Collaboration patterns in patent networks and their relationship with the transfer of technology: the case study of the CSIC patents[1]

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Abstract

The aim of this paper is to observe differences between research areas when it comes to establish collaboration ties with local, national or international partners. It also intends to determine in what extent the collaboration can influence the patent transfer. A collaboration network between CSIC researchers and their external collaborators was built. Several statistical tests were used to find significant differences between research areas. A multiple regression model was also utilized in order to know what type of collaboration is more successful to transfer a patent. The results show that there are two well-defined groups. A "Bio" group with a high international collaboration pattern but less national participation; and a "Physicist" group supported by a high proportion of national partners but with few international connections. The regression analysis found that the national collaboration is the variable that most increase the patent transfer.

Keywords: Scientometrics, Multiple Regression Model, Patent licensing, Collaboration pattern, Research areas.

Introduction

Collaboration is an inherent aspect of the research activity, because the information exchange reinforces the discussion and the production of new knowledge (Katz and Martin, 1997). There are different motives that explain collaboration processes: geographical proximity, specialization of science, growing of interdisciplinary fields and the development of new communication media. However, these motives may change across different disciplines and types of research. Frame and Carpenter (1979) already observed significant differences between disciplines when it comes to collaborate among them. In an international survey, they found that physics and earth/space sciences set up more international partners than engineering sciences. Bordons and Gomez (2000) studied the collaboration pattern across different disciplines in Spain and they found similar results as well. Similar studies using patent co-inventorship showed that the chemistry and biotechnology established more international partners than the electronics and material fields. In these cases, the chemistry is the scientific area which shows the highest centrality degree in any patent network (Balconi et al., 2004; Göktepe, 2006; Lissoni et al., 2008).

These differences across disciplines also occur between different types of research. Thus, in applied research the economic reasons prevail against the social ones because the costs of the research determine to seek partners that contribute with funds or materials (Price, 1986). For example, Hagstrom (1965) claimed that applied research tends to be more interdisciplinary and may therefore require a wider range of skills which favours the collaboration. Similar differences were found between applied and basic research in Computer Sciences (Yoshikane et al., 2006). These patterns are also

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evident when it comes to analyze the collaboration in patent networks. Meyer and Bhattacharya (2004) compared papers and patent co-authorship networks, showing that the inventors collaborated less than the authors and they usually did not take part in cross-institutional patents. This suggests that the collaboration between inventors is lower because it not only entails to share authorship but also rights and knowledge with a high economic value (Lissoni and Montobbio, 2008). Thus the cross-institutional collaboration acquires a special significance because it may evolve technology transfer, especially in the industrial sector. In a study of the 548 Danish firms, it was found that the collaboration increased the impact of new innovations, being more significant the domestic contribution (Vinding, 2002). Although it seems that this relationship between local and international collaboration differs according to the research area (Godoe, 2000), several studies have addressed this issue by studying the relationship between collaboration and patent transfer. Lee (2009) studied the Korean patent applied in U.S., detecting that the collaboration was the only variable that affected to the license of a patent. In the same way, Sapsalis (2007) found a strong relationship between collaboration degree and patent licensing. Beside to the collaboration, there are many other factors which influence the technology transfer to industrial sector. Mowery and Agrawal (2000) and Ziedonis (2001) found that there was a geographical variable that explained the patent licensing in the university. Boccardelli et al. (2010) found that the expertise in patent licensing is a contributing factor to transfer new patents, while Spasalis (2007) detected that the number of forward patent citations positively affects the probability to license a patent.

Objectives

The aim of this work is to solve two questions:

- Firstly, this paper intends to study differences between research areas according to their technological activity, expressed through the patent production. It expects to observe collaboration patterns and to set up groups with similar behaviour, analysing differences in the distribution of national and international partners.
- Next, the aim of this work is also to answer if there is any relationship between the patent licensing and the number of partners that participate in the invention. It also intends to know what type of collaboration (local, national or international) is most successful to transfer a patent.

Methods

Definitions

Before to detail the methodology used to respond the above questions, a definition of the main concepts is necessary in order to delimitate and clarify the items used in this study:

Invention: It is defined as the human creation of a new technical idea and the physical means to accomplish or embody the idea (McCarthy et al., 2004). Each invention may be protected in several countries or regions through a patent application. This means that from one invention may be derived several patents. Lowe (2002) suggests to use inventions instead of patents because these speak more to a legal construction than to an economic or scientific phenomena.

Patent: in this study, a patent is considered as the application of an invention submitted to a patent office, regardless of if the protection is granted or not. Only patent applications are analysed, because in that moment an invention is published and became public knowledge, which allows to know the most immediate overview of the state of art and the starting point of the transferring of inventions to the productive sector.

Transferred invention: Every invention that has been run by the productive sector is considered a transferred invention. The way in which this transfer takes place may be varied, but there are three main types of transfer:

- License: it is the most common type of transfer. The owner of the patent permits the use, performance, and/or sale of the intellectual property by another party, mainly the private sector.
- Ownership: the inventor of a patent assigns the ownership of the patent to the company which contracted the research.
- Co-ownership: in this case the ownership of the patent is share by the company which contracted the research and the organization that employs the researches.

Data source

The patent production of the Spanish National Research Council (CSIC) during 2005 to 2009 was used to answer the above questions, concretely 1433 patent applications from 834 inventions. Several databases both internal and external were used to collect this information. The external databases were Invenes from the Spanish patent office (OEPM) to obtain the national applications; Patent scope of the World Intellectual Property Organization (WIPO) to get information about international patent; Espacenet from the European Patent Office and Freepatentsonline.com to search patent application filled in non European countries such as Japan, China or the United States. These databases allow to identify and to complete the information about the CSIC patents such as the number of internal, national or international collaborators. Internal databases provided information about if the patent was transferred or not and in which way was it carried out.

Network

Once identified the inventions of the CSIC's researchers, we have extracted the list of authors of each invention. These authors were identified and associated to their work place. In the case of CSIC's researchers, we have specified the research institute. Then a collaboration network was built in which each node represents a person and a link between two nodes describes the collaboration relationship of two researchers that participate together in a patent application. From this network it was extracted the centrality degree of each researcher and each partner was also classified into:

- Local collaborator: it means partners from the CSIC but not from the same institute
- National collaborator: it means partners from other Spanish institutions
- International collaborator: it means partners from international institutions

This procedure allows to detect differences between research areas and licensed patents according to distinct types of collaborators.

Statistics

Some statistical tests were used to contrast the differences between types of research areas according to their collaboration degree:

- Kruskall-Wallis H test (1952) detects if *n* data groups belong or not to the same population. This statistic is a non-parametric test, suitable to non-normal distributions such as the power law distributions observed in scientometrics distributions.
- Dunn's post test (1961) compares the difference in the sum of ranks between two columns with the expected average difference (based on the number of groups and their size). It is used after the Kruskall-Wallis or Friedman test. The Dunn's test shows which samples are different.

A multiple regression model was carried out in order to estimate and quantify the relationship between the number of licensed patents and the type of collaboration (internal, national, international) existing between their inventors. Linear regression permits to know if there is dependence between variables and what the relative weight of each variable is in the model. Regression goes beyond correlation because it adds prediction capabilities. Due to this we have decided to use a regression model better than a correlation in order to know if the collaboration is a factor to improve the technology transfer in academic institutions.

It is necessary to assume two restrictions on this model: the independence of the observations and the normality of the distribution. The first one states that none of the observations determine the following one. This occurs, for example, when it works with temporary series in which an observation is dependent on the before one, bringing about spurious relationships between the analyzed variables. The second assumption constrains the variables to have a normal distribution which density function has to be symmetric. Due to this, the used variables in this study have been transformed to logarithm.

It is usual to detect collinearity between the predictor variables in multiple regression models, because they are highly correlated between them. This statistical phenomenon can be observed with some statistics. Tolerance is $1 - R^2$ for the regression of that independent variable on all the other ones, so the greater tolerance coefficients, the more independent the variables are. A score less than .2 indicates collinearity. The Variance-inflation factor (VIF) is the reciprocal of Tolerance and values more than 4 indicate collinearity.

These statistical tests were performed with SPSS 17 and XLStat 2008 statistical packages.

Results

Differences between research areas

The research activity of the CSIC is allocated in eight different research areas. Each researcher belongs to a unique research area. The Humanities and Social Science area was not studied because it did not show any patent. The Kruskall-Wallis H test was used in order to detect statistically significant differences between the marginal distributions of the number of collaborators according to the research areas. It noted that there are significant differences (K=83.8; p-value=<.0001) and the Dunn's post test allowed to distinguish these different groups. Table 1 reports the mean of rank of collaborations by each area, in which the Natural Resources' researchers are who least participate with other authors in the network (mean of rank=385.2) while the Physical ones are the inventors who most collaborate (mean of rank=926.8). Mean of rank is used instead of the mean of partners because these distributions do not follow a

Gaussian distribution and the mean of partners would not be representative. Mean of rank is the mean of the positions that each observation occupies in the ranking. Thus, the Physics researchers have an average higher positions in the ranking of the most collaborative, i.e. they have more partners, than the Natural Resources' ones.

Table 1 also reveals that there are several groups (4) that overlap. However, it may be observed that there are two sets with few samples in common: the "Bio" group (B) formed by Biology and Biomedicine, Food Sciences and Technology and Agricultural Sciences; and the "Physicist" group (D) constituted by Agricultural Sciences, Materials, Chemical and Physical Sciences and Technology. These thematic groups show that researchers which work in Bio-related areas make less contact than the Physic-related researchers. Thus the mean of ranks of the Bio group is 761.2 while the mean of ranks of the Physic group is 867.5. Natural Resources area constitutes its own set because there are few researchers that generate patents and they have a peripheral participation in the network. Agricultural Sciences act as a bridge between both sets because its collaboration pattern is not different from the other sets.

Samples	*Researchers*	*Mean*	*Mean of ranks*	*Groups*			
Natural Resources	40	2.825	385.2	A			
Biology and Biomedicine	392	5.077	698		B		
Food Science and Tech.	188	5.394	764.6		B	C	
Agricultural Sciences	110	5.691	820.9		B	C	D
Materials Science and Tech.	275	6.484	844.4			C	D
Chemical Science and Tech.	350	6.914	878			C	D
Physical Science and Tech.	258	7.078	926.8				D

Table 1. Differences between research areas according to the number of total collaborators (Dunn's post test)

If these differences between research areas were observed only considering the national partners, we would appreciate that there still are significant differences between the marginal distributions of collaborators per area (K=47.8; p-value=<.0001). Table 2 indicates that the Food Sciences and Technology's researchers are now who least participate with national partners (mean of rank=279.6), while the Physical Sciences and Technology ones still are the most collaborative inventors (mean of rank=395.5). Natural Resources area was removed because it presented few cases that distorted the analysis. Now, the Dunn's post test distinguishes more clearly the above two clusters: the "Bio" (A) and the "Physicist" (B) groups. Although the Agricultural Sciences and Materials Sciences and Technology areas are overlapped, the Food Sciences and Technology (mean of rank=279.6) and the Biology and Biomedicine (mean of rank=282.4) areas more significantly differ from the Chemical (mean of rank=385.1) and Physical (mean of rank=395.5) Sciences and Technology areas. These results stress the differences between groups, showing that the "Bio" areas have less national collaborators than the "Physicist" ones.

Samples	*Researchers*	*Mean*	*Mean of ranks*	*Groups*	
Food Science and Tech.	80	2.7	279.6	A	
Biology and Biomedicine	174	2.414	282.4	A	
Agricultural Sciences	32	3.031	296	A	B
Materials Science and Tech.	117	3.342	338.9	A	B
Chemical Science and Tech.	166	4.024	385.1		B
Physical Science and Tech.	100	3.59	395.5		B

Table 2. Differences between research areas according to the number of national collaborators (Dunn's post test)

Finally, Table 3 presents the same classification but now according to the international collaboration. It also exhibits significant differences between (K=39.3; p-value=<.0001) the research areas when they participate with international partners. However, these differences change in comparison with the previous two cases (total and national collaboration). Now, the two most differentiated groups (A and C) are not set up by thematic criteria but by the own research characteristics of each area. Thus the group that less collaborate (A) is constituted by Food, Physical and Materials Sciences and Technology areas, while the group that most have international partners (C) is formed by Biology and Biomedicine, Chemical Sciences and Technology and Agricultural Sciences areas. It is interesting to notice that areas such as Biology and Biomedicine (mean of rank=113.4) and Agricultural Sciences (mean of rank=144.5) with low national and total collaboration now emerge with a higher international collaboration rank. In the case of Agricultural Sciences, the international collaboration comes mainly from the Plant Biotechnology research. Contrarily, Materials (mean of rank=84.6) and Physical Science and Technology (mean of rank=79.8) areas decrease considerably their international collaborations. Maybe, because they work in areas (Computing, Electronics) where the national support is stronger and their inventions are more demanded by the local industry.

Simples	*Researchers*	*Mean*	*Mean of ranks*	*Groups*		
Food Science and Tech.	9	1.333	45.5	A		
Physical Science and Tech.	27	1.889	79.8	A	B	
Materials Science and Tech.	63	2	84.6	A	B	
Biology and Biomedicine	38	2.974	113.4		B	C
Chemical Science and Tech.	56	5.036	129.3			C
Agricultural Sciences	13	4.308	144.5			C

Table 3. Differences between research areas according to the number of international collaborators (Dunn's post test)

Collaboration in the patent transfer

The second objective of this paper is to know if the collaboration is a contributing factor to help the transfer of technology through patents. Three collaboration categories, local, national and international partnerships, were used to know if these variables favour the transfer of patents and observe to what extent what type of collaboration most increases the transfer of patents.

A multiple regression model was formulated to detect the relationship between the number of licensed patents by research institute (dependent variable) and the number of local, national and international co-inventors of those institutes (independent variables). Grouped data by institutes were used to build a classical regression model since if disaggregated data were used the licensed patent becomes a dichotomous variable, (to be or not to be licensed) which will oblige us to adopt a logistic regression model. This model was rejected because the estimation and quantification of the results is more difficult. A logarithmic transformation of the variables was also performed in order to fit with the normal probability distribution.

Model	*Unstandardized Coefficients*		*Standardized Coefficients*	*t*	*Sig.*	*Collinearity Statistics*	
	B	Std. Error	Beta			Tolerance	VIF
(Constant)	-.284	.113		-2.521	.014		
National collab.	.360	.072	.459	4.978	.000	.460	2.176
Local collab.	.202	.066	.261	3.047	.003	.532	1.879
International collab.	.203	.075	.219	2.693	.009	.594	1.684

Table 4. Coefficient of the Multiple Regression Analysis

The regression model provides a good fit (adjusted R^2=.66) which allows to claim that the collaboration strongly favours the transfer of a patent. Table 4 summarizes the resulting coefficients and their statistical signification. It points that the three types of collaboration are accepted by the model because their coefficients are statistical significant (t>2). The collinearity statistics indicate absence of collinearity between the independent variables both in the Tolerance and the VIF. Results show that the three types of collaboration contribute to the transfer of patents in a different way. Thus the National collaboration is the variable that most contribute (β_1=.459), followed by Local (β_2=.261) and International collaboration (β_3=.219). These results may be interpreted as an increase of the 10% of the national collaboration causes a 4.59% growth of licensed patents, 2.61% if the collaboration is local and 2.19% if this collaboration is international. Standardized coefficients are used because they better reflect the contribution of each variable to the model.

Discussion

The obtained results on the differences between research areas show that there are two well defined thematic groups that have a differentiated collaboration pattern. The “Bio” group presents a low total and national collaboration ratio, while it stands out in the international collaboration. Contrarily, the “Physicist” is characterized by a high total and national collaboration ranks but poor international collaboration, with the exception of the Chemistry area. This behaviour could be due to that the “Physicist” group works in fields with more national support such as Computing, Electronics or Nanomaterials, while the Biotechnology mainly creates links to European and Latinamerican partners. It is interesting to notice that the observed collaboration patterns in both national and international scenarios are very different between them, which suggests that to establish ties with both national and international partners would not be solely a geographical issue but there would be other important inherent reasons for each area.

Contrarily, disciplinary studies based on international papers (Frame and Carpenter, 1979; Bordons and Gomez, 2000) claimed that the physics was the research field with most international collaboration. In those works, basic disciplines such as astrophysics and high energy physics turned the physics into a highly collaborative area. However, patents are indicators of applied research instead of basic research which could show a different picture in the internationalization of the research disciplines. Thus, taking into account patent data, the results of this study fit with the analysis of the Italian patents of Balconi et al. (2004). They showed that the chemistry and biotechnology disciplines established more international partners than the electronics and materials domains. In a descriptive analysis of the Lund University patents, Göktepe (2006) also observed that the chemistry slightly presented higher co-inventors degree, while materials sciences showed lesser co-inventors. In this way, while the basic physics is more international the applied physics is developed in local environments. This allows us to state that the collaboration patterns in research areas change depending on whether our study is focused in basic sciences (journal articles) or applied science (patents). These differences are tangible when it is observed that the biology is the central core in the basic research (Boyack et al., 2005), while the chemistry is to the applied research (Lissoni et al., 2008).

However, these results have to be interpreted in the context of the CSIC. For example, the research areas are administrative divisions that define the researchers' specialization. However, it may be interdisciplinary activities that could be allocated in different research areas. This is the case of the strong international collaboration of the Agricultural Sciences area which is due to the plant biotechnology, research field close to the Biology and Biomedicine area and the third most international collaborative area. On the other hand, the collaborative pattern of the CSIC research areas could be subject to particular factors such as the maturity and specialization of an area, which may influences the established of ties with local, national or international partners. Further researches in this direction would compare and confirm if these results are due to the particular CSIC performance or, on the contrary, it is extensible to other research institutions.

In this sense, the results about the regression analysis suggest that the type of collaboration most effective to transfer a patent is the established with national partners. This could be because roughly the 71% of the companies that license a CSIC patent are Spanish ones. Hence, these results may be symptomatic of a limited internationalization of the applied sciences of this institution. Although it is also possible that the CSIC would have less international partners because it occupies a central place in the Spanish Research & Development system, since it is the most patenting institution in the country (CSIC, 2006) and it is the principal national partner to compete in the European research programmes (Ortega and Aguillo, 2010). Anyway, forthcoming studies on other research organizations would show if this preference for national partners of the CSIC is peculiar or it is characteristic of the innovation processes (Hansen, 1999).

Conclusions

The obtained results let conclude that there are significant differences between research areas according to their collaborative pattern. Two well defined groups are detected: The “Bio” group which sets up more collaboration ties with international partners than with national ones; and the “Physicist” group that has a more national profile with less international contacts. This conclusion is framed in the applied research context, in which it seems that the “Bio” areas (Biology and Agriculture) tend to produce inventions with a large international presence mainly in the biotechnology field. Whereas the “Physicist” group (Materials and Physics) maintains a strong local and national network of partners, who are involved in supplying new applications to the local industry in fields such as computer sciences and electronics.

It also can conclude that the type of collaboration most effective to transfer patents is the national collaboration. This variable almost duplicates the probability of the other variables, which shows that the CSIC strongly depends of the national industry in order to disseminate their applied research outputs.

References:

Agrawal, A. (2000). Importing scientific inventions: direct interaction, geography and economic performance. Mimeo: Massachusetts Institute of Technology

Balconi, M., Breschi, S., & Lissoni, F. (2004). Networks of inventors and the role of academia: an exploration of Italian patent data, *Research Policy*, 33: 127–145

Boccardelli, P., Leone, M. I., Magnusson, M., & Reichstein, T. (2010). Fuel on the Invention Funnel: Technology Licensing-in, Antecedents and Invention. [Working Paper]. DRUID, Aalborg. pp. 35. http://www3.druid.dk/wp/20100013.pdf

Bordons, M., & Gomez, I. (2000). Collaboration networks in science In: B. Cronin & H. B. Atkins (eds.). The web of knowledge: a festschrift in honor of Eugene Garfield. New Jersey: Information Today

Boyack, K. W., Klavans, R., & Börner, K. (2005). Mapping the backbone of science. *Scientometrics,* 64(3), 351-374.

CSIC (2006). Plan de Actuación 2006-2009. Madrid: CSIC

Price, D. J. de S. (1986). Little Science, Big Science ... and Beyond. New York: Columbia University Press.

Dunn, O. J. (1961). Multiple comparisons among means, *Journal of the American Statistical Association*, 56: 54-64

Frame, J. D., & Carpenter, M. P. (1979). International Research Collaboration. *Social Studies of Science*, 9(4): 481-497

Godoe, H. (2000). Innovation regimes, R&D and Radical innovations in telecommunications. *Research Policy*, 29: 1033-46

Goktepe, D. (2006). Identification of University Inventors and University Patenting Patterns at Lund University: Conceptual- Methodological & Empirical Findings. DRUID Winter Conference, Copenhagen, Denmark http://mpra.ub.uni-muenchen.de/1628/1/MPRA_paper_1628.pdf

Hagstrom, W. O. (1965). The Scientific Community. New York: Basic Books, Inc.

Hansen, M. T. (1999). The Search-Transfer problem: the role of weak ties in sharing knowledge across organization subunits. *Administrative Science Quarterly*, 44: 82-111

Katz, J. S., & Martin, B. R. (1997). What is research collaboration? *Research Policy*, 26(1): 1-18

Kruskall, W.H., & Wallis, W. A. (1952). Use of ranks in one-criterion variance analysis, *Journal of the American Statistical Association*, 47(260): 583-621.

Lee, Y. G. (2009) What affects a patent's value? An analysis of variables that affect technological, direct economic and indirect economic value: An exploratory conceptual approach. *Scientometrics*, 79(3): 623-633

Lissoni, F., & Montobbio, F. (2008) Guest authors or ghost inventors? Inventorship attribution in academic patents. The 25th DRUID Celebration Conference 2008 on Entrepreneurship and Innovation, Copenhagen, Denmark http://www.econ.kuleuven.be/msi/_docs/workshops/2008-04-24.pdf

Lissoni, F., Llerena, P., McKelvey, M., & Sanditov, B. (2008). Academic patenting in Europe: new evidence from the KEINS database. *Research Evaluation*, 17(2): 87–102.

Lowe, R. A. (2002). Entrepreneurship and information asymmetry: Theory and evidence from the University of California. Working Paper 11/25/02, http://littlehurt.tepper.cmu.edu/gsiadoc/wp/2003-09.pdf

McCarthy, J. T., Schecter, R. E., & Franklyn, D. J. (2004). McCarthy's desk encyclopedia of intellectual property, (3ª ed.), Washington: The Bureau of National Affairs

Meyer, M., & Bhattacharya, S. (2004). Commonalities and differences between scholarly and technical collaboration: An exploration of co-invention and co-authorship analyses. *Scientometrics*, 61(3):443-456

Mowery, D. C., & Ziedonis, A. A. (2001). The Geographic Reach of Market and Non-Market Channels of Technology Transfer: Comparing Citations and Licenses of University Patents. NBER Working Paper Series, w8568 http://dimetic.dime-eu.org/dimetic_files/MoweryZiedonis2004%20University%20Licenses%201.pdf

Ortega, J. L., & Aguillo, I. F. (2010), La participación española en los programas europeos: análisis estructural del área de salud del 6º Programa Marco, *Revista Española de Documentación Científica*, 33(2):287-297

Powell, W. W., & Grodal, S. (2004). Networks of innovations. In: J. Fagerberg, D. Mowery & R. R. Nelson (eds.). The Oxford Handbook of Innovation, Oxford: University Press.

Sapsalis, E. (2007). From Science to License: An exploratory analysis of the value of academic patents, Working Papers CEB 07-018.RS, Universite Libre de Bruxelles. https://dipot.ulb.ac.be:8443/dspace/bitstream/2013/53932/1/RePEc_sol_wpaper_07-018.pdf

Vinding, A. L. (2002). Interorganizational diffusion and transformation of knowledge in the process of product innovation, Ph. D. Thesis, Aalborg University http://www.business.aau.dk/~alv/Vinding-Dissertation.pdf

Yoshikane, F. (2006). Comparative analysis of co-authorship networks considering authors' roles in collaboration: Differences between the theoretical and application areas. *Scientometrics,* 68(3):643-655