**Are “star scientists” connecting to industry? Analyzing industry-university knowledge flows in the Argentinean biotechnology activity.**

**Abstract**

Universities and public research institutions are one of the most relevant sources for firms’ innovation activity. Data on Argentinean biotech researchers is used to trace knowledge flows within the academic community and between science and industry. We found that the Argentinean biotech scientific activity is not isolated from the international scientific community, but connected through researchers that collaborate both with local peers and with foreign colleagues. These researchers (who we call ‘international academic gatekeepers’) perform a boundary spanning role which can be very valuable to channel world leading research into their location. These researchers are also ‘star scientists’, that is, outstanding researchers in terms of their publication activity. To address the micro-determinants of U-I interactions we studied whether researchers’ characteristics and position in the academic network affect their likelihood to connect to industry. We found that neither ‘star scientists’ nor ‘international academic gatekeepers’ are conduits of knowledge to the local industry. Other factors such as holding a PhD degree or get involved in PhD thesis supervision increase researchers’ likelihood to connect to industry. Our study provides new empirical evidence to a non-conclusive debate in the literature: which is the kind of knowledge that is valuable for industry?

**INTRODUCTION**

‘There is no applied science if there is no science to be applied’ used to say the Argentinean Professor Bernardo Houssay, Nobel Prize laureate in Medicine. Accordingly, we take a deep look to the scientific activity in the biotech field in Argentina so to better understand the current and the potential development of the Argentinean biotech industry.

We know that firms' access to knowledge generated outside their boundaries contributes to their economic and innovative performance.[[1]](#footnote-1) And, universities and public research institutions (PROs) are often highlighted as one of the most relevant sources for firms’ innovation activity.[[2]](#footnote-2) This is especially the case for those firms active in science-driven sectors.[[3]](#footnote-3)

A vast stream of literature has focused on firms’ motives to interact with the scientific world. However, we adopt a different, but complementary, approach. We start by looking at the scientific world itself, and then analyze one possible channel through which scientific knowledge flows to the industrial world: scientists’ involvement in R&D projects with industry.

We base the study on the scientific and industrial biotechnology activity in Argentina. We have personal and professional data of Argentinean biotech researchers working for Argentinean PRO in two provinces: Santa Fe and Cordoba. In the first part of the paper we shed light on scientists’ sources of knowledge outside of the world leading regions. We intend to address how researchers share and exchange knowledge with colleagues, and to what extent scientific collaborative efforts are limited to local interactions. We trace scientific collaborations by analyzing scientific publications co-authorships. We explored the co-author network in order to identify researchers´ collaborative patterns. We found that many researchers participate in the international academic community but who are also rooted in the local scientific one. We name them ‘international academic gatekeepers’. We argue that the value of these researchers is that, through their external collaborations, they can have access to novel, and even frontier knowledge, which they can diffuse within the local community. Researchers scientific collaborations outside the local scientific community can be a way to refresh and update the local scientific knowledge base.

Then, we analyze who are the researchers that collaborate with industry. We know that researchers can be important conduits of knowledge from the scientific world to the industrial sphere. For instance, ‘star scientists’ (outstanding researchers in terms of their publication productivity) acting as boundary spanners between industry and science have been key for the development of the US biotech industry (Zucker et al 1998). However, from a developing country point of view, ‘good’ science-industry spanners should not only be outstanding scientists but, more importantly, those who can channel world leading research into the local community. These researchers can constitute vehicles through which local firms’ update and enhance their knowledge bases. Thus, we address the extent to which ‘international academic gatekeepers’ further channel knowledge to the local industry.

This paper is structured as follows. Section 1 reviews the literature on gatekeeping. We show how the gatekeeper concept can be useful to understand how knowledge flows both within the academic community and between science and industry. Section 2 analyses the scientific collaborative patterns in the biotech field in Argentina and addresses the characteristics of those researchers acting as ‘international academic gatekeepers’. Section 4 focuses on U-I interactions and analyses the characteristics of those researchers which are most likely to collaborate with industry. Section 5 provides a discussion of the obtained results

**SECTION 1 - THEORETICAL BACKGROUND**

**The gatekeeper concept**

The idea of gatekeeping was introduced by Lewin (1947) within the psychology field.[[4]](#footnote-4) Gatekeepers are those individuals that are positioned in a way so that they bridge previously unconnected groups. Their position gives them certain control over information flows. Rogers (1976) describes what a gatekeeper is by saying that `if you have ever tried to get a rush memo to your boss, and his secretary told you that he was `in conference' you know what a gatekeeper is' (page 134). In addition, a gatekeeper also has advantages in terms of having access to non-redundant sources of information. Their position, named ‘structural hole’ by Burt (1992), gives them advantages in terms of having access to information which can be ‘more additive than overlapping’ (Burt 2001, page 5).

The literature on organizational communication took the idea of gatekeeping, and further transformed it into the ´technological gatekeeper´ concept (Allen 1964, Allen 1966, Allen 1977, Tushman 1977). This stream of literature studies how firms acquire external technological and scientific information by looking at how R&D employees keep aware of research results obtained outside the company they work for.[[5]](#footnote-5) Research findings show that new technical information penetrates the R&D department of a firm in a two step-process. The information flows into the organization through a set of `key individuals' who channel this information to other organization's members. These key people, labelled ‘technological gatekeepers’, are simultaneously the most externally and internally connected employees.[[6]](#footnote-6) In terms of their external organization communication, they have a broader range of contacts outside the organizations (maintained through a formal and informal basis) than the average of their internal colleagues. As regards their internal connections, they are the ones to whom other colleagues working in R&D frequently turn for technological information and advice.

The technological gatekeeper can also be a vehicle to transfer knowledge to less developed firms or areas (Allen et al 1971). Allen et al (1971) claim that a small country faces the same need for external information as any company because neither of them can be technologically self-sufficient. Therefore, there is a need for an ‘international technological gatekeeper’ that belongs to two networks: the external network of foreign information sources and the internal network of information users. Developing countries should ‘engender’ international knowledge gatekeepers by assisting educated people to do research abroad (or any other forms to extend their foreign technical experience).[[7]](#footnote-7) Studies about less developed countries’ scientific community have shown both the existence and relevance of ‘international academic gatekeepers’.[[8]](#footnote-8) In addition, Barnard et al (2010) found that in the local scientific community of South-Africa, ‘international academic gatekeepers’ are the most competent and productive researchers. This evidence is aligned with the ideas of Allen (1977) who identified three characteristics that technological gatekeepers usually have (in the context of firms): they are high technical performers, most gatekeepers are first-line supervisors, and they are those whom technical managers generally recognize as having such a role.

A relevant condition for the international gatekeeper to exist, and for its role to be useful, is the existence of a sufficient level of knowledge overlap between individuals in order to ensure effective communication (Cohen and Levinthal 1989). In the case of academic collaborative networks, local scientists need to have accumulated the necessary knowledge to be able to access and profit from world leading research, and then, other local researchers need to also have the necessary absorptive capacity to further take advantage of that knowledge. In a study of international collaboration between Asia and Europe in a science-driven area, such as stem cell research, it is shown that researchers sharing similar professional or scientific standards help for international cooperation (Wink 2008).

In the case of the academic community of biotech scientists in Argentina we intend to address the patterns of scientific collaborations as well as identifying the existence and characteristics of those researchers acting as `international knowledge gatekeepers'.

**Science and industry interaction**

Following the above described literature on gatekeeping we claim that for industry-science interactions to take place there must exist agents who are able to span the boundaries between the industrial and the academic world. We speculate that within the academic world, some researchers may play such ‘gatekeeper role’ spanning both worlds.

Zucker et al (1998) show that, for the US, firms’ access to cutting edge science, through their links to ‘star scientists’, was key to explain the creation and development of the biotech industry in that country. However, according to Gittelman and Kogut (2003), firms' access to ‘superior’ or frontier scientific knowledge do not necessarily lead them to produce successful technological innovations. Hence, the literature is not conclusive regarding the kind of scientific knowledge that is valuable for industry. In other high-tech industry as advanced materials, ‘Pasteur scientists’ rather than ‘start scientists’ were more prone to become gatekeepers between science and industry. The former differ from the latter in their stronger inclination towards conducting research that has a potential for real world application. For the tissue engineering field, Murray (2002) found that gatekeepers were scientists who tend to build inter-institutional ties across science and industry by performing sponsored research, licensing and firm founding.

Other factors that were found relevant to characterize U-I gatekeepers in the biotech field were researchers' age, citation history and Nobel status (Audretsch and Stephan 1996). In a less science-intensive sector such as the wine sector, Giuliani et al (2010) show that researchers' individual characteristics matter more in determining linkages with industry than the context and the organization in which they operate. In the wine industry, the most influential factors affecting collaboration of researchers with industry appear to be researchers' age, sex and their ‘centrality’ in the academic system.

In this study we contribute to the above literature by studying the characteristics of Argentinean biotech researchers that collaborate with the local industry. We investigate whether a researcher's position in the academic network (a ‘gatekeeper’ position) affects his propensity to collaborate with industry.

**SECTION 2 – SCIENTIFIC COLLABORATION**

**Data and method**

The study relies on data built upon a survey run by the ECLAC[[9]](#footnote-9) Buenos Aires office in the year 2010 to scientific researchers engaged in biotech research who were affiliated to PROs in two Argentinean provinces: Córdoba and Santa Fe. These two provinces account for a great deal of the biotechnology activity that takes place in Argentina.

One important characteristic of the survey is that its unit of analysis consists of those researchers who were directors of biotech research projects in 2010. Thus, the population of scientists is based on an elite of the most important researchers in the biotech field in the two Argentinean provinces.[[10]](#footnote-10) The unit of analysis chosen implies that the sample of researchers may not be representative of the universe of biotech researchers in Argentina, and hence, generalization of results should be with cautious.

The population of the study consists of 137 scientists that directed biotech research projects in 10 PROs in the province of Santa Fe and 168 researchers in 8 PROs located in the province of Cordoba.[[11]](#footnote-11)

Based on data of researchers' name and institutional affiliation we elicited the publication record of each researcher in the SCOPUS database for the period 1975-2011. We also gathered data regarding co-authors' location (of their institutional affiliation) with the aim of unravelling the spatial characteristics of the academic formal network (see Annex A).[[12]](#footnote-12)

The resulting formal academic network of Argentinean biotech researchers[[13]](#footnote-13) is made up by the focal nodes (who are those researchers that lead biotech research projects in PROs located in Santa Fe and Cordoba provinces) and their partners (who are the focal nodes' co-authors). When focal nodes are connected, they have co-published papers with other researchers in the period analyzed. Co-authors are differentiated according to the location of their institution affiliation.

**Scientific collaborative patterns: results**

The analysis of the scientific collaborative networks of Argentinean biotech researchers shows that researchers frequently collaborate both with local and foreign peers. In Table 1 we show some network statistics to help to understand the dynamics of the collaborative networks (the network visualizations are provided in Annex B).

**Table1: Network statistics**

|  |  |  |
| --- | --- | --- |
|  | **Santa Fe** | **Córdoba** |
| **Focal nodes** | **138** | **168** |
| **Isolates** | **8** | **40** |
| **Average degree** | **91.35** | **47.29** |
| **Total partners** | **3476** | **2777** |
| **-Argentinean partners** | **1580** | **1708** |
| **-External partners** | **1896** | **1067** |

In the co-authorship network between 75% and 95% of researchers in Cordoba and Santa Fe, respectively, have forged collaborations. A large share of researchers’ collaborations is internationalized. For instance, in the case of Santa Fe, co-authors of biotech researchers are mostly foreigners (1896 of a total of 3476). The level of internationalization of researchers' co-authors may have to do with research topics (some topics are more focused on local needs while others are more international in scope) and researchers' knowledge distance to the frontier.

Interestingly, we observe that non-local links are not randomly made but purposively directed towards the world-leading regions(see Table 2). Foreign co-authors located in the US are the most frequently chosen. They are followed by European researchers located in countries such as Spain, Italy, Germany, France and the UK. Researchers from Japan, which is the second most important country in terms of scientific production in biotechnology (Albornoz, 2008), are also among those partners more often chosen by Argentinean biotech scientists. Among Latin American countries, Brazil emerges as an important partner regarding scientific collaboration in biotech, followed by Mexico and Chile.

**Table 2- Foreign Partners in the co-authorship network –Top 10 countries**

|  |  |
| --- | --- |
| **Santa Fe** | **Córdoba** |
| **Origin researchers’ co-authors**  | **No. Co-authors** | **Origin researchers’ co-authors**  | **No. Co-authors** |
| United States | 519 | United States | 359 |
| Brazil | 244 | Spain | 174 |
| Spain | 235 | Brazil | 88 |
| Germany | 150 | Germany | 76 |
| Italy | 115 | France | 39 |
| France | 109 | U.K. | 36 |
| U.K. | 83 | Chile | 35 |
| Portugal | 49 | Italy | 25 |
| Japan | 44 | Japan | 21 |
| Mexico | 34 | Sweeden | 19 |

The observed frequency of collaborations with colleagues in biotech leading regions leads us to put forward the following thoughts. First, collaborations may effectively be vehicles that enable access to frontier knowledge. Second, although scientists affiliated to Argentinean academic institutions may investigate topics related to local problems; they also perform research that is appealing for the international academic community. Last but not least, there is a critical mass of researchers in Argentina with enough absorptive capacity to be able to jointly investigate and publish with colleagues in the world-leading biotech regions.

How many of these researchers collaborate both locally and externally? We made use of the degree centrality measure[[14]](#footnote-14) to identify researchers' networking patterns. We classified researchers in the following categories: ‘local stars’, ‘external stars’, ‘international academic gatekeepers’ and ‘isolates’.

‘Local stars’ are researchers that co-author publications only with researches located in Argentina; ‘external stars’ are researchers that or co-author publications only with colleagues located in other countries; ‘international academic gatekeepers’ are researchers that co-author publications both with colleagues in Argentina and abroad[[15]](#footnote-15); and, ‘isolates’ are researchers who do not co-author publications with other colleagues in the period analyzed.

Table 3 shows the number of researchers that play the different network roles described above. The share of researchers acting as ‘international knowledge gatekeepers’ is noteworthy. In the co-authorship network these researchers account for 70% of the biotech scientists located in Santa Fe province (107 researchers) and a half of researchers in Cordoba province (87). In an emerging country, the value of having international academic gatekeeper is that they can be channels through which world-leading research, carried out in other countries, enters the local academic community.

**Table 3 Distribution of researchers by network position**

|  |  |  |
| --- | --- | --- |
| **Network position** | **Santa Fe** | **Córdoba** |
| **Local Star** | **21** | **39** |
| * Within researchers’ province
 | 9 | 20 |
| * Within Argentina
 | 12 | 19 |
| **External Star** | **1** | **1** |
| **International Academic Gatekeeper** | **107** | **88** |
| * Locally-oriented
 | 74 | 66 |
| * Externally-oriented
 | 33 | 22 |
| **Isolates** | **8** | **40** |

**Who are the ‘international academic gatekeepers’?**

In the last part of this section we analyse the characteristics of those researchers that perform the role of ‘international academic gatekeeper’ spanning the local and the international scientific community. We employ *Bonferroni* and *Kruskal Wallis* tests to identify researchers’ personal and professional characteristics that differ across researchers’ positions in the academic network. We aim at unravelling whether ‘international academic gatekeeper’ are in any sense ‘different’, apart from their networking patters, from other local researchers.

The analysis is based on a sample of Santa Fe and Cordoba researchers. We have more detailed personal and professional data for 30 researchers in Santa Fe and 66 in Córdoba. The sample includes researchers from the most relevant, in terms of number of researchers, public research institutions and universities. In addition, it provides a good representation of these largest institutions, but overestimates some of the smaller ones. [[16]](#footnote-16)

**Table 4 - Variables**

|  |  |
| --- | --- |
| **Variable Name** | **Description** |
| Gender | Share of female researchers |
| Age | Average age of researchers |
| PhD | Share of researchers with a PhD diploma |
| Study Abroad | Share of researchers with educational experiences in other countries |
| Institution | Share of researchers aﬃliated to universities |
| Articles | Average number of articles published in the period 1979-2010 that shows up in SCOPUS database |
| Patents | Average number of patents applied by Researchers |
| Citations | Average number of citations in SCOPUS database, corrected by number of publications and researchers’ age |
| Thesis Supervision | Average number of PhD and Post-doc students supervised in the period 2005-2010 |
| Cooperations | Average number of R&D collaborations and technology transfers regarding the most relevant research project in 2010 |

*Descriptive analyses –* ‘International academic gatekeepers’, ‘local stars’ and ‘isolates’ differ in a significant way in the degree of education achieved, their productivity in terms of publications, the quality of their work and their dedication to supervised PhD and post-doc thesis (see Table 5). Some comments about these findings are provided below.

The share of scientists that have a PhD degree and that had educational experiences in other countries is higher for gatekeepers than for the other two types of researchers. However, the major difference among the three groups, which is also statistically significant, is the share of researchers that have PhD degree. Around 90% of gatekeepers have a PhD diploma, whereas 78% of `local stars' and 57% of isolates are also PhDs graduates. The relevance of holding an advanced educational degree was also found significant to explain professional interactions of agricultural researchers in Ghana, Kenya and India with colleagues in the developed world (Shrum and Campion, 2000).

**Table 5 – Researchers’ characteristics**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variables | Gatekeepers[Mean (S.D.)] | Local Stars[Mean (S.D.)] | Isolates[Mean (S.D.)] | Sig. ¹,² |
| Gender (% Female) Age (number) | 44.44(0.50) 48.96 (9.58) | 68.42 (0.46)47.92 (9.95) | 57.14 (0.51)47.91 (9.61) |  |
| PhD (%)Study abroad (%) | 92.06(0.27) 66.67 (0.47) | 73.68 (0.42)42.11 (0.51) | 57.14 (0.51)50.00 (0.51) | \*\* |
| Institution(% Universities) | 60.38 (0.49) | 84.21 (0.42) | 85.71 (0.36) | \* |
| Articles (number) Patents (number) | 23.60 (17.29) 0.85 (1.80) | 7.42 (4.27)0.71 (1.72) | 00.21 (0.8) | \*\*\* |
| Citations corrected | 0.20 (0.20) | 0.10 (0.11) | 0 | \*\*\* |
| Thesis supervision (number) | 4 (3.89) | 2.31 (2.16) | 1.07 (1.89) | \*\* |
| Cooperations (number) | 1.03 (1.59) | 0.5 (0.75) | 0.57 (1.28) |  |

¹ Levels of signiﬁcance: 10% (\*), 5% (\*\*) and 1% (\*\*\*).

² The *Bonferroni test* was performed for the variables *No. Articles*, *Patents*, *Citations*, *Alliance*, *Age* and *Number PhD thesis supervised*. In addition, the *Kruskal Wallis test* was performed for the following variables: *gender*, *institution*, *PhD*, *Studies Abroad* and *Academic and Non-academic activities*.

Surprisingly, there are not significant differences regarding the share of researchers that studied in other countries. We expected that researchers that studied abroad would have an advantage regarding the possibility to co-author papers with foreign authors in comparison to other researchers. This expectation relies on the idea that studying abroad is a fruitful way through which researchers could expand their range of contacts outside their country of residence. However, we do not find evidence to support this idea. Similar results were found by Shrum and Campion (2000).

As regards researchers' productivity, number of articules published is the only statistically significant variable. Local stars published less than a third of what gatekeepers have published between 1979 and 2010. Isolates are researchers that do not have publications that show up in SCOPUS database during the period.[[17]](#footnote-17) Hence, gatekeepers are ‘star scientists’ as Zucker et al (1998) defined them. In addition, gatekeepers' work is more cited than that of `local stars', and that difference is statistically significant.[[18]](#footnote-18)

Another statistically significant difference among the types of researchers analyzed is the extent to which they supervised PhD and post-doc students. On average, a gatekeeper supervised 4 students in the period 2005-2010. However, local stars supervised two and isolates just one student in the same period. Given that gatekeepers are the ones with the higher publication rates, their work tends to have a higher impact and relevance (measured by their degree of citation) and with relatively more patents, we can expect that students chose them to supervise their work. Our evidence contradicts Shrum and Campion (2000) who find that thesis supervision negatively affects professional collaborations.

Another observation is that gatekeepers are relatively less affiliated to universities than ‘local stars’ and isolates are.

**SECTION 3 UNIVERSITY-INDUSTRY COLLABORATIONS**

Are ‘international academic gatekeepers’ conduits through which the local industry accesses frontier and novel knowledge? In this section we contribute to understand the micro-determinants of U-I interactions.

**Data and variables**

The analysis is based on the same sample of researchers employed in the previous section. The dependent variable is the count of R&D collaborations and transfers of technology that researchers have engaged regarding their most relevant research project in 2010.[[19]](#footnote-19)

In addition to the explanatory variables employed in the previous section (and described in Table 4), we incorporated a set of variables related to researchers’ position in the academic collaborative network and the variable Age2. Measures of researchers' position in the academic network are introduced to test whether researchers with diverse positions in the academic network are likely to provide different type of knowledge to firms. The variables introduced are the following:

GATEKFORMAL. It measures the ratio of non-local collaborations to the average shortest weighted path of a researcher to all others in the local network. This is the gatekeeping measure introduced by (Barnard et al, 2010).

GATEKINF. It is a dummy variable which takes the value 1 for those researchers that exchange knowledge in an informal way both with colleagues in the local academic community and with colleagues located in other countries.[[20]](#footnote-20) With the introduction of this variable we aim at capturing whether researchers’ that are embedded in a collaborative network, but not necessarily a formal one, are valuable for industry.

GATEK-LINKED. It is a dummy variable which takes the value 1 for those researchers who are not themselves gatekeepers but who are (directly and undirectly) connected to others who are. We aim at controlling if those researchers who are not academic gatekeepers themselves, but are connected to those which are, are the ones who are likely to interact with industry.

LOC-CONNECT. It indicates the centrality of the researcher in the local academic network. It is measured by calculating the number of direct links (number of co-authors) that the researcher has within the Argentinean scientific community. The more central a researcher is, the more knowledge he/she has access to, and the more valuable the researcher becomes for the industry as a source of knowledge.

In addition, we introduced the variable Age2 to test for a curvilinear relation between age and the propensity to become a gatekeeper. We expected that mid-age researchers are more likely to become gatekeepers than younger or older scholars.

**Results**

We adopted a negative binomial specification to model count data, and tried several models to explain collaborations between industry and academic researchers.[[21]](#footnote-21) Model 1 considers demographic characteristics, educational background, academic activities (thesis supervision), and controls (location and institution affiliation of researchers). Model 2 incorporates variables related to researchers' productivity and prestige. And, Model 3 adds the network position variables. Table 6 illustrates the results.

Women and younger scholars have the highest propensity to collaborate with industry. Similar results were found by Giuliani et al (2010) when analyzing U-I interactions in the wine sector. However, in contrast to their results, we do not find our results to be statistically significant.

Researchers that hold a PhD diploma are more prone to collaborate with industry. However, neither their position in the academic network nor researchers' productivity or their research quality affect the likelihood that researchers engage in cooperations with biotech firms. Therefore, we could say that even though scientists’ knowledge is valued by industry, their potential access to cutting edge science in not perceived as that valuable by industry.

**Table 6 Determinants of collaborations with industry - Negative binomial speciﬁcation**

|  |  |  |  |
| --- | --- | --- | --- |
| Variables | Model 1 | Model 2 | Model 3 |
| Gender | 0.28 (0.33) | 0.41 (0.37) | 0.40 (0.36) |
| Age | -0.05 (0.14) | -0.03 (0.14) | -0.06 (0.14) |
| Age2 | 0.001 (0.05) | 0.001 (0.001) | 0.001 (0.001) |
| PhD | 1.60 (0.82) | 1.62 (0.83) | 1.67 (0.84)\* |
| Study Abroad | -0.02 (0.39) | -0.11 (0.40) | 0.05 (0.40) |
| Thesis Supervision | 0.11 (0.04)\* | 0.11 (0.04)\* | 0.13 (0.04)\*\* |
| Publications |  | -0.002 (0.01) | -0.009 (0.01) |
| Patents |  | 0.05 (0.11) | 0.08 (0.11) |
| Citations |  | 0.94 (0.93) | 0.82 (0.96) |
| GATEKFORMAL |  |  | -0.01 (0.06) |
| GATEKINF |  |  | -0.98 (0.56) |
| LOC-CONNECTED |  |  | 0.005 (0.01) |
| GATEK-LINKED |  |  | -0.21 (0.70) |
| Controls |  |  |  |
| Location | -0.79 (0.36)\* | -0.72 (0.37) | -0.62 (0.36) |
| Organization | -0.19 (0.37) | 0.01 (0.41) | -0.08 (0.40) |
| Constant | -1.43 (3.64) | -2.51 (3.82) | -1.80 (0.37) |
| Number of Obs | 96 | 96 | 96 |
| Alpha | 1.07 (0.41) | 0.96 (0.40) | 0.82 (0.38) |

Levels of signiﬁcance: 10% (\*), 5% (\*\*) and 1% (\*\*\*)

**Table 6 Correlation Matrix**

Surprisingly, the other variable that affects researchers' interactions with industry is their involvement in thesis supervision. Thus, we arrive at the original finding that those researchers that have been more engaged in supervision of PhD or Post-doc students in the period 2005-2010, were more prone to be engaged in R&D collaborative work with firms in 2010. We could naturally think that devoting time to thesis supervision, reduces the time available to do other type of activities such as R&D collaboration with industry. However, we observe the opposite effect. Some explanations for the obtained result can be that by supervising students researchers they may be encouraged to perform more applied work. We can think of two ways through which the researcher is connected to the industry. One is that researchers are linked to the industry through their PhD students' projects in which themselves are involved (e.g. a student who has a PhD project related to the development of a process technology that can be useful for certain type of industries or who discovers something that can be potentially useful for industrial processes). The other, which for us seems more likely, PhD students may then work for the industry and the former supervisor becomes the natural academic connector.

**SECTION 4 - CONCLUDING REMARKS**

This paper has analyzed Argentinean researchers' collaborative scientific activity in the biotech field. We studied scientific collaboration activity based on co-authorship data. We found that researchers shared knowledge almost equally with colleagues located in Argentina and in other countries. And, that the geographical scope of non-local collaborations was very much concentrated on the biotech world-leading centres.

Another set of results is related to researchers acting as gatekeepers within the academic community, and between the industrial and the academic world. Within the academic community we found that more than a half of biotech scientists share knowledge both at local and international level. As Schott (1993), Barnard et al (2010), Shrum and Champion (2000) and Ynalvez y Shrum (2009) also found, externally connected researchers are still very much locally embedded. We found that these ‘international academic gatekeepers’ are also ‘star scientists’ as Zucker (1998) defined them. Star scientists are researchers who have an outstanding performance in terms of publications. In the Argentinean case, academic gatekeepers double the number of publications obtained by researchers who only had local connections. Researchers' with higher publication performance are consulted by other colleagues, and may also have enough prestige to be able to span collaborations with researchers in other countries. Similar results were found by Barnard et al (2010).

As regards industry-science linkages our findings suggest that researchers that are ‘star scientists’ or who have a strategic position within the academic network are not more prone to collaborate with industry than any other researcher. This result is in contrast to what was found for the development of the US industry, where the most productive and prestigious researchers within the academia contributed to fuel the biotech industrial development Zucker (1998). In the Argentinean case, it seems that it is not the case. In this country, ‘star scientists’ may tend to be more focused on basic research, and their identity may be more aligned with the values and the reward system that characterized the academic world: the production of scientific publications. As Gittelman (2003) argues, the ‘most valuable’ knowledge for the scientific community may not necessarily be as valuable to generate industrial innovations. Industrial researchers may not perceive some cutting-edge scientific knowledge (that star scientists have access to) as valuable or may not have the necessary absorptive capacity to perceive its value (biotech research is characterised by a high degree of `natural excludability (Zucker et al 1998)).

We found that researchers' academic degree as well as their involvement in PhD and post-doc students' supervision are the most relevant factors that account for researchers’ likelihood to set up linkages to industry. Thus, industry does value educated researchers (holding a PhD degree), but not necessarily value as much those researchers that are on the frontier of the field (‘star scientists’). In addition, we found that PhD students can become links that connect scientific researchers and industry.

Our results contribute to better understand the micro-determinants of U-I interactions. In addition, they provide new empirical evidence to address a non-conclusive debate in the literature: ‘which is the kind of scientific knowledge that is valuable for industry?’. Further research should be done in this direction.

**ANNEX A – METHODOLOGICAL NOTES**

When creating the co-authorship network we faced some methodological problems related to the so-called “names game” (Trajtenberg et al, 2006). The latter refers to the difficulty to identify “who is who” within publication or inventor databases. Difficulties arise when, for instance, the same exact name appears with two or more institutional affiliations. This can be either because the same person has worked for different institutions or because we are facing a case of homonyms (the “John Smith” problem). The SCOPUS database provides an ID number for researchers which, in principle, could be useful to solve this problem. However, we encountered that, very frequently, a researcher's ID number is not unique (researchers may have more than one ID number). Another source of struggle arises due to the fact that same names may be spelled differently across publications or patents. A quite frequent source of error is when names have accents: they may appear with accents in some publications, and without accents in others.

Different methodologies have been proposed in order to tackle the `names game' in a comprenhensive way (Trajtenberg et al, 2006, Lissoni et al 2006, Raffo and Lhuillery 2009, Carayol and Cassi 2009). The drawback of the methodologies proposed is that each of them lead to different resulting outputs (Raffo and Lhuillery, 2009). However, a convergence emerged regarding the steps to follow to deal with the `names games' in a homogeneous way. These steps consist of three sequential stages: the parsing stage, the matching stage and the filtering stage. In this study, we followed these steps in order to generate the co-publication database of Argentinean biotech researchers.

On the parsing stage we cleaned the database removing blank spaces, symbols, accentuated characters and setting one case type. This step is meant to minimize the occurrence of false positives. That is to fail to match names which are the same. Then, the matching stage consisted of adopting a simple string match so that those agents that have identical or very similar names are presumed to be `suspects' of being the same person. This procedure, though restrictive, gives the highest precision rates (minimizes the chances of false positives) although do not perform that well in reducing false negatives. The adoption of this procedure coupled with other more sophisticated algorithms (e.g. vectorial decomposition algorithms such as N-Gram, Token, etc.) (Raffo and Lhuillery, 2009) or a bayesian approach (Carayol and Cassi 2009) may help to gain in efficiency by recovering true matches and discarding false ones. Therefore, the filtering stage becomes necessary to identify the `true' matches from the `false' ones. That is, decide whether the same names correspond to the same person. We performed this latter task by using complementary information about each researchers' institutional affiliation and city of residence.

**ANNEX B – CO-AUTHORSHIP NETWORKS’ VISUAL REPRESENTATION**

The networks of scientific collaboration of researchers located in Santa Fe and Cordoba provinces can be visualized in Figure 1 and 2 Annex B, respectively. In each graph representation the focal nodes are represented by white circles, other Argentinean researchers working in PROs of the country[[22]](#footnote-22) are depicted by grey circles and researchers located in other countries are the black squares.

**Figure 1- Collaborative networks of Santa Fe biotech researchers.**

**Figure 2 Collaborative networks of Cordoba biotech researchers.**

**Annex C**

**Biotech researchers by institutional affiliation**

|  |
| --- |
| **Santa Fe** |
| **Institution** | **Total researchers****(share)** | **Sample****(share)** |
| Universidad Nacional de Rosario (UNR) | 50 (36.49) | 9 (30) |
| Instituto de Biologia Moleculary Celular de Rosario (IBR) | 39 (28.46) | 7 (23.3) |
| Universidad Nacional delLitoral (UNL) | 27 (19.70) | 8 (26.6) |
| Centro de Estudios Fotosinteticosy Bioquimicos (CEFOBI-CONICET) | 7 (5.10) | 1 (3.33) |
| Instituto de investigación básica y aplicada en las áreas de Fotosíntesis, Enzimiologa y BiologíaMolecular de Plantas (CIFASIS-CONICET) | 4 (2.91) | 0 |
| Instituto de Fisiologia Experimental(IFISE) - CONICET | 2 (1.45) | 0 |
| Instituto de Quimica Rosario(IQUIR - CONICET) | 3 (2.18) | 3 (10) |
| Instituto Nacional de TecnologiaAgropecuaria (INTA) | 3 (2.18) | 2 (6.66) |
| Instituto de Desarrollo Tecnologico para la Industria Qu’mica (INTEC-CONICET) | 1 (0.72) | 0 |
| Instituto de Lactologia Industrial (INLAIN-CONCIET) | 1 (0.72) | 0 |
| Total Researchers | 137 | 30 |

|  |
| --- |
| **Cordoba** |
| **Institution** | **Total researchers****(share)** | **Sample****(share)** |
| Universidad Nacional de Cordoba (UNC) | 102 (60.71) | 38 (57/57) |
| Instituto Nacional de Tecnologia Agropecuaria (INTA) | 10 (5.95) | 6 (9.09) |
| Universidad Catolica de Cordoba (UNC) | 21 (12.5) | 9 (13.63) |
| Universidad Nacional de Rio Cuarto (UNRC) | 10 (5.95) | 2 (3.03) |
| Insittuto de Investigacion Mercedes y Martin Ferreyra (INIMEC-CONICET) | 10 (5.95) | 5 (7.57) |
| Universidad Nacional de Villa Maria | 4 (2.38) | 1 (1.51) |
| Universidad TEcnologica Nacional (UTN) Facultad Regional Cordoba | 1 (0.59) | 0 |
| CEPROCOR | 10 (5.95) | 5 (7.57) |
| Total Researchers | 168 | 66 |

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1. See, among others, Allen (1964), Allen (1966), Utterback (1971), Utterback (1974), Tushman (1977), Gittelman and Kogut (2003), Kline and Rosenberg (1986). [↑](#footnote-ref-1)
2. See Arundel and Geuna (2004), Kauffman and Todtling (2001), Meyer-Krahmer and Schmoch (1998). [↑](#footnote-ref-2)
3. See, among others, Powell et al. (1996), Rees (2005), Gilding (2008) and Fontes (2005). [↑](#footnote-ref-3)
4. Many different fields, from political science to management of technology, borrowed and applied the gatekeeper concept when concerned about control, access and diffusion of knowledge, information, technology and others (Barzilai-Nahon2008). [↑](#footnote-ref-4)
5. See study cases of US enterprises in different areas, e.g. energy conversion and electronics (Allen 1969), food, paper and informatics (Brown 1979), medical instruments (Tushman and Scanlan 1981), mineral exploration (Nochur and Allen 1992), chemicals (Allen 1977). [↑](#footnote-ref-5)
6. The two-step process of information flow was previously studied in the mass communication literature: the mass media influences people not directly, but through opinion leaders (Katz and Lazerfeld 1955). A similar process was found in the diffusion of hybrid seed corn (Rogers and Shoemaker 1971) or the introduction of a new drug to a physician’s community (Coleman et al 1966). [↑](#footnote-ref-6)
7. This contradicts the spontaneous nature of the gatekeeper ( Allen 1977), and supports the idea that special policies can be designed to facilitate the gatekeeper’s role (Tushman and Katz 1980, Utterback 1974) [↑](#footnote-ref-7)
8. See Schott (1993), Barnard et al (2010), Shrum and Campion (2000), Ynalvez et al (2009), Gaillard (1991). [↑](#footnote-ref-8)
9. United Nations Economic Commission for Latin America and the Caribbean [↑](#footnote-ref-9)
10. The database was generated by interviewing the directors of all academic and research institutions located in Santa Fe and Cordoba provinces which were involved in biotech research. They provided us with the names and contacts of those researchers who led biotech research projects in the institutions they chaired. [↑](#footnote-ref-10)
11. All PROs that are involved in biotech research in Cordoba and Santa Fe are covered by this study. [↑](#footnote-ref-11)
12. Many studies make use co-authorship data of scientific publications to trace collaborative activity (Ponds et al 2007, Barnard et al 2010, Wagner and Leydesdorff 2005, Liang and Zhu 2002, Wang et al 2005, Hoekman et al 2010, Adams et al 2005, Onyanacha and Maluleka 2011). We acknowledge that analyzes of collaborations from ibliographic sources can be restrictive and also misleading in some cases (Shrum, 1997). International publication databases can often underrepresent research in the developing world. As we consider ‘elite’ local researchers, we expect this drawback to be minimized. [↑](#footnote-ref-12)
13. When performing network analysis, a biased database derived from identity errors can lead to substantially different results. When two agents are considered to be the same person when they are not can lead to a much more connected network than the real one. Conversely, when one person appears to be two, we may fail to recognise links, and the possible existence of `bridges' between apparently dis-connected networks. As we are aware of these sorts of mistakes, we implemented methodological steps towards minimizing them. [↑](#footnote-ref-13)
14. The degree centrality is a simple measure as it counts the direct ties with other nodes of the network. [↑](#footnote-ref-14)
15. We can further distinguish them according to the degree of external openness of their connections. We define the ratio ‘external degree centrality’ to ‘local degree centrality’, where ‘external degree centrality’ are the number of links with researchers located in other countries and ‘local degree centrality’ are the number of links with Argentinean colleagues. When the ratio is greater than 1 the knowledge gatekeeper is more ‘externally oriented’ and when the ratio is less than 1 it is more ‘locally oriented’. When the ratio equals 1 we can assume that the knowledge gatekeeper is ‘balanced’. [↑](#footnote-ref-15)
16. The table in the Annex C shows that the sample of researchers covers the majority of institutions where biotechnology is performed in Santa Fe and Córdoba. [↑](#footnote-ref-16)
17. By definition, isolates are also researchers that have publications without co-authors. We do not have that type of isolates in the dataset. [↑](#footnote-ref-17)
18. We measured research quality as the number of times that a researchers' work has been cited by other publications in the SCOPUS database. The more cited a paper is, the larger its impact which can be taken as an indicator of its value and quality. Thus, citation counts are used to build prestige rankings of scientists. We operational zed the variable citations by counting the number of citations per researcher and normalized it by the researchers' number of publications and age. The latter is introduced as a way to correct for the fact that older researchers may have more time to accumulate publications than younger ones. [↑](#footnote-ref-18)
19. The information needed to create the variable was gathered from ECLAC's survey's questionnaire. [↑](#footnote-ref-19)
20. The ECLAC’s survey provided data to construct this measure. The question used to track informal knowledge exchanges was: ‘Do you know other researchers within your field that do research in topics related to your research project?’ Only in case that a researcher answered that he/she knew colleagues that do research in the same research area, he/she was further asked to list their names, the institutions they work at, their country of residence and if he/she sought information/technical advise from them. [↑](#footnote-ref-20)
21. We chose the negative binomial specification as the dependent variable (number of collaborations) was both a count and showed overdispersion. The latter led us to reject the Poisson regression model in favour of the negative binomial specification. [↑](#footnote-ref-21)
22. These researchers are differentiated from the focal nodes since they do not fulfil the two requisites of doing biotech research in PROS of Santa Fe and Cordoba, and manage biotech research projects. Therefore, these researchers can be either researchers that have to do with biotech research in other Argentinean provinces, or scientists enrolled in PROs of Santa Fe or Cordoba but that they are not in charge of research projects. [↑](#footnote-ref-22)