The key factors affecting knowledge transfer and scientific productivity: evidence for Argentine Public Research Organizations

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Abstract

In recent years, the literature has paid particular attention to analyzing different sources of knowledge as determinants of innovation. In this context, the institutions that make up the national innovation system are central to increasing the technological capability base. Much of the research interest focuses on analyzing how science-based knowledge generated by universities is transferred to industry. This paper explores the determinants of the performance of research groups in public institutions from Argentina in terms of both technology transfer and scientific productivity. Our motivation for considering these two dimensions of performance is to analyze comparatively the determinants of both performance indicators, based on the idea that in Argentina the groups that are more oriented towards technological transfer are different from those dedicated exclusively to scientific activities. Our empirical analysis is based on information for 314 Argentine ICT research groups. Results show that scientific productivity depends on the proportion of PhD holders, the linkages with other institutions for R&D and training, and the funding research groups receive from Argentina's National Scientific and Technical Research Council (CONICET) and from National Agency for Scientific and Technological Promotion (ANPCyT). The determinants of technology transfer are the linkages the groups establish with other institutions for technological developments. Instead, the greater the funding that groups receives from universities, the fewer their transfer activities. Finally, the results also suggest not only the absence of the linear model of innovation, but the existence of a completely opposite relationship: scientific productivity has a negative impact on groups' technological performance.

Keywords: ICT research groups, Public Research Organizations (PROs), scientific productivity, and knowledge transfer.

Introduction

Innovation literature has made major contributions to understanding the way in which the innovation process takes place. Originally, basic and applied research generated in public centers was assumed to drive the technological developments that would eventually lead to innovation. This process was referred to in the literature as the "linear model of innovation" and it predominated the scientific and policy scenes of the 1950s (Bush, 1945; Freeman, 1996; Stockes, 1997). Several decades later, evidence emerged revealing innovation to be a more complex process involving nonlinear relationships and multiple feedbacks between the components of systems (universities and research centers, firms, intermediary organizations), which resulted in the development of new approaches such as the "non-linear model of innovation" (Kline and Rosenberg, 1986), the Pasteur´s Quadrant (Stockes, 1997) and the "triple helix"(Etzkowitz and Leyersdorf, 2000).

Nowadays, there is broad consensus on the systemic nature of innovation, which emerges from the interaction of a multiplicity of organizations that make up the so-called national innovation system. From this systemic perspective, knowledge is not assumed to be automatically transferred from the scientific and technological system to the productive sector. This situation, which has been called "systemic failure" (Georghiou and Metcalfe, 1998; Lee, 2013), requires governments to intervene through active innovation policies that promote cooperation and knowledge exchange between the scientific and productive sectors.

In this context, there have been a proliferation of studies examining interactions between universities and firms from different perspectives (Agrawal, 2001; Cohen et al., 2002; Fontana et al., 2006; D'Este and Patel, 2007; Arza and López, 2008; Arza and Vazquez, 2010; among others). However, the empirical evidence shows that these interactions are only virtuous in specific environments in which firms and public research institutions have high capacities and where there are also instruments to promote linkages between the various actors in the innovation system. In developing countries, in contrast, institutional environments are weak, the development of capacities is limited, and as such, the patterns identified by the non-linear model of innovation do not seem to take place.

In this context, the objective of this article is to study public research organizations (PROs), which are one of the main components of the national innovation system. In particular, we are interested in contributing empirical evidence on the factors associated with the performance of the research groups that belong to Argentine PROs, in terms of their scientific output and their activities relating to technology transfer to the productive sector. The motivation behind considering these two dimensions of performance is to comparatively analyze whether their determinants are similar or different, based on the idea that in Argentina those groups that are more oriented towards technological transfer have different characteristics from those that focus exclusively on scientific activities.

There have been relatively few studies that have explored this issue from the perspective of universities research groups in developing countries.

Most of the literature on the relationships between firms and universities focuses on individual researchers rather than groups. Given that knowledge generation and transfer are collective phenomena, this paper's primary contribution will be to add new evidence to this literature.

A second contribution will be to study the performance of research groups in a specific field of knowledge. We consider that this type of analysis, focused on a single area, is a key matter in that there is broad consensus on the idea that the characteristics of technology transfer differ according to the type of knowledge involved. In this context, we study the determinants of performance of Information and Communication Technologies (ICT) research groups in public institutions from Argentina. The starting point for this paper is the idea that the potential transfer processes and the form these take will differ according to the field of knowledge in question. Furthermore, this is a sector which has grown significantly over the past ten years both from an academic perspective and in terms of its business dynamic. On the one hand, ICT training has increased significantly with the creation of university degrees in this field at both public and private universities. On the other hand, in the private sector, the number of firms and employment in this field have grown at higher rates than other sectors. However, both academia and private enterprise are still at an evolutionary stage in which clear intra-sectoral specialization has yet to be identified (Barletta et al, 2013). This evidence has prompted us to wonder how far synergies exist between the private and academic worlds in terms of knowledge transfer.

This research is based on a survey of research groups conducted by the Argentina's Ministry of Science and Technology—and not individual researchers[1]—on the understanding that knowledge generation is a collective phenomenon. This feature differentiates our paper from most of the literature focused on university–industry interactions from the perspective of individual researchers (De Fuentes and Dutrenit, 2012).

This paper is organized as follows. After this introduction, there is a brief review of the literature on university–industry interactions and a presentation of hypotheses (section 2). Section 3 describes the data and variables and presents the descriptive statistics. Results are presented in Section 4 and concluding remarks in Section 5.

2. Conceptual background and hypotheses.

In recent years, the literature has paid particular attention to analyzing different sources of knowledge as determinants of innovation. These sources come from both within firms and outside of them. Among the latter, the scientific output of universities features in the literature as a source of outside knowledge that can be key to developing firms' absorptive capacity and their innovative dynamic. Thus, the linkages that firms establish with public research institutions within the national system of innovation are central to increasing the technological capability base (especially in knowledge-intensive sectors). In particular, much of the research

[1]An exhaustive review of the literature on university–industry relations from the perspective of individual researchers is provided by Perkmann et al. (2013).

interest is focused on analyzing how science-based knowledge generated by universities is transferred to industry.

The results of research projects at public institutions are reflected in scientific journal articles and technology transfer activities. A university's performance is largely determined by the level of development of its "academic capacity." This concept, which was coined by Liefner and Schiller (2008), refers to the set of functional and organizational capacities displayed by institutions of higher education in the process of technological upgrading and learning, especially in latecomer countries. Functional capacities include teaching and research activities that are directly linked to the demands of society and the productive sector. Organizational capacities refer to an incentive structure that promotes relationships between universities and the productive sector through financing schemes and regulations that give rise to knowledge creation and transformation.

In most developing countries, and in Argentina in particular, scientific output responds to the traditional evaluation schemes for professional researchers in which incentives are linked to academic output and little value is placed on transfer activities. The success of this sort of scientific career depends almost exclusively on publishing research results in peer-reviewed international journals, and thus it responds mainly to the old model of innovation (Gittelman and Kogut, 2003). In the terms of Liefner and Schiller (2008), a slight development in the components of academic capacity can be observed. Functional and organizational capacities are practically absent from institutions of higher education in developing countries since the main functions of universities continue to center on maintaining their role in education and basic science, and there is very little debate around the role that universities should play in society and the way in which they can contribute to responding to the demands of the productive sector.

In this context, it is to be expected that the determinants of the scientific productivity of research groups would be associated with the traditional driving factors for scientific activity. Hypotheses 1 to 3 intend to account for these factors. Firstly, with regard to researchers' characteristics, it is to be expected that groups with a higher proportion of PhD holders have greater scientific output since the education level of research group members is an indication of their experience and track record. Thus, hypothesis 1 proposed that *the greater the proportion of PhD holders in the research group, the greater its scientific productivity*. In this sense, there is sufficient empirical evidence on the impact of researchers' degree levels on their scientific productivity (D' Este and Patel, 2007; Ubfal and Maffioli, 2011). D'Este and Patel (2007) provide empirical evidence of the determinants of technology transfer based on a data set of 4337 university researchers from the UK. They show that researchers' individual characteristics have a stronger impact than the characteristics of their departments or universities when explaining the variety and frequency of interactions. Those researchers with previous experience of collaborative research are more likely to be involved in a greater variety of technology transfer channels and also to engage more frequently across a wider set of channels. Academic status also has a significant and positive impact on the variety of interactions.

In turn, is to be expected that the ties that groups maintain with other PROs will also have a positive impact on their scientific output. These linkages, be they formal or informal, involve two-way knowledge flows between partners that are a result of shared research projects and, in many cases, result in co-publications. Therefore, hypothesis 2 stresses that *research groups' linkages with other institutions focused on R&D and training have a positive impact on their scientific productivity*.

Likewise, as noted above, the incentive system for research in Argentina "rewards" publications in international peer-reviewed journals, and is guided and regulated by various public institutions that concentrate many of the country's researchers (the most relevant are the National Scientific and Technical Research Council, CONICET[2], and the National Agency for Science and Technology Promotion, ANPCyT[3]). As such, hypothesis 3 states that *public funding sources have a positive impact on research groups' scientific productivity*.

This logic of the scientific system often comes into conflict with that of the technological innovation system. *"Innovation builds on knowledge made in science, but science that is 'good' for innovation is propelled by a logic that is different than that employed by a scientific community to determine 'valuable' or 'important' science"* (Gittelman and Kogut, 2003, p. 367). That is to say, the factors that determine each of these two logics also differ. De Fuentes and Dutrenit (2012) suggest that the drivers, channels, and perceived benefits derived from linkages are different among PROs and firms. While PROs form linkages in order to seek research funding, firms form linkages with universities to seek human resources.

In this sense, most of the literature has focused on analyzing factors that influence the possibility of PROs transferring knowledge to industry (Landry et al., 2005; Bercovitz and Feldman, 2003; Agrawal and Henderson, 2002; Louis et al., 2001; Di Gregorio and Shane, 2003; Friedman and Silberman, 2003; Schartinger et al., 2001; Tornquist and Kallsen, 1994; De Fuentes and Dutrenit, 2012).[4] In particular, these articles analyzed both the individual factors (researchers) and organizational factors (universities) that explain the technology transfer

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[2] CONICET, created in 1958, is an autonomous institution dedicated to promoting the development of science and technology. It is the country's most important scientific institution and the second in Latin America according to the Journal SCImago Rank. Its main functions are to promote the careers of research scientist and technical support staff. It has 8,508 researchers and 2,425 people working as support staff (2014).

[3] ANPCyT is a national agency under the Ministry of Science, Technology and Innovation. Through its four funds (FONCYT, FONTAR, FONSOFT, FONARSEC), the agency provides financing lines for scientists engaged in basic research and firms interested in developing technological innovation. Basic research is mainly financed through the Fund for Scientific Research and Technology (FONCyT), which supports researchers from non-profit public and private organizations in the country.

[4] Garcia et al. was the only study we found that analyzed the university–firm relationship in Brazil from the perspective of research groups rather than individual researchers. They used a base of 612 research groups from all academic disciplines based at 79 universities. They found that groups from universities that ranked higher in the Brazilian postgraduate evaluation system had greater numbers of linkages with the private sector. However, as they only studied groups with industry linkages, their results cannot be compared with those of this study.

activities carried out by PROs. For instance, Bercovitz and Feldman (2003) examine the effect of individual attributes, organizational incentives, and social interactions on the decision to engage in technology transfer activities, based on data on individual researchers from the medical schools of two American universities. They have fund that experience, calculated as the number of years since the researcher's last graduate degree, has a negative effect on participation in technology transfer.

As such, and in contrast to what is stated in hypothesis 1, it is to be expected that research groups with a lower proportion of PhD holders are less likely to have access to funding from the science and technology system and thus tend to seek funding from external sources that largely come from the private sector. According to Giuliani et al. (2010), "*scholars with a PhD might be involved in more 'blue-sky' research and consequently be more interested in publishing in scientific journals than in networking with industry. In this case, scholars with lower levels of education—i.e. no doctoral degree—might be willing to dedicate more time to setting up linkages with firms*" (Giuliani et al. 2010, p. 750). However, the empirical evidence is not conclusive with regard to the direction of the relationship between technology transfer and the proportion of PhD holders. According to Giuliani et al. (2010), from a resource-based perspective, it is to be expected that researchers with PhDs would have higher possibilities of becoming involved in transfer activities. In this sense, part of the literature on technological transfer activities stresses that researcher seniority plays an important role in predicting the knowledge-related collaboration between research groups and non-academic organizations (Boardman, 2008, 2009; Boardman and Corley, 2008; Bozeman and Gaughan, 2007; D'Este and Perkmann, 2011; Haeussler and Colyvas, 2011; Link et al., 2007; Ponomariov, 2008).

As a consequence, and given that the relationship between academic degree and the possibilities of knowledge transfer is an ongoing debate in the literature, we propose to empirically test this relationship without arguing in advance in favor of a particular direction.

On the other hand, as a determinant of technology transfer, we consider the linkages research groups have with other institutions in order to carry out technological developments. This type of cooperation can contribute to the development of skills that are absent from research groups and that would allow them to form linkages with firms and improve their transfer capabilities. Cooperation between research groups may be due to the need to complement skills as a result of demands from the private sector. As such, hypothesis 4 states that *research groups' linkages with other institutions focused on technological development have a positive impact on their transfer activities*.

Finally, in relation to the impact of funding sources on transfer activities, Lee (1996) and Colyvas *et al* (2002) find that departments with a higher level of private financing might be more willing to support technology transfer to industry than those university departments mainly financed by public sources. Furthermore, Bozeman and Gaughan (2007) find that scientists with industry contracts interact with industry more than those who are exclusively government funded. In this sense, there is often a tension between the need to fund academic research via industry and the need to preserve academic freedom (Lee, 1998). Following these findings, we propose—as hypothesis 5—that *the greater a research group's public funding, the smaller the likelihood that it will transfer knowledge to the private sector*.

Aside from the factors associated with research groups' performance, there are many precedents in the literature that provide empirical evidence on the relationship between scientific productivity (or academic quality) and technology transfer. In this case, the results found are mixed and the evidence goes in both directions. Many studies show a positive relationship between quality of university research and likelihood of interaction with industry (Louis et al., 1989; Mansfield, 1991; Mansfield and Lee, 1996; Tornquist and Kallsen, 1994, for the US; Haeussler and Colyvas, 2001, for Germany and the UK; Gulbrandsen and Smeby, 2005, for Norway; Bekkers and Boda Freitas, 2008, for the Netherlands). These studies, conducted mostly in developed countries, argue that the quality of academic research is a critical factor in determining universities' potential to contribute to firms' innovation activities (Mansfield, 1991, 1995; Mansfield and Lee, 1996; Tornquist and Kallsen, 1994; D'Este and Iammarino, 2010; Blumenthal et al., 1996; Gulbrandsen and Meby, 2005). According to these authors, academic research excellence induces industrial laboratories to carry out joint research activities, particularly in high-tech sectors. Another set of articles analyze academic excellence through productivity levels, as we propose in this paper. They also find a positive relationship between this variable and the likelihood of linkages with industry (Bekkers and BodaFreitas, 2008; Gulbrandsen and Smeby, 2005; Haeussler and Colyvas, 2001; Louis et al., 1989).

However, it is broadly recognized that, in developing countries, PROs can be characterized by limited interactions with the private sector because researchers are more focused on basic research than technological projects. Besides, firms from developing countries do not consider PROs to be an appropriate innovation partner (Cimoli, 2000; Casiolatto et al., 2003; Lall and Pietrobelli, 2002). At the same time, in contrast to the situation in more developed economies, where the interactions are based on the development of patents and cooperative agreements for R&D. In developing countries like Argentina, these kinds of technology transfer are unusual since patenting activity is reduced (not only at universities but also in the private sector), as are academic spin-offs and R&D agreements. In these countries knowledge diffusion occurs mainly through publications, informal interactions, participation in conferences, and technology services provided by researchers.

In this context, and given these features of developing economies, it cannot be assumed that scientific knowledge can be transferred in a linear fashion to innovation processes within firms, for various reasons: i) because researchers have no interest in commercializing their knowledge, ii) they do not know how to do so, or iii) the university and innovation policy does not provide incentives for this transfer, among other reasons. In addition to the low proportion of "formal" transfer channels (patents and R&D agreements), this situation leads to our sixth hypothesis, which challenges the ideas of the linear model of innovation applied to ICT research groups. The explanation for this is that researchers' incentives for carrying out transfer activities or improving their academic career are different. In this case, PROs are interested in acquiring new sources of funding and ideas for future research (De Fuentes and

Dutrénit, 2012). As such, we argue that scientific productivity and technology transfer are not interrelated worlds. Therefore, hypothesis 6 stresses that *the level of research groups' scientific productivity has a negative impact on their likelihood of develop technology transfer*.

3. Data and variables.

The empirical evidence is based on the "National Survey of ICT Research Groups" carried out by the Secretariat of Studies and Prospective at Argentina's Ministry of Science and Technology during 2013. The sample was made up of 460 researcher groups and the response rate was 68% (314 groups). In total, these groups are made up of 3784 members and, on average, the size of each groups is 12 people. From the perspective of education, on average 20% of members hold PhDs, 11% have master's degrees, 41% are graduates, and 29% are undergraduates.

The groups had been created relatively recently. Half were created from 2007 onwards, a quarter between 2000 and 2006, and the remaining quarter before 2000.

More than 80% of these groups are from Argentine public universities, notably the National Technological University, the University of Buenos Aires, and the National University of La Plata. Around 10% of groups belong to centers associated with CONICET, and the remaining 8% are from other scientific and technological institutions (such as INTA, INTI, CNEA, and CITEDEF[5]).

The main areas of research are Information Systems, Software and Computer Engineering, and Computer Methodology (35%, 32%, and 30% of the groups, respectively), followed by Telecommunications and Electronics, Human-Centered Computing, and Hardware. Groups were also asked about the potential sectors of application for their results, and Software and Computer Services, Education, and Manufacturing were highlighted in this regard.

Most groups work at institutions located in provinces with larger urban areas, like Buenos Aires, Santa Fe, and Córdoba provinces, and the City of Buenos Aires (CABA) (35%, 13%, 10%, and 11%, respectively). However, the rest are located in 17 other provinces, which accounts for the distribution of ICT research activities across the country.

3.1 Performance indicators for ICT research groups.

In order to measure the groups' performances, we have built two variables that account for scientific productivity and technological performance. These two indicators represent the dependent variables in the models that will be estimated later.

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[5] National Institute for Agricultural Technology (INTA), National Institute for Industrial Technology (INTI), National Commission for Atomic Energy (CNEA), Institute of Scientific and Technological Research for Defense (CITEDEF).

Scientific productivity is measured as the ratio between the number of papers published in indexed national and international journals and total group members.[6] It was built for two periods -2007-2009 and 2010-2012- based on SCOPUS information[7].

The mean of scientific productivity is relatively small (0.18 papers per member in 2010–2012) with minimum of 0, and a maximum of 4. Table 1 shows that average productivity is independent of both the age and size of the groups.

Table 1 Scientific productivity according to research groups' size and age.

	Mean	Sd	Max
Age			
Before 1989	0.071	0.097	0.27
1990s	0.227	0.322	1.83
2000 to 2007	0.267	0.462	2.50
After 2007	0.125	0.395	4.00
Total	**0.175**	**0.394**	**4**
tau-b: -0.1857 ***			
Members			
Less than 5	.239	0.683	4.00
6 to 10	0.222	0.382	1.83
11 to 21	0.123	0.189	0.75
More than 21	0.077	0.116	0.421
Total	**0.177**	**0.396**	**4**
tau-b: 0.0294			

In order to measure technology transfer activities two indicators were considered. The first indicates whether the groups carried out technological developments (prototypes, engineering models, systems, procedures, etc.) during 2010–2012. The second indicates whether the groups carried out technological services (testing, advice, and consultancy) in the same period. Patents were not included as a measure of transfer activity due to their limited relevance in the case under study. Indeed, the patent ratio is very low even in more developed countries. Lissoni *et al* (2009) show that, in the case of three European countries (France, Italy, and Sweden), only about 5% of the total population of researchers have obtained any patents. Furthermore, in ICTs patents and licenses are not a transfer channel for relevant knowledge in the way that they are in other disciplines such as chemical engineering, biomedicine, and material science (Bekkers and Bodas Freitas, 2008; Perkmann et al., 2013).

[6] A similar indicator is used by Dutrénit et al. (2010) to measure the scientific productivity of the National Innovation System in Mexico. The indicator is calculated as the ratio between the number of publications indexed by the Institute for Scientific Information (ISI) and the number of members of Mexico's National System of Researchers (SNINV).

[7] Scopus is a bibliographic database containing articles published in scientific journals from different disciplines.

Table 2 shows that 31% of groups carried out both technological developments and services, and one third of the groups did neither of these activities. The remaining groups have undertaken one of the two activities.

Table 2 Technological developments and services carried out by research groups during 2010–2012.

Technological Developments	Technological Services		
	No	Yes	Total
No	33	13	46
Yes	23	31	54
Total	56	44	100
	Pearson chi2(1)=	24.8922	Pr = 0.000

As Table 2 shows, technological developments and services are highly correlated. So, these two variables were combined in order to build an indicator of technological performance (or technology transfer activity) that takes three values: 0 if the group neither conducted technological development nor services (33% of groups), 1 if the group carried out one of these two activities (36%), and 2 if the group conducted both types of activities (31%).

The analysis of the relationship between groups' scientific productivity and the technology transfer activities suggests the absent of a statistical relationship between both indicators.

The non-parametric correlation test between these variables reveals there not to be a significant association between them. The Kendall tau-b correlation coefficient is 0.0594 with a p-value of 0.2234. These contradictory results can be explained by the presence of a simultaneity bias between technology transfer and scientific productivity.

3.2 Explanatory variables

We take into account three set of indicators as explanatory variables. Firstly, the proportion of group members with doctoral degrees is taken as a proxy for academic capacity. The average proportion of PhD holders among the groups is 20%.

Secondly, we consider the linkages that groups hold with other institutions. As the literature suggests, each group's capabilities level is not explained only by its internal resources but also by the possibility of it using external knowledge, which leads to an improvement in the initial capacities. Thus, it is expected that both the technological and scientific performance of research groups depend on linkages with other public institutions. Linkages with scientific and technological institutions with the following goals were considered: i) research and development (R&D_Link), ii) technological development (Tech_Dev_Link), and iii) training (Training_Link). For each goal, groups indicated what kind of institution they interact with: i) Argentine public universities, ii) Argentine private universities, iii) foreign universities, iv) other scientific and technological institutions, and v) agencies for international cooperation. We built different indicators from these responses that add up the number of linkages. As such, each indicator takes values ranging from 0 (if the group has no interactions) to 5 (if the group has interactions with all the above types of institution). Table 3 presents the descriptive statistics for this variable. As can be seen in the table, only 35% of the groups have linkages with at least one institution for technological developments, while this proportion increases to 60% when the goal of the linkage is the training, and it reaches 80% when the objective is R&D.

Table 3 Linkages with scientific and technological institutions.

	Objectives		
Number of linkages	R&D	Technological Development	Training
0	21.6	64.8	40.0
1	28.3	24.4	28.3
2	23.5	7.6	20.0
3	16.8	2.2	7.3
4	7.6	1.0	2.5
5	2.2	0.0	1.9
Total	100	100	100

Thirdly, we considered the source of the research groups' financial support, taking into account the ANPCyT, CONICET, universities, and the private sector. All are continuous variables that take values from 0 to 100 indicating the percentage of financing that comes from each of these four sources. On average, universities finance 59% of research projects and the ANPCyT and CONICET 13% and 6%, respectively. Finally, firms financed on average 10% of the total number of projects in 2012.

4. Results

This section has two objectives. Firstly, we present the determinants of the ICT groups' scientific and technological performance (hypotheses 1 and 5). Secondly, we test if scientific productivity negatively affects technology transfer activities (hypothesis 6).

4.1. Determinants of research groups' scientific productivity and technological transfer activities.

In order to test the hypotheses, two set of regressions were estimated associated with each dependent variable: scientific productivity and transfer activity. Tobit models were estimated to analyze the factors that affect scientific productivity, given the censored distribution of this variable (from 0 to infinite). To analyze the factors underlying technology transfer activity, an ordered discrete variable was created which takes three values: absence of transfer activities (0), presence of technological developments or services (1), and both (2). Following this definition, ordered Logit models were estimated. For each regression, a set of explanatory variables indicating research groups' capabilities, linkages, and financial support were successively introduced.

Finally, the following control variables were included: i) groups' scientific productivity during the previous period, 2007-2009, ii) group size (number of members), iii) the square of group size (used to capture a non-linear relationship with group performance), iv) the age of the group (starting year of research activities), and v) the geographical location (dummy variables which indicate whether the group is located in Córdoba, Santa Fe, and Buenos Aires provinces, and CABA, the Argentine provinces with the largest populations and GDPs, with "the rest of the country" as a reference group).

Results are presented in Table 4 (marginal effects for model estimations are presented in the Appendix). The first regression (first column) includes only the proportion of PhD holders as an independent variable. In the second regression, the set of linkage variables are included, and in the third, funding sources are finally added (second and third columns, respectively). The same procedure is employed to estimate technology transfer activities (columns 4–6).

The results presented in column 1 indicate that research groups' scientific productivity is positively affected by their proportion of PhD holders and corroborates hypothesis 1. We also find a causal relationship with size—indicating the importance of scale effects—but not with the age of the group. This last result contrasts with the idea of path dependence as an important determinant of scientific productivity, although the correlation between the groups' ages and sizes can also explain this lack of association.

When the set of linkage variables (column 2) are incorporated, the above results do not show significant variation. Regarding groups' linkages, interactions focused on training and—to a lesser extent—joint R&D activities are relevant determinants when explaining the average number of papers per member. This result supports hypothesis 2.

The third column shows the estimated results incorporating the set of variables related to the sources of each group's financial support. In this model, of the three public funding sources considered (ANPCyT, CONICET, universities), support received from ANPCyT and CONICET has a positive impact on scientific productivity. These outcomes could be the result of the incentive schemes defined by both institutions, which place strong emphasis on the number of researchers' published papers because financing instruments give support mainly to basic science. Therefore, hypothesis 3 is partially supported by this result. Relative independence can be observed between group scientific productivity and funding from universities. Private financial support is not significant either, but this result coincides with the idea stated above regarding the dissociation between the scientific and productive worlds.

Columns 4 to 6 present the estimated results regarding the technology transfer activities of ICT research groups. In contrast to the result highlighted earlier, technological performance is not affected by the research group's proportion of PhD. There are different possible explanations for this result. On the one hand, it may suggest that other abilities—not necessarily related to human resource qualifications—are required in order to carry on technology transfer activities. Another possible interpretation of this result is that technological transfer activities developed by ICT research groups have a relatively low levels of complexity, since they not require highly qualified profiles. A third explanation could be that the most advanced ICT companies hire PhD holders directly instead of generating transfer contracts with universities.

Among control variables, the results show a positive influence of the age of the group (the older the group, the greater the degree of technological transfer). The location dummies show that research groups located in Santa Fe province have a higher probability of participating in technological activities compared with their peers in the rest of the country. Finally, the relevance of technological developments and services depends on the number of members in the research group, which provides evidence about the importance of scale effects (column 4). However, this last result is only valid up to a certain threshold, given that the square of the group's size has a negative impact.

The model presented in column V includes linkages with other institutions. According to the arguments set out in hypothesis 4, the linkages that groups form in order to carry out joint technological developments have a significant positive impact on transfer activities.

The last regression incorporated the set of variables that consider groups' reception of financial support from ANPCyT, CONICET, universities and private sector (Column VI). In this case, the probability of achieving technological transfer results decreases with the increase in the participation of funds from universities, which partially corroborates hypothesis 5. This provides evidence regarding the bias towards funding basic research through funds provided by the main institutions of the national innovation system.

Table 4 Determinants of groups' scientific productivity and technology transfer activities

	Tobit regressions. Dependent variable: Scientific productivity			Ordered logit regressions. Dependent variable: Technology transfer activities		
	I	II	III	IV	V	VI
% PhD holders	1.373***	1.281***	0.819***	-0.422	-0.669	-0.934
Linkages						
R&D_Link		0.096**	0.066*		0.084	0.037
Training_Link		-0.003	-0.004		0.077	0.026
Tech_Dev_Link		-0.034	-0.009		0.858**	0.834**
Financial support						
ANPCyT			0.006***			-0.002
CONICET			0.005**			-0.002
Universities			-0.001			-0.010***
Private sector			-0.001			0.000
Control variables						
Scientific Productivy 2007-2009	1.171***	1.098***	0.913***	-0.517	-1.143**	-1.290**
Size	0.083	0.059	-0.012	0.668***	0.510***	0.464***
Size^2	-0.000*	-0.000*	-0.000	-0.001**	-0.000*	-0.000*

Age	-0.049	-0.041	-0.044	-0.283**	-0.318**	-0.333**
Córdoba	-0.133	-0.109	-0.154	0.187	0.164	0.053
Santa Fe	0.204	0.175	0.019	0.812**	0.667*	0.506
CABA	0.299**	0.261*	0.201	0.020	-0.052	-0.145
Buenos Aires	0.091	0.092	0.038	0.506*	0.249	0.029
Constant	Yes	Yes	Yes	Yes	Yes	Yes

*p < 0.5; **p < 0.01; ***p < 0.001

4.2 The relationship between technology transfer activities and scientific productivity.

An identification problem arises in association with testing hypothesis 6, given that scientific productivity and technological transfer activities are determined simultaneously.[8] As such, direct estimation between these variables would lead to biased and inconsistent estimations. To identify the causal effect of academic performance, we used an estimation based on instrumental variables. This identification strategy consisted of generating a localized exogenous variation using variables that are redundant when explaining technological transfer activities but that are highly correlated with academic productivity. The estimation strategy is a two-stage procedure. First, predicted scientific productivity was generated using two variables that characterize the journals where research groups publish their articles. The first one is the total number of publications of each journal during the period 2010-2012. The second one is the total number of citations for each journal during the period 2010-2012[9]. Since these variables are independent of individual researcher's characteristics, they would be considered independent of their technology transfer activities. At the same time, it is expected that these variables will be positively correlated with groups' scientific productivity[10]. Therefore, these two variables can be considered as valid instruments. Additionally, to estimate the scientific productivity the proportion of PhD holders and the previous groups' performance was considered.

The linear prediction of scientific productivity of ICT research groups was (Productivity_hat) used then to estimate its causal effect on transfer activities.

Table 5 presents the estimated results and allows us to confirm the negative impact of research groups' scientific productivity on their technological performance, thus confirming the sixth hypothesis.

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[8] The simultaneity bias is explained by both the simultaneous measure of this variable (period 2010–2012) and the presence of unobserved common causes.

[9] Using two variables as instruments provides an additional identifying restriction. Thus, to tests their validity we conduct a Sargan Test.

[10] This condition can be tested with a joint significance test on the excluded exogenous variables in the first stage regression. Stock et al. (2002) recommend an F statistic greater than 10 to avoid weak instruments problem that can create small sample bias in IV estimates.

This result stresses the existence of significant differences between research groups with two different profiles: one focused on basic research and the publication of papers, and the other focused on technological transfer and consultancy activities. This result coincides with the evidence of Arza and Vazquez (2010) which states that, within more qualified research groups, interactions with firms based on technological services negatively impact researchers' "intellectual benefits". This result would seem to confirm that the role of universities as an alternative source of knowledge is marginal in developing countries when it comes to explaining economic upgrading and technological progress (Liefner and Schiller, 2008). In these countries, universities' contributions center on education, in contrast to the role they play in many developed countries contributing to the development of science-based industries and the generation of spin-offs. The productive structure of less-developed economies such as Argentina, which revolve around industries that rely heavily on natural resources, where knowledge-intensive sectors have only a marginal presence, and there is a low proportion of firms with in-house R&D, partly explains the role of universities being less relevant with regard to the possibilities of transferring technology. In ICTs in particular, while knowledge is the activity's main input, the growth of the sector is relatively recent and a clear specialization in more complex segments is yet to be seen.

Table 5 Impact of scientific productivity on technology transfer activities.

	Coef.	**P>z**
Productivity_hat	-0.806	**
Size	0.28	*
Size^2	-0.000	
Age	-0.011	
Córdoba	0.713	**
Santa Fe	0.639	**
CABA	0.156	
Buenos Aires	0.465	**
Wu-Hausman F-Test	5.350	
p-value	0.022	
Sargan Test	0.192	
p-value	0.979	

Note: Robust Standard Errors; Significance levels: *p < 0.5; **p < 0.01; ***p < 0.001

5. Conclusions

The results of this paper highlight the existence of two different worlds among ICT research groups belonging to PROs from Argentina.

On the one hand, one set of groups reflects the traditional scientific world, whose main incentives are the number and quality of articles they publish. The highest levels of scientific productivity of these groups are associated with a high level of proportion of PhD, the linkages they hold with other institutions for R&D, and with the funding they receive from CONICET.

On the other hand, there is a set of groups that focuses mainly on technology transfer, which have low proportion of PhD holders and which carry out relatively few scientific activities. In this case, the main determinants of technological performance are groups' linkages with other institutions for technological developments. In contrast to the first group, the greater the funding that these groups receive from universities, the fewer their transfer activities.

Results also suggest that the mechanism of knowledge transfer does not seem to reflect a direct relationship between scientific and technological productivity performance as it is expected from the linear model of innovation perspective. However, results show the existence of an opposite relationship: scientific productivity has a negative impact on groups' technological performances.

The possible explanations underlying this negative relationship between productivity and scientific transfer activities may include any or a combination of the following: i) the existence of an inadequate incentive scheme, ii) the drivers and benefits of collaboration are different for researchers and firms, iii) the existence of a large cognitive distance (Nooteboom, 2000) between firms and universities, iv) capabilities required for academic research are not the same that those required for transfer activities. As Pavitt (1996: 12608) has stressed "the main economic value of basic research is not in the provision of codified information, but in the capacity to solve complex technological problems, involving tacit research skills, techniques, and instrumentation and membership in national and international research networks". Finally, another factor that would explain this negative relationship may be associated with the Argentine productive structure—perhaps demand from industry has low technological complexity.

The evidence shows the existence of a scientific world associated with ICTs that has grown significantly in the last 10 years, but decoupled from the productive sector, which has also grown (employment in Argentine software firms grew at an average annual rate of 14%, while employment growth in manufacturing was 5%). This situation highlights the need to consider development of the scientific and productive sectors jointly, improving scientific standards but also creating the conditions for knowledge transfer processes and co-production between these two worlds. This would require generating incentives from an approach based on a non-linear model of innovation, without neglecting the importance that scientific production represents for the development of the ICT sector in the coming decades in order to promote the transfer of their results to the productive system and society in general.

In terms of public policy implications, on the one hand, it would be important for Argentina's two most important research funding institutions (ANPCyT and CONICET) to make changes to their incentive schemes and evaluation systems. Both institutions need to promote the transfer of research project results to the productive system. Such policies would complement scientific and transfer activities, increasing the level of complexity and capabilities involved in the latter and bringing the knowledge generated by the scientific system to meet the demands of the productive sector. On the other hand, given the fact that knowledge transfer from universities to industry is not automatic, it would be important to move toward the creation of intermediate public institutions to promote this relationship as well as toward the construction of informal interaction spaces. The creation of these institutions is particularly relevant given that, as Ambos et al. (2008) suggest, the tension between academic activities and transfer is greater at the individual researcher level than at that of organizations (universities). Tensions are more pronounced at the individual level because researchers who are seeking commercial results tend to be very different from those seeking to obtain academic results, and researchers tend to opt for one of these paths but not both. Universities could solve this tension by generating dual structures, based on the creation of Technology Transfer Offices that serve to reconcile business demands with academic.

Appendix: Marginal Effects for model estimations.

	Tobit regressions. Dependent variable: Scientific productivity	Ordered logit regressions. Dependent variable: Technology transfer activities	
		= 1	= 2
% PhD holders	0.819***	-0.006	-0.182
Linkages			
R&D_Link	0.066*	0.000	0.007
Training_Link	-0.004	0.000	0.005
Tech_Dev_Link	-0.009	0.005	0.163***
Financial support			
ANPCyT	0.006***	-0.000	-0.000
CONICET	0.005**	-0.000	-0.000
Universities	-0.001	-0.000	-0.002***
Private sector	-0.001	0.000	0.000
Control variables			
Scientific Productivy 2007-2009	0.913***	-0.008	-0.252**
Size	-0.012	0.003	0.090***
Size^2	-0.000	-0.000	-0.000*
Age	-0.044	-0.002	-0.065**
Córdoba	-0.154	0.000	0.010
Santa Fe	0.019	-0.014	0.107
CABA	0.201	-0.002	-0.028
Buenos Aires	0.038	0.000	0.006

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