towards a taxonomy and a theory", *Research Policy*, 31, 1163-1180.

Petersen, I. and J. Rumbelow (2008), "University-Firm Interaction in South Africa: Extent and Intensity", paper presented at the *Globelics Conference*, Mexico City.

Rivera, R., J.L. Sampedro, G. Dutrenit, J.M. Ekboir and A.O. Vera-Cruz (2009), "Commercial farmers-academic researchers linkages and researcher productivity: The Mexican case", paper presented in Globelics VII, Dakar, Senegal.

Rosenberg, N. and R. Nelson (1994), "American universities and technical advance in industry", *Research Policy,* (23), 323-348.

Schartinger, D., C. Rammer, M. Fischer and J. Frohlich (2002), "Knowledge interactions between universities and industry in Austria: sectoral patterns and determinants", *Research Policy*, 31, 303-328.

Sutz, J. (2000), "The university-industry-government relations in Latin America", *Research Policy*, Vol. 29, pp. 279-290

Swann, G.M.P. (2002), Innovative business and science and technology base: An analysis using CIS3. Data report for the Department of Trade and Industry, DTI, London, UK

Welsh, R., L. Glenna, W. Lacy and D. Biscotti (2008), "Close enough but not too far: Assessing the effects of university-industry research relationships and the rise of academic capitalism", *Research Policy, 37*, 1854-1864.