‘BENEATH THE TIP OF THE ICEBERG’: THE MULTIPLE FORMS OF UNIVERSITY-INDUSTRY COLLABORATIVE LINKAGES

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Abstract

This article focuses on the wide variety of channels through which the process of knowledge transfer occurs. The overall objective is to show the complexity of relationships between researchers and firms in a university system, and to identify some specific factors that influence such interactions. Our case study involves a face-to-face survey of 765 heads of research teams in a regional system to contrast the multiple forms of university-industry collaborative linkages. Drawing on the exploitation of a data set developed for the purpose, we show that for a majority of universities the thrust of their collaborative experiences is devoted to tacit knowledge rather than to intellectual property rights. Researchers actively engage in the provision of different services to firms such as consulting work, commissioned or joint research projects, and human resources training. Research teams also participate in non-academic knowledge dissemination and informal networking. The results of our study enable us to draw some policy implications for university administrators and policymakers. A focus on patents and spin-offs as indicators of collaborative research ignores the limits of many of the economic and productive contexts in which universities are embedded. It may also be detrimental to the strengthening of emerging trends that are oriented towards softer collaborative experiences and other forms of knowledge transfer.

Keywords
University-industry relationships; Knowledge transfer; Intellectual property rights; Regional university system

1. Introduction

Third mission activities in universities are currently an issue of growing importance in the agenda of university strategies and R&D policy initiatives (Martin et al., 1996; Etzkowitz et al., 2000). However, both policymakers and scholars devoted to the study of third mission activities normally place the emphasis on what are considered the core activities involved in the transfer of technology from universities to industry at large i.e., the generation of patents and the creation of spin-off firms stemming from research projects, that is, those collaborative activities related with the exploitation of intellectual property rights (IPR).

This emphasis is built on an assumption about the environment of what constitutes an average university that is not supported by empirical evidence. On the one hand, only a minority of universities have the capacity to engage in patenting activities and the creation of spin-offs (Owen-Smith, 2003). On the other, the productive environments of a considerable proportion of universities are constituted by firms that have little absorptive capacity for R&D innovation given their limited size and the relatively low technological content of their productive processes (Bonaccorsi and Daraio, 2007). As a result, an increasing number of scholars are pointing to the need for further research on the variety of different types of collaborative links that exist between firms and universities (Laursen and Salter, 2004; D`Este and Patel, 2007).

In the light of these considerations, we depart from the following research question: What are the main forms of university-industry relationship that can be found in a regional university system? We argue that IPR are only the tip of the iceberg of a wide range of knowledge transfer processes for two main reasons. First, IPR mechanisms are concentrated only on some fields and on a small proportion of the scientific community whilst most researchers do carry out different kinds of collaborative activities with firms. Second, in the more IPR oriented scientific specialties, IPR interactions emerge as the visible part of a complex set of relationships that are usually interconnected. Such collaborative practices are influenced, among other factors, by both the work characteristics of the research teams and the experience of the researchers. We assume that the usual accounts of technology transfer offices do not provide an accurate picture of the current relationships. Given that many of the collaborative activities are carried out by researchers in an independent manner, it is necessary to look carefully at them from the bottom level of a university structure: the research teams. Our methodological strategy is to use the research teams of a university system as a unit of analysis, and to identify multiple forms of university-industry linkages and the main trends that emerge in those interactions with industry.

Our strategic research site is a whole regional university system[1]. We study collaborative activities between universities and firms in Andalusia, a region of Southern Spain traditionally characterized by its weak industrial fabric, and an emerging but yet detached ‘mode 2’ (Gibbons et al., 1994) university system that is representative of a considerable number of European regions (Garlic, 1998; Howells et al., 1998). In the framework of this project, we have carried out a face-to-face survey of 765 heads of research teams located

[1] The study also covers public research organizations (PRO) located in the region, mainly CSIC (Consejo Superior de Investigaciones Científicas) institutes. Given that universities are highly predominant, and careers and organizational procedures in most PRO are similar to the ones used by universities, for clarity purposes we use the terms ‘university research system’ or ‘university-industry collaboration’. When we refer to ‘universities’ we also include PRO in the region.

in the region, aimed at creating an exhaustive indicator set that includes collaborative R&D activities that often go unreported in most studies.

The article is divided into six main sections. After this introduction, section 2 provides some background on this issue by discussing the current literature on the contrast between the emphasis on IPR and the trends that diversify the relationships with firms. Section 3 is aimed at describing the characteristics of the region of our case study. We highlight the specific traits of the institutional and productive environment that influence knowledge transfer processes. In section 4 we present our methodology, including the steps in our inductive analytical strategy as well as a description of the data source, the sample, the fieldwork and the indicator set. Section 5 presents our main findings. Discussion of the results and conclusions appear in section 6.

2. Background

This section examines the current scenario in order to establish a basis on which to develop our thesis and theoretically orient the observations of our empirical study. An explanation is provided of the mechanisms that contribute to the increase in certain forms of IPR. This explanation is followed by a review of the empirical studies that identify factors that influence relationships between universities and their socio-economic environment, highlighting the elements in these studies that help generate a variety of relationships with businesses.

2.1. *The contested terrain of university-industry relationships*

The transformations in the production of knowledge that have taken place in recent decades, particularly since the 1980s, have placed universities at the heart of knowledge societies. The so-called linear innovation model, which encouraged scientific organisations to make discoveries and subsequently transfer them to technology development entities and firms, has gradually given rise to more interactive and dynamic relationships (Cohen et al., 2002). These transformations were partly fuelled by the actual internal development of universities, and influences external to academic institutions. Greater organisational and institutional complexity has spurred progress in the search for different exchanges of knowledge and its more effective exploitation (Etzkowitz et al., 2000). The proliferation of knowledge-based innovation has changed the role previously played by universities as the main vehicle for transferring technology. However, rather than diminishing their importance as producers of scientific knowledge (Godin and Gingras, 2000), it has changed the nature and execution of that production, and especially the way in which they interact with industry. The process has also become multidirectional, leading to multiform knowledge flows.

However, there is a marked contrast between the importance attributed to certain forms of technology transfer and the real relationships that exist between universities and industry. Both R&D policies geared to linking universities more strongly to economic development and the actual management of universities have favoured certain mechanisms, particularly those related with the exploitation of IPR such as patents, licenses and certain spin-off transactions. Specialised literature increasingly supports that these types of interactions do not occur in most universities, and that it is more accurate to refer to knowledge transfer flows rather than just the transfer of technology. In fact, only a small proportion of all knowledge transferred to industry flows through the channels identified in most policy approaches (Cohen et al., 2002). Other exchanges are more frequent, ranging from consultancy work and commissioned research to personnel mobility or different forms of knowledge dissemination. As noted in our introduction, the productive environments of many universities are formed by firms with little absorptive capacity for R&D innovation given their limited size and the relatively low technological content of their productive processes. This is particularly true of many regional innovation systems. Moreover, third mission activities are still not institutionalised in many universities around the world, meaning that there is little or no formal record of the nature of those activities, let alone the variety of forms which they take. The varieties of knowledge transferred from universities to industry and the processes which enable those transfers remain poorly understood. Despite these acknowledged limitations, a focus on IPR activities continues to be at the forefront of the strategies of numerous governments and university managers. The inadequacies of this approach are frequently accentuated in the literature (Geuna and Muscio, 2009) but only rarely have systematic explanations been given for the forces that fuel the emphasis on commercialisation. Furthermore, studies in this field tend to offer little evidence to refute this trend. Considerably more research has been conducted on patents and spin-offs than on empirical studies which demonstrate the many different collaborative relationships that exist within university systems, possibly because such studies present greater methodological difficulties and are often contingent upon the area where the university is located.

2.2. *Why are IPR activities considered to be the core of university knowledge transfer?*
Governments and universities emphasize the commercialisation of scientific results for various reasons, which may be analysed at different levels. One group of macro-level influences derives from patent regulations, as well as the promotion of certain successfully commercialised technologies. Meso-level influences are related to the organisational changes that accompany the growth of technology transfer offices. Lastly, at the micro level, there are mechanisms that allow individual researchers to obtain incentives and rewards associated with IPR activities. All these elements together provide positive feedback within the whole process and help to consolidate it, thus contributing to its long-term growth.

Many of the studies on the macro-level influences noted above have stressed the role played by legislation and regulations, especially the Bay-Dole Act in the United States. This law empowered universities and other public research institutions to economically exploit inventions developed through research financed with federal funds. It was based on the assumption that there was an important stock of valid knowledge within these institutions which had hitherto remained unexploited, allied with a conviction that patents could act as a catalyst to boost private-sector investment in R&D (Mazzoleni and Nelson, 1998). The growth of IPR processes is therefore considered to be a direct consequence of this law, which specifically sought to facilitate the application of research results in industry. From this perspective, the development of technology transfers through patents and licences is due to the combination of greater business-sector confidence in external R&D, and the growing desire of university managers to open universities to new possibilities (Thursby et al., 2009). The effects of the American law later extended to Europe, where similar policies were implemented.

The boost provided by legislation was fuelled by the success of the key technologies of the knowledge economy. The increase in the exploitation of patents by universities coincided with the expansion of productive processes that led the third industrial revolution (Castells, 1995), especially those based on information technologies, biotechnology, biomedicine, and material sciences. Advances in these fields were very closely linked to universities, and were easily transferable to certain forms of IPR, fuelling a substantial increase in their revenues, together with the creation of very dynamic local firms. This enhanced the visibility of such transfer practices, sometimes accompanied by the legitimacy resulting from the scientific and economic success of certain research fields. The combination of visibility and legitimacy had an imitation effect. The organisational learning models available for less developed university systems, often affected by political pressures and the paucity of public resources, have derived from the most successful models. All this has enabled the IPR transfer system to be institutionally reproduced at other universities (Drori et al., 2003), even in those that are not as research intensive, have a teaching focus, or are located in traditional productive environments with little absorptive capacity.

IPR practices at the meso-level are generally promoted by the organisations that manage transfer processes. In the 1980s and 1990s, these practices were institutionalised through the creation of different organisations dedicated to promoting and facilitating exchanges with industry (e.g. science parks, incubators), including, most notably, so-called technology transfer offices. These new organisations were conceived as the main mechanisms for channelling interactions between universities and firms. Governments and universities also launched different programmes and incentives in pursuit of the same objective. The aim of this strategy was to establish more efficient administrative management systems designed to obtain information on the activities performed by academic departments and teachers and also to capture new sources of income (Fernández de Lucio and Conesa Cegara, 1997). The relationships between universities and their local environments were promoted in the hope that this would foster greater socio-economic development due to the growing importance of knowledge for national and regional innovation systems.

Some social mechanisms that strengthen the role of IPR derive from these specialised organizations and support programmes focusing on the promotion and management of certain transfer practices. Technology transfer offices are useful because they can provide support in obtaining and licensing patents. They also make it easier to collect information on encoded scientific results compared with other research activities that are difficult to monitor. IPR management improves due to the management services afforded by technology transfer offices, enhancing the visibility of university outputs, affording legitimacy by strengthening the visibility of relationships with the industrial sector and sometimes enabling the obtainment of economic returns. As a result, universities promote incentives to help teaching and research staff to transfer their discoveries to patents and at the same time increase organisational efforts to gather data and facilitate the registration of patents. In contrast, other transfer processes do not adapt so easily to measurable approaches. It is also more difficult to monitor other cooperative activities carried out independently by academics with industry. Furthermore, statistical data on IPR is more readily available in government agencies and universities. Patent information is standardized internationally and easy to compare. Its ease of use contrasts with the difficulty involved in gathering information on other transfer activities, which are harder to capture and interpret within the management framework due to the strong impact of contextual factors (scientific field, type of centre, local practices, etc.).

Finally, micro-level causes are found on the behaviour and careers of individual researchers. The existence of specialised university structures and regulations means that practices less recognised in the past can now be institutionalised. Researchers gradually absorb, assimilate and integrate incentives from research policies and new practices promoted by governments and universities into their form of work (Colyvas and Powell, 2006). This process is far from homogeneous and is highly complex, particularly in terms of the adaptation of scientific activities in organisations that regard themselves as conforming to Mertonian rules on the ‘ethos of science’ (universalism, communism, disinterestedness and scepticism) to others based on entrepreneurial attitudes (George and Bock, 2008). The demands of an entrepreneurial approach require focusing on execution, the short term transformation into sellable products, and the obtainment of profit. Such a transformation is influenced by economic and other intangible stimuli (Turpin and Garrett-Jones, In press) through the incentives and rewards system operating in job appointments and scientific careers.

At the micro level, the mechanism that helps consolidate the role of IPR transactions is related to evaluation procedures. Evaluation agencies attribute increasing importance to these practices as standardized indicators of the quality of researchers’ work. The existence of a possible substitution effect between IPR activities and publications has even been reported (Gulbrandsen and Smeby, 2005). In other words, both are relatively interchangeable as a merit criterion without negatively affecting a scientific career since patents and publications tend to go hand in hand (Geuna and Nesta, 2006) and are even mutually strengthening because inventors publish significantly more (Van Looy et al., 2006). In fact, in industries such as biotechnology, the patent-publication pattern is not uncommon since firms engage in significant publishing activity (Nelson, 2009). It is therefore conceivable that researchers with a certain level of prestige in these fields are more willing to patent their results than to be involved in other transfer actions, at least in the initial or intermediate phases of their respective careers. The patent-publications link is connected with the efforts made by scientists in general to preserve the identity of their academic role, even when participating in transfer activities (Jain et al., 2009).

2.3. *Factors that diversify the relationships between universities and industry*

Despite the existing bias towards certain specific forms of knowledge transfer, numerous studies on this subject have revealed that it is insufficient to solely prioritise licences, patents and spin-offs as the only mechanisms for transferring knowledge because these are minority activities and therefore present an incomplete picture of reality, since they ignore important channels. This, in turn, distorts the real valuation of universities’ influence and importance to the private sector and innovation more generally (Agrawal and Henderson, 2002; Cohen et al., 2002; Geuna and Muscio, 2009). In any event, IPR mechanisms coexist with many different knowledge transfer activities, as described in the literature. The following factors do have an objective existence and these, according to their configuration, add variable elements to interactions between universities and industry.

A first source of influences comes from the characteristics of firms surrounding the university. The diversity of the productive sector prompts a diversification of relationships with universities. Larger firms operating in more knowledge-intensive sectors, and therefore with substantial absorptive capacity (Cohen and Levinthal, 1990) can adapt scientific discoveries more easily to their productive processes and commercialise these discoveries. Consequently, a firm’s size and the industrial sector in which it is situated are major factors explaining the type and level of interaction (Mohnen and Hoareau, 2003; Laursen and Salter, 2004; Fontana et al., 2006). As a result, one determining factor is the productive environment of the region where the university is located. In regions with a concentration of high technology firms, more agreements in terms of patent exploitation or co-patents can be expected (Friedman and Silberman, 2003), as well as relationships with firms outside the region when the technologies developed by universities are good enough to transcend territories and play in the global economy. Other firms, however, demand specific consultancy and/or technical support services (scientific and technical knowledge and problem-solving capacities) or try to get advantages through staff exchanges and the mobility of human resources from universities. Tacit knowledge and informal contacts are also considered crucial aspects in these interactions (Bozeman et al., 1995). Therefore, firm demand and receptivity are important in explaining the variety of models (Geuna and Muscio, 2009).

A second factor generating heterogeneity in university-industry relationships is the level of social capital. Social capital refers to the network of relationships that each interacting actor has built during his or her respective professional career. The greater availability of social capital fosters exchanges. This factor is closely related to the degree of confidence achieved; hence, this is reflected in the greater frequency of interactions and longer-lasting links, which are particularly visible in the case of entrepreneurial firms (Murray, 2004). The growing diversity of firms, together with the creation of new industrial fabric, implies the availability of different types of social capital that give rise to multiple university-industry relations, ranging from informal and tentative to more formalised relations. Establishing contacts that forge links of trust is also crucial for transmitting tacit knowledge. Geographical proximity may also have a favourable influence on social capital and play a key role in the transfer of knowledge (Zucker et al., 1998). It is expected that universities embedded in local and regional environments (through community work, exchange of students with local firms and service orientation to the near productive sector) can built social capital that foster a diversity of links with firms.

A third factor to be considered is the institutional structure of the university. The conception and implementation of third mission activities by universities are reflected in their strategic decisions on the articulation of knowledge transfers. The way these practices are managed, as well as organisational facilities and established incentives systems, will influence their development. Several factors have been identified as enhancing university technology transfer: a clear university mission which supports technology transfer, the experience of the university technology transfer office, and greater rewards for staff involvement in technology transfer (Friedman and Silberman, 2003). Thus, the institutional structure of the university can facilitate IPR-based transfer practices (e.g. when it has economic resources and specialised personnel to facilitate the licensing of patents as opposed to informal or other types of contracts) and to reward academics' achievements in a different way. Equally important is the orientation of policies that affect university financing.

Finally, the characteristics of researchers appear as an additional cause of heterogeneity to be considered. Faculties themselves often play a critical role in university-industry technology transfers (Thursby et al., 2009). In fact, some studies show that the characteristics of individual researchers have a stronger impact than the specific characteristics of departments or universities (D`Este and Patel, 2007). Furthermore, since much scientific activity is performed by research teams, a series of characteristics of actions carried out with industry are linked to the form of internal organization of work and to the accumulation of capacities to achieve this objective. These characteristics include team size, available funds, teamwork and experience deriving from the stability and age of the team. Another set of variables that affect knowledge transfer derive from the orientation of scientific work and the distribution of time between teaching and research. Lastly, team leaders can play a crucial role in building a favourable attitude towards transfer. Therefore, their prestige both inside and outside the scientific community (especially among firms in the sector), their individual experience and their degree of seniority will influence the level of interaction established by the team.

This study takes into account the structure of the university system and the productive environment in a region as contextual and conditioning factors when examining the empirical evidence. The analysis employs several institutional factors referring to the scientific discipline and the type of centre as well as some characteristics of research teams, their forms of work and their leaders' profiles.

3. Our case study

Our case study focuses on the regional system of Andalusia[2]. This is a strategic region for studying the wide variety of relationships with industry. Andalusia has an extensive public university system resulting from growth based on a traditional and centralized university model and a productive sector with relatively little absorptive capacity. Nevertheless, both the productive sector and the university system have benefited from innovation policies that have allowed universities to acquire scientific capacities and build links with industry, as well as the emergence of innovative firms, thus diversifying relations between both sectors. The relationships between universities and industry are also institutionalised unevenly among different scientific disciplines. For all these reasons, this case study has implications for many university systems, especially those located in catch-up regions (Fuchs and Shapira, 2005).

In terms of its innovation system, Andalusia can certainly be considered a catch-up region because its indicators are still not on a par, from a convergence standpoint, with those of developed European countries. Figures for investment in R&D are still low by international standards (1.5% of GDP) and are concentrated in the public sector (65% of total expenditure). The productive environment is formed largely by small and medium-sized services firms or traditional manufacturing ones. As a result, the industrial sector generally still has little capacity for investment in R&D (COTEC, 1998; CICE, 2006). Low absorptive capacities are also reflected in the number of patents generated in the region[3]. Nevertheless, the region has emerging industries, especially in the new energy, aeronautics and agrofood sectors, as well as active innovation policies (CES, 2008).

The regional university system is governed by a national regulation, which confers universities a certain degree of independence in decision making, although they depend on the regional government for financing and management. The system has been built on sustained growth since the 1980s aimed at providing educational services. Therefore, it has the characteristics of a traditional university system in which professors have focused primarily on teaching and the production of academic publications. The overall regional

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[2] Andalusia is situated in the south of Spain. With nine million inhabitants, it is the largest region in the country in population and the second largest in terms of surface area. It is extremely diverse in both its territorial composition and its degree of development and income-per-capita in urban, rural and coastal areas.

[3] A total of 413 patents in 2005, 113 of them were registered by Andalusian universities (CICE, 2006). These figures are low when compared with other regional university systems with stronger scientific background which are located in more knowledge intensive environments.

university system[4] is extremely diverse in terms of its scientific capacities. Some centres have a long tradition of outstanding scientific achievement (mainly those located in the oldest universities: Granada and Seville), others focus almost exclusively on graduate education. There are also new centres resulting from recent investments in R&D.

Given the difficulties involved in developing an innovation system that is convergent with other more developed countries, and in spite of their weaknesses, universities have been the main resource of R&D in the region. The university sector has the highest concentration of persons capable of producing scientific knowledge, taking into account the small number of doctors in public research centres and firms[5]. For that reason, universities have been one of the main beneficiaries of regional science policy[6]. The main instrument of this policy has been the financing of university research teams, which have received sustained financial support since the late eighties (Pérez Yruela et al., 2003). Since the national government introduced formulae to finance projects open to universities nationwide, the regional government decided to concentrate on ensuring its actions do not overlap with other existing initiatives. The principal aim of this financing for research teams[7] was to encourage academics to compete actively in project programs under the National R&D Plan and the European Framework Programme.

This policy has also had an impact on the internal organisation of universities because it has made research teams part of university structures. In contrast to the teaching orientation of university departments, the creation of an official register of research teams has established it as the basic organisational unit responsible for conducting scientific research. Universities have used this official register as a tool for managing and capturing resources. This situation has become much more formalised, to the extent that most recent regulations - both the University Law of 2003 and regional regulations governing the university system - treat research teams as a core element in the organisational structure of universities.

Although traditional science policy has focused on the creation of scientific capacities, since the late 1990s (particularly since 2003 when university policies and industrial innovation were unified in the same department of the regional government), programs have been launched to facilitate collaboration with industry. These include the creation of a public and private technology fund to finance business projects, which requires the participation of a university research team and the creation of specific lines of financing for universities to carry out applied research projects and create spin-offs.

Collaboration between university researchers and firms has acquired different levels of institutionalisation. There is a diverse network of technology transfer offices at all the universities, although they do not have either a unified structure or common policy which it is reflected in their communication strategy (Ramos-Vielba and Clabo-Clemente,

[4] The regional university system consists of nine public universities that employ close to 17,000 professors and researchers in all of the university categories (Fernández-Esquinas, et al., 2008), together with 1,200 which are part of public research organisations (CICE, 2006).

[5] According to the figures from the Institute of National Statistics referred to 2007, the percentage of researchers at universities is 65%, compared with 10% in the public administration and 25% in firms.

[6] Sometimes due to the combination of political interests in the regional government, where R&D managers have been linked with universities, and on other occasions due to the difficulty in directing science policies to firms with little absorptive capacity and due to the need to concentrate industrial policy on reconverting large obsolete industrial sectors.

[7] Research teams have traditionally been associated with the financing of other tools of regional science policy such as research grants, contracts for research assistants and infrastructure. The regional government has not financed projects until 2006, when a competitive grant process was announced for universities and public centres.

2008). In general, it would be correct to say that technology transfer offices operate on the initiative of university teachers who require their services. The most developed activities are patent licensing, the establishment of exploitation and collaboration contracts and support for participation in EU Framework Programme projects. The latter activity is particularly important in technology transfer offices because the departments and research teams normally lack the administrative infrastructures necessary to handle the bureaucratic burden associated with European projects. As regards the recognition of transfer activities in the professional careers of researchers, the most recognised activity is patenting, because patents can be included in the procedures of evaluation agencies. For research teams working in fields in which opportunities for patenting their results are scarce (e.g. social sciences, humanities and environmental sciences), knowledge transfer is difficult to evaluate and barely formalised in evaluation protocols.

All the aforementioned characteristics give rise to an assorted situation in the area. The region has a very extensive public university system that has developed R&D competence substantially in some departments and is able to interact with new growing industrial sectors thanks to public aid. From the business perspective, the region has an equally varied productive sector in terms of its absorptive capacities, resulting in a huge diversity of demands placed on universities.

4. Methodology

Our methodology is based on a primary data set obtained using a survey that we conducted in 765 research teams in Andalusia in 2008. We follow an inductive strategy employing procedures that allow complexity to arise. The first step of the analysis is to map out the participation of research teams in a wide range of collaborative activities using a specific group of indicators. In the second step, we reduce the original indicator set. For that purpose we apply a factor analysis to identify correlations and underlying dimensions. Subsequently, a conglomerate analysis enables us to detect homogeneous clusters of research teams. We classify the research teams in terms of the types of transfer activities they carry out. The last step consists of assigning meaning to those conglomerates by identifying the main characteristics of the research teams in each resultant cluster. Our analysis takes into account three groups of factors referring to some characteristics of research teams, their forms of work and their leaders’ profiles.

4.1. *Data source, sample and fieldwork*

The source for our survey is the official registry of research teams in the public R&D sector run by the regional government to allocate R&D funding to researchers, and, at the same time, to gather information from the scientific community. We use the research team as the unit of analysis. A research team is defined as a ‘a stable group formed by one or more scientific leaders, several researchers, young people on training internships and technical support personnel, that share technical-scientific goals, resources, infrastructures and equipment, with joint participation in research, development and innovation projects in collaboration with firms or public organizations’ (CICE, 2006). Since practically the entire scientific community is organized in research teams and registered, it is believed that using them as the unit of analysis makes it easier to observe third mission activities.[8] It is our view that research teams, by including people from all professional categories,

[8] The registry of research teams covers more than 90% of the scientific community in the public sector. Researchers that are part of bodies outside of the public sphere or those that do not realize year-on-year activities in said teams are not included in the registry.

from research assistants to full professors, provide better coverage than a survey targeting individuals.

The reference population is made up of 1,769 research teams registered in 2006. The regional government has provided the name of the leader and other basic information. For our purposes the research teams were separated using two criteria: the type of entity where they realize their activity (universities, institutes that are part of the Spanish National Research Council –CSIC-, hospitals or other regional government centres) and the nine disciplines in which they are inscribed.

A sample of 800 research teams were chosen, stratified using proportional allocation based on the nine scientific areas. A simple random selection in each stratum resulted in a proportional distribution of the sample by types of centre and scientific field in the region. The survey was conducted using a personal interview at the workplace of the team leader or, in his absence, another member assigned by him. A total of 765 people responded to the survey, giving a response rate of 95%. The characteristics of the sample can be seen in Table 1. The majority are teams from universities (89%), since these have the greatest weight in the public regional R&D system. With regard to the scientific field, they can be placed in 'Humanities and Artistic Creation' (28%), followed by 'Health Science and Technology' and 'Social Science, Economics and Law' (both with 13%) and 'Experimental Sciences' (11%). The majority of the teams are mid-sized: between six and ten members (43%) and between eleven and fifteen members (24%). These are well-established teams since half of them have been together for between eleven and twenty years.

[Table 1 around here]

4.2. *Indicator set*

During the selection process for the indicators it was deemed necessary to adapt the different possible relationships between universities and firms to the survey fieldwork. First, a long list of knowledge transfer activities was created based on a review of the literature. After doing several pre-tests, thirteen were chosen. Interactions that are so specific that they only correspond to one scientific specialty or to one sector of activity, and therefore have very low frequencies, were added to categories of a similar collaboration type. Nevertheless, in addition to the pre-codified list of indicators, the survey permitted an open option of 'other types of collaboration' which was assigned by the interviewer and codified afterwards. The indicator set[9] covers collaborative activities in all disciplines carried out either with industries located in the region or outside.

The indicator set considers four groups: a) R&D activities and formal consulting work, b) training and transfer of personnel, c) commercialisation related to IPR, d) other contacts (see Table 2). Those groups are divided into thirteen types of possible relationships. For each type both firms and research teams were asked if they had formed this relationship within the previous seven years (2000-2007) and the number of interactions during the same period.

[9] Elsewhere we show the validity of this indicator set by contrasting the results obtained by its application to both research teams and firms (Ramos-Vielba, et al., In evaluation), and also in an analysis carried out with a sample of industrial firms of the region (Fernández-Esquinas, et al., In evaluation).

[Table 2 around here]

5. Findings

5.1. *Mapping out collaborative activities by research teams*

Table 3 shows the participation of research teams in collaborative activities. Informal links (45%) stand above the rest. The other indicators can be grouped in three categories:

- A high number perform expertise consulting for firms (38%) and research projects commissioned by firms (34.8%). Teams that do joint research (30.6%) also stand out, which is in the same proportion as those that organize non-academic knowledge diffusion activities with firms (meetings, conferences, fairs, etc.).
- Second, there is a notable presence of activities related to human resources, which flow both ways: specific training taught by the research teams to a firm (24.2%), internships of research team members in firms (20.4%), and exchange of scientific and technical personnel (12.4%).
- Participation in the exploitation of patents occur in 10.1% of the cases, being more common than renting facilities or equipment (8.4%) and the creation of spin-offs or start-ups in collaboration with a firm (6.1%).

A total of 425 cases, or 55.5%, of the sample had participated in at least one of the types of collaborative activities with firms, not including informal relationships, in the period 2000-2007. Thirteen cases declared that they had only had informal contact and the number of research teams that had not participated in any type of cooperative relationship was 327 (42.7%).

[Table 3 around here]

5.2. *Factor and conglomerate analysis*

In the factor analysis we excluded the informal relationships and those that corresponded with other types of activities. The only meaningful result is the one that uses dummy variables, which indicate the existence of a relation for each item (that is, variable is equal to one if the research team participated in each type of collaborative activity and 0 otherwise). Table 4 shows the rotated component matrix used to interpret the factors.[10] The first factor identifies activities related to human resources (specific training for a firm's workers, internships for postgraduates in firms, or personnel exchange), in addition to those that organize non-academic knowledge diffusion activities with firms. The second factor is made up of variables that include exploitation of patents, creation of spin-offs and joint research projects. The third factor comprises variables related to research projects commissioned by firms or consulting work for them. The forth factor is equivalent to renting facilities or equipment and the last one is the creation of a joint venture or hybrid centre. The five factors have been assigned the following denomination in accordance with the characteristics of the activities they contain:

F1: 'Training and exchange of human resources and knowledge diffusion'
F2: 'Commercialisation: patents, spin-offs, and joint R&D projects'
F3: 'Knowledge services for firms: commissioned research projects and consulting work'
F4: 'Use or renting of facilities or equipment'

[10] Percent of variance for each factor can be observed in Table I of the Statistical Appendix. The same procedure of a factor analysis followed by a cluster analysis was conducted using interval variables referring to the number of contacts in the same given period. These analyses have not led to clearly identifiable results. The interval measurements obtained using this fieldwork scheme does not contain information to create significant groups.

F5: ‘Joint ventures or hybrid research centres’

[Table 4 around here]

The next step in the analysis is aimed at establishing a typology of research teams according to their type of collaboration with firms, as well as a profile of the groups of teams identified. This consists in using the five factors obtained to detect teams that engaged in common cooperative activities. The procedure used is cluster or conglomerate analysis,[11] which was only employed with research teams that engaged in some type of cooperation. Therefore, 45% of the teams in the sample (348 teams in total) that stated that they had not participated in any type of cooperation were classified as ‘cluster 0’ (C0), labelled as ‘teams that do not cooperate with firms’. In addition to cluster 0, this analysis produced six clusters. Table 5 shows the composition of the aggregates, as well as the activities performed by each type of cluster. The aggregation indicates the performance of various activities in collaboration with firms; this combination made a cluster homogeneous and differentiated it from the others. However, it is important to highlight that although these aggregates were characterised as maintaining privileged relationships, one specific type of collaboration was never isolated but closely related to other collaborations, for example, between research projects and consultancy work. Projects were also developed together with participation in mixed centres, the transfer of patents and the creation of spin-offs. However, they were not so closely associated with the rendering of services or, in particular, training activities. In contrast, the latter were developed jointly with non-academic knowledge dissemination activities.

[Table 5 around here]

5.3. *A profile of research teams according to the relationships with industry*

The profile of each cluster is established taking into account certain features of the research teams that, as reported in the literature, may have a certain influence on the relationships of academic researchers with firms. For this purpose, eleven variables were selected reflecting three sets of features. The first group referred to the so-called ‘structural’ characteristics of research teams, such as the scientific field, type of centre, size and age of the team. The second group of variables reflected the conditions in which they carried out their activity. Two of them referred to the organisation of work: one variable indicated the way in which these teams make decisions, distinguishing between individual, collective and hierarchical forms, while the other distinguished between forms of team work. The remaining variables in this group were the most-time consuming activity (teaching versus research work) and the volume of managed resources from both public and private financing. The third group of variables reflected certain characteristics of the head of the research team in terms of his/her degree of ‘seniority’, such as the professional category and years of experience after obtaining a PhD. Another variable was included in this third group on the customary degree of scientific excellence in the public R&D sector in Spain (number of six-year periods evaluated positively by an external agency - CNEAI - based on scientific publications).

The results of the exploration are shown in Table 6. The total column shows the distribution of these variables for the whole sample. In addition to the characteristics relating to size, distribution by area and type of centre, the form of work variables offered

[11] The procedure consisted of a two-step cluster analysis using Schwarz’s Bayesian Criterion (BIC) implemented in SPSS version 14.

a general view of the conditions of research teams in the regional university and research system. Thus, it can be seen that work is distributed almost equally between research and teaching. In terms of financial resources, many teams have moderate income (30% have less than 50 thousand Euros per year), while one third of the teams in the sample receive substantial financing (more than 500 thousand Euros per year). The results for the other variables were highly dispersed, reflecting the wide variety of situations in this region-wide system. The cells in the table show the frequency distribution of the eleven variables in each cluster. Residual analysis for detecting significant differences between observed and expected frequencies are used and highlighted in the table.

[Table 6 around here]

The following description of the clusters is based on the results obtained with the procedures described above. Firstly, their main characteristics are highlighted, adding a label according to the types of collaboration with firms defining each typology. Their weight in the sample as well as other relevant relationships with the local productive sector is specified. Secondly, a profile was established of each cluster according to the main characteristics in terms of structure, work conditions and team leader's characteristics. This allowed us to assign meaning to the clusters and identify the influences that affect relations between researchers and industry in a regional university context.

C1. ‘Institutionalised collaboration’. This is the smallest cluster, accounting for 2.2% of the total sample and 4.1% of the collaborating teams. Its distinctive characteristic is that all the teams in this cluster had participated in the creation of a centre jointly owned with a company (normally a hybrid technological centre). This characteristic is also exclusive to this cluster because no other group in the sample maintained these types of relationships. Other characteristics of the teams in this cluster were that many rendered consultancy work (88.2%) and carried out projects commissioned by firms (76.5%), as well as joint R&D projects with aid from public programs (82.4%).

In terms of their structural features, almost all the teams work in the fields of agricultural sciences, natural resources and biomedicine (more than 80% in total). There are hardly any small teams. However, these teams are newer than the rest, possibly because they were formed when a new centre was created. The form of work used by the teams in this cluster is teamwork. They also engage more in research than the other teams. They receive substantial financing but do not generate the most income. In terms of professional category, the heads of these research teams do not necessarily occupy senior posts in the university hierarchy. Instead, there are more researchers hired specifically for these posts. There are hardly any young doctors: in terms of experience, most are in the intermediate stages of their careers as researchers.

C2. ‘Infrastructure and services providers’. These account for 7.7% of the sample. These research teams engage mainly in rendering or receiving a specific service to or from firms through the leasing or transfer of facilities or resources available at the university. All the teams in this cluster engaged in this activity, although many also provide consultancy work (81.4%) and carry out research commissioned directly by firms (64.4%) and joint projects with public funds (61%).

This cluster includes mainly natural and life sciences and, in particular, engineering teams. In contrast, the number of social sciences teams was much lower. In terms of form of work, fewer teams used individual work procedures. Dedication to teaching is also lower. In terms of financial resources, these teams tended to receive large amounts of financing. More than half handled more than 400 thousand Euros per year, with very few in the lower income bracket. The characteristics of these team leaders are largely different from those of more senior university staff, such as full professors.

C3. 'Intellectual property providers'. These account for 9.4% of the sample. Their main characteristic is that they had licensed or transferred to a firm the exploitation of a patent (72.9%). Another noteworthy collaboration is the creation of a spin-off (40%). Both characteristics are connected and also very uncommon in the other clusters. Moreover, the teams in this cluster participate very actively in other types of collaboration because they often rendered consultancy work, carried out commissioned projects and collaborated with firms in joint research projects. However, they also have certain characteristics that contrasted with those of the other teams described previously because they hardly participated in the leasing of facilities or equipment or in the creation of mixed centres.

Most members of these teams work in the fields of agricultural science and technology, although there are a large number also engaged in biomedical science. There was a greater presence of researchers from the CSIC. This cluster also includes larger teams and older teams. They mainly work in teams and focused less on teaching. They also obtain the most income: 70% were in the highest income bracket and there were very few teams in the lower brackets. As regards the characteristics of their leaders, most are researchers and full professors. The other variables indicate that these teams have more experience (seniority). They have also accumulated more positive evaluations in the form of six-year periods and had the most experience as doctors.

C4. 'Providers of commissioned research.' This is one of the largest clusters, with 96 research teams accounting for 12.5% of the sample. Their distinctive characteristic is that their collaborations with firms focused mainly on consultancy work (72.9%) or R&D projects (97.9%) with financing from firms and exclusively for firms that operate, to some extent, as clients of research teams. Compared with the other clusters, this cluster has few relations with firms in the other possible collaboration channels. They mainly engage in dissemination activities (43.8%), although much less than the other clusters.

The profile of this cluster corresponds mainly to agricultural and other natural sciences, and technologies, this being the cluster with the largest number of technology teams. There are also more teams from public research centres. No significant differences are observed in terms of team size, although this group has the smallest number of young teams, only 3%. In terms of forms of work, very few teams work individually. Similarly, there are fewer teams in the lower income brackets: half receive more than 500 thousand Euros per year. The variables relating to seniority present intermediate values.

C5: 'Providers of human capital'. Together with the previous cluster, this one is also one of the largest, accounting for 12.4% of the sample. The distinctive feature of the teams in this cluster was that they concentrate more on human resources training, either training of firm workers by the university (83.2%) or through training of postgraduates and internships at firms (68.4%). Other activities carried out jointly include consultancy services and research projects (between 55% and 63%) and, in particular, the organisation of non-academic knowledge dissemination activities with firms. 88.4% of the teams in this cluster have developed this type of activity, and substantially more than those in the other clusters.

This cluster also includes the largest number of social sciences and law teams, as well as universities. Most of these teams are intermediate in size and concentrated more on teaching. It is worth highlighting that more teams in this cluster receive large amounts of financing, although not many differences were observed. No significant differences were observed in terms of the characteristics of the heads of these teams.

C6: ‘Providers of exploratory research.’ This cluster accounts for 10.2% of the sample. The distinctive characteristic of this cluster is that the teams collaborate in more joint research projects with firms. These projects are carried out with public funds in which the firms made no monetary investments and these teams do not receive any remuneration. Hence, the unusual feature of their relationship is that these projects focus on exploring new knowledge rather than generating knowledge or technological applications adapted directly to the productive process of the firm, i.e. the normal reason for financial consideration in projects and consultancy services envisaged in the other modalities. This cluster also includes teams that provide consulting work, albeit fewer than those of teams in the other clusters (46%), as is the case with their other activities. It would therefore appear that these teams mainly cooperate in projects developed under public programs requiring the active participation of a firm.

The profile of teams in this cluster is not significantly different to that of the overall sample in the case of most of the variables. It is only worthy highlighting that more teams in this cluster received intermediate volumes of financing.

Finally, it is important to point out the features of cluster 0, which do not engage in any type of collaboration with firms, because its profile is substantially different to almost all the others. Firstly, this cluster contains most humanities teams and those based at universities. It also included small teams and the fewest old teams. Secondly, this cluster includes more teams that work individually and concentrate mainly on teaching. These teams also have the lowest levels of financing. However, no significant differences were observed in terms of experience and professional prestige with respect to the overall sample; hence, this cluster is different in terms of its relationship with firms and form of work, but not in terms of the distribution of posts and status in university organisations.

6. Discussion

In our study we have applied an inductive procedure that takes into account different types of collaborative interactions to observe how they are carried out by research teams in diverse settings and disciplines. Six profiles of clusters emerged from this process, representing multiple forms of university-industry relationships. These types of transactions have been labelled according to the knowledge-related activity involved. Therefore clusters have been named providers of: ‘institutionalized collaboration’, ‘infrastructure and services’, ‘intellectual property’, ‘commissioned research’, ‘human capital’ and ‘exploratory research’.

This approach can be used as a theory building exercise based on the assumptions underlined in the literature as well as the empirical dilemmas in complex university systems. Our typology of university-industry collaborative linkages represents the main dimensions of knowledge transfer; it therefore contributes to decomposing the complexity of university-industry relationships. The results can help refine independent variables and ground hypothesis for further causal analysis. Moreover, the methodology used in this study points to the need for filling the existing empirical gap, where official data bases and reported activities by university administrative units bound most studies. To date the analytical alternative entails choosing between a focus on those collaborative exchanges well measured by statistics or the use of proxy variables that yield very abstract results. We have thus demonstrated the utility of a new methodological strategy.

Our further analysis extends the evidence already shown by other studies and verifies the interactive nature of the process. Although meaningful clusters have been identified, none of them carry out a single type of collaborative linkage. On the contrary, research teams in each cluster combine the use of diverse channels for knowledge transfer practices to different extents. It confirms that codified knowledge and informal relationships are antecedent to other more codified and formal kinds of knowledge exploitation.

The main characteristics of the research teams included in each cluster shows that some university-industry relationships are highly discipline and context dependent. The scientific fields more active as providers of institutionalized cooperation and property rights are natural sciences (mainly Agriculture) and life sciences (Biomedicine). Technology is the most important field in the cluster focused on providing commissioned research. Nonetheless, when looking at the Social Sciences, we found that they are present in most of the clusters, particularly as suppliers of human resources. Humanities is the area of knowledge standing out among those research teams with no participation in collaborative activities of any kind. However, they are also present in some of the clusters, especially those providing services and carrying out commissioned research, in addition to supplying human capital. On the other hand, capacity and experience seem to be certainly essential to be able to participate in IPR interactions, since the largest and oldest teams are the most noticeable in the cluster devoted to patents and the creation of spin-offs. The heads of those teams are also well experienced researchers, usually full professors who have accumulated more positive evaluations in the form of six-year periods and had the most experience as doctors.

6.1. *Policy implications*

Some policy implications derive from the results of our study. The first one refers to the university organizational arrangements as a consequence of the incentive and evaluation systems for resource allocation and job appointments. If policies aimed at fostering interactions concentrate primarily on a single collaborative activity, they are not taking into account a number of important types of relationships with industry that are developed in most university systems. Consequently, the emphasis on certain mechanisms, such us IPR, generates a lack of incentives for those researchers at early stages in their careers to participate in other forms of knowledge transfer which are not so well considered in the evaluation of academic merits.

Other far-reaching implications for universities are related to the data sources used for grounding their decision making processes. When observed carefully, a diversity of relationships is carried out by professors in an independent fashion. Most of these collaborative activities with industry are not reported by technology transfer offices, especially because no standardized metric has been established to process this information. If universities take into account only the easy-to-measure output, they contribute to a vicious circle where the more visible activities are precisely the ones that can be rewarded in practice, and also the ones that can be studied more easily by empirical research.

A further group of policy implications is related to policies at regional or national levels. Some of the empirical results can be extrapolated to different contexts since patents and spin-offs are rarely either isolated or carried out in a linear manner. They are pursued in an interactive way, so they can be strengthened if they are combined jointly with some other activities, especially those with intense knowledge content. Nevertheless, the scientific capacities of the university system and the industrialization of the economic setting surrounding become key issues. IPR research results have little impact on local environments when local industries are not able to apply patents and licenses to their businesses. This situation can contribute to lost opportunities for knowledge development within some regions, due to the relevant knowledge being exported to more distant productive areas. In addition, the failure to develop knowledge transfer nodes with local industries can become problematic over the medium to longer term, as not infrequently the transfer of tacit knowledge, such as human resource exchanges and consultancy work, appears to represent an initial step in university-industry linkages which can later develop into research projects with IPR components. IPR are normally the most visible part of the knowledge transfer iceberg because they emerge once a vivid set of university-industry interactions has already taken place.

6.2. *Conclusions*

This paper contributes to the study of university-industry collaboration using a methodology based on research teams as the unit of analysis. The application of an extensive indicator set inspired in the current literature has revealed some valuable insights into a complex phenomenon which contains many variations at different levels of scale. The results confirm that knowledge transfer processes between universities and industry clearly does occur through a variety of mechanisms, revealing differences in the extent to which research teams engage in those linkages. There are, therefore, high levels of heterogeneity in terms of the involvement of universities with the productive environment.

Our analysis supports the relevance that universities hold for the productive sector as a source of innovation. The resources they provide to firms are varied in nature and their use is dissimilar depending on the available effective possibilities, as well as the strategies and priorities of the actors. Our study shows that those activities focused on the exploitation of IPR are just the tip of the iceberg of knowledge transfer activities between universities and industry. Although IPR interactions have been the traditional foci of R&D policies, they only emerge when absorptive and exploitation capacities exist, which are acquired through a wide range of contacts with universities. This is applicable to catch-up regions, although it can also be extrapolated to other more knowledge intensive environments.

IPR activities can be considered the tip of the iceberg for several reasons. First, they are the most visible aspect of knowledge transfer but not the principal one in the majority of university systems. Second, to generate patents and spin-offs it is in fact necessary to accumulate the adequate research infrastructure and the relevant capacities in human capital, such as senior researchers and technicians with the appropriate expertise, backgrounds and experience. Our results support the observation that patents and spin-offs mean a further stage based on previous university-industry interactions. Third, those research teams most active in patents do not focus exclusively on those. They rather combine patents with diverse interactions with industries. Finally, some specialities in both social sciences and natural sciences simply do not transfer codified knowledge but they do transfer tacit knowledge. Consequently, it is important to recognise that a variety of different types of interactions contribute to the improvement of specific industries' absorptive capacities because they generate long-term relations of trust that are associated with a variety of different collaborative experiences.

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Table 1. Characteristics of the research teams in the sample

		Frequency	**Percent**
Type of centre	Universities	683	89.3
	Spanish National Research Council (CSIC) centres'	39	5.1
	Hospitals	31	4.1
	Other research centres of the Andalusian government	12	1.6
Scientific field	AGR – Agro-food	51	6.7
	BIO – Biology and Biotechnology and Life Sciences	60	7.8
	CTS – Health Science and Technology	105	13.7
	FQM – Experimental Sciences	90	11.8
	HUM – Humanities and Artistic Creation	220	28.8
	RNM – Natural Resources, Energy and Environment	63	8.2
	SEJ – Social Sciences, Economics and Law	103	13.5
	TEP – Production and Construction Technologies	41	5.4
	TIC – Information Science & Communications Technologies	32	4.2
Number of members	From 1 to 5	77	10.1
	From 6 a 10	331	43.3
	From 11 a 15	185	24.2
	From 16 a 20	88	11.5
	From 21 a 25	40	5.2
	More than 25	42	5.5
	Do not know / No answer	2	0.3
	Mean	12.2	
	Std. Deviation	7.7	
Research team age	Up to 5 years	89	11.6
	From 6 to 10 years	158	20.7
	From 11 to 15 years	187	24.4
	From 16 to 20 years	195	25.5
	More than 20 years	122	15.9
	Do not know / No answer	14	1.8
	Mean	14.1	
	Std. Deviation	7.1	
TOTAL		**765**	

Table 2. Types of interaction

Domains	University-industry collaboration
a) R&D activities and formal consulting work	1. Consultancy work from a university or public research centre 2. Commissioned R&D projects (financed exclusively by the firm) 3. Joint R&D projects (shared financing or with public support)
b) Training and transfer of personnel	4. Training of postgraduates and internships at a firm 5. Temporary exchange of personnel 6. Specific training of firms´ workers provided by the university
c) Commercialisation and IPR-related activities	7. Use or renting of facilities or equipment 8. Exploitation of a patent or utility model / Joint patents 9. Creation of a new firm (spin-offs and start-ups)
d) Other contacts	10. Participation in a joint venture of hybrid research centre 11. Informal relationships 12. Other types of collaborative activities 13. Non-academic knowledge dissemination activities

Table 3. Participation of research teams in collaborative activities

	% answering 'yes'	% Do not Know/ No answer	Collaborative intensity: number of interactions				
			N	Mean[1]	Std. Deviation[1]	Mean[2]	Std. Deviation[2]
Consultancy work	38.0	0.0	291	3.7	8.9	2.1	7.0
Commissioned R&D projects from firms	34.8	0.0	266	3.2	6.2	1.8	4.9
Joint R&D projects	30.6	0.0	234	1.5	2.7	0.9	2.1
Training of postgraduates and internships at a firm	20.4	0.4	156	1.1	2.2	0.6	1.7
Exchange of personnel	12.4	0.0	95	0.7	1.9	0.4	1.5
Training of firm workers by the university	24.2	0.3	185	1.6	3.6	0.9	2.9
Use or renting of facilities or equipment	8.4	0.0	64	0.5	2.0	0.3	1.5
Patent exploitation or joint patents	10.1	0.3	77	0.6	4.9	0.3	3.7
Creation of spin-offs and start-ups	6.1	0.0	47	0.1	0.4	0.1	0.3
Joint ventures with firms	2.4	0.0	18	0.0	0.2	0.0	0.2
Informal relationships	45.0	0.0	421	3.7	7.8	2.1	6.2
Other types of collaborative activities	2.7	3.3	21	-	-	-	-
Non-academic knowledge dissemination activities	30.6	0.0	234	2.3	4.7	1.3	3.7

[1] Base: research teams displaying at least one interaction

[2] Base: total of research teams

Table 4. Factor analysis of the types of interaction by research teams. Rotated Component Matrix

	Components *				
	1	**2**	**3**	**4**	**5**
Consultancy work	0,143	0,207	0,571	0,286	0,148
Commissioned R&D projects from firms	0,065	0,000	0,848	-0,048	-0,011
Joint R&D projects	0,187	0,584	-0,138	0,151	0,267
Training of postgraduates and internships at a firm	0,674	0,146	-0,161	0,183	0,203
Exchange of personnel	0,514	0,274	0,047	0,299	0,008
Training of firm workers by the university	0,740	-0,060	0,153	-0,134	-0,087
Use or renting of facilities or equipment	-0,064	0,017	0,092	0,881	-0,041
Patent exploitation or joint patents	0,004	0,789	0,078	-0,062	-0,233
Creation of spin-off and start-ups	0,085	0,616	0,161	0,023	0,092
Joint ventures with firms	0,023	0,028	0,096	-0,047	0,930
Non-academic knowledge dissemination activities	0,561	0,086	0,211	-0,227	0,009

Values for each type of interaction: 0 'No interaction', 1 'At least one interaction'.
Extraction method: Main Components Analysis. Rotation method: Varimax with Kaiser normalization
* % of variance explained: 59.2%.

Table 5. Clusters of research teams according to their relationships with industry (Percentage)

	Clusters in two phases					
	1	**2**	**3**	**4**	**5**	**6**
Consultancy work	88.2	81.4	81.9	72.9	62.1	46.2
Commissioned R&D projects from firms	76.5	64.4	76.4	97.9	57.9	9.0
Joint R&D projects	82.4	61.0	81.9	20.8	55.8	60.3
Training of postgraduates and internships at firms	64.7	40.7	41.7	7.3	68.4	24.4
Exchange of personnel	35.3	28.8	36.1	5.2	33.7	9.0
Training of firm workers by the university	52.9	37.3	52.8	26.0	83.2	11.5
Use or renting of facilities or equipment	17.6	100.0	1.4	.0	.0	.0
Patent exploitation or joint patents	11.8	23.7	79.2	.0	1.1	2.6
Participation in spin-offs and start-ups	23.5	15.3	40.3	1.0	3.2	.0
Joint ventures with firms	100.0	.0	.0	.0	.0	.0
Non-academic knowledge dissemination activities	70.6	50.8	66.7	43.8	88.4	17.9

Table 6. Profiles of clusters (Percentage by columns)

		CLUSTERS							
		C0	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**TOTAL**
STRUCTURAL CHARACTERISTICS OF THE TEAM	**SCIENTIFIC FIELD**								
	Natural Sciences (AGR+RNM)	4.6	**41.1**	**25.4**	**27.7**	21.8	17.8	19.2	14.6
	Life Sciences (BIO+CTS)	18.7	**41.1**	25.4	29.1	15.6	22.1	26.9	21.6
	Experimental Sciences (FQM)	14.0	11.7	11.8	13.8	7.2	6.3	12.8	11.8
	Humanities (HUM)	**44.7**	5.8	16.9	5.5	12.5	24.2	21.7	28.9
	Social Sciences, Economics and Law (SEJ)	16.0	0.0	3.3	4.1	16.6	**21.0**	7.6	13.4
	Technologies (TEP+TIC)	1.7	0.0	**16.9**	**19.4**	26.0	8.4	11.5	9.4
	TYPE OF CENTER								
	Universities	**92.9**	82.3	88.1	76.3	87.5	92.6	85.8	89.3
	CSIC	1.1	5.8	8.4	**15.2**	**9.3**	3.1	7.6	5.1
	Others (Hospitals & regional)	5.8	11.7	3.3	8.3	3.1	4.2	6.4	5.5
	SIZE OF THE TEAM								
	From 1 to 5	**15.2**	0.0	3.3	1.3	8.3	7.3	8.9	10.1
	From 6 to 10	**52.0**	52.9	45.7	23.6	34.3	27.3	50.0	43.3
	From 11 to 20	26.3	35.2	33.8	**52.7**	44.7	**49.4**	33.3	35.5
	Live than 21	6.4	11.7	16.9	22.2	12.5	15.7	7.6	10.9
	AGE OF THE TEAM								
	Up to 5 years	12.8	**29.4**	13.7	8.3	3.2	9.6	17.9	11,8
	From 6 to 10 years	23.6	11.7	22.4	13.8	23.6	15.0	19.2	20.8
	From 11 to 15 years	25.4	11.7	25.8	20.8	30.1	27.9	19.2	24.9
	From 16 to 20 years	24.8	23.5	24.1	27.7	24.7	31.1	26.9	26.0
	Live than 20 years	13.1	23.5	13.7	**29.1**	18.2	16.1	16.6	16.3

		CLUSTERS							
		0	**1**	**2**	**3**	**4**	**5**	**6**	**TOTAL**
FORMS OF WORK OF THE TEAM	**FORM OF WORK**								
	All in team	12.5	35.2	22.0	22.2	19.7	14.7	22.0	16.8
	Majority in team	53.5	52.9	67.7	65.2	67.7	**71.5**	61.0	60.5
	Individually	**33.9**	11.7	10.1	12.5	12.5	13.6	16.8	22.5
	DECISION MAKING								
	The final decision is made by the head of the team	10.2	11.7	10.1	11.2	13.6	13.8	12.8	11.5
	Consensus decision-making process	78.0	82.3	79.6	80.2	76.8	76.5	73.0	77.6
	Majority rule and individual decisions	11.7	5.8	10.1	8.4	9.4	9.5	14.103	10.8
	MOST TIME-CONSUMING ACTIVITY								
	Teaching	**52.2**	31.2	33.8	27.1	51.0	50.5	46.1	46.9
	Research	36.7	62.5	**59.3**	**65.7**	39.5	36.5	50.0	43.5
	Other research activities	10.9	6.2	6.7	7.1	9.3	12.9	3.8	9.4
	PUBLIC AND PRIVATE FINANCING (IN THOUSANDS OF EUROS)								
	50 or less (thousand €)	51.6	18.7	4.1	0.0	15.1	22.7	13.8	30.1
	50-100 (thousand €)	11.4	6.2	2.0	6.2	10.4	5.0	11.1	9.2
	100-200 (thousand €)	9.7	6.2	12.5	7.8	9.3	15.1	19.4	11.3
	200-300 (thousand €)	8.3	6.2	10.4	6.2	9.3	7.5	15.2	9.0
	300-400 (thousand €)	5.0	25.0	14.5	7.8	5.8	7.5	11.1	7.5
	400 + (thousand €)	13.7	37.5	56.2	71.8	50.0	41.7	29.1	32.7

		CLUSTERS							
		0	**1**	**2**	**3**	**4**	**5**	**6**	**TOTAL**
	PROFESSIONAL CATEGORY								

Full university professor	43.2	29.4	40.6	48.6	36.4	41.0	38.4	41.6
University professor or equivalent	49.1	47.0	38.9	26.3	51.0	48.4	44.8	45.8
CSIC researcher	1.7	5.8	6.7	**15.2**	**10.4**	2.1	7.6	5.2
Contracted doctors and other researchers	5.8	17.6	**13.5**	9.7	2.0	8.4	8.9	7.2
NUMBER OF ACCUMULATED SIX-YEAR PERIODS								
0	11.1	7.1	14.2	12.6	11.8	15.7	7.8	11.7
1	16.6	14.2	19.6	11.2	**27.9**	12.3	18.4	17.4
2	20.6	35.7	16.0	14.0	13.9	20.2	11.8	18.1
3	20.3	7.1	21.4	16.9	26.8	23.5	25.0	21.5
4 and more	31.1	35.7	28.5	**45.0**	19.3	28.0	36.8	31.1
YEARS' EXPERIENCE AS A DOCTOR								
0-10 years	7.9	0.0	8.6	9.8	8.3	12.6	6.4	8.4
11-20 years	31.3	43.7	39.6	21.1	**42.7**	28.4	32.0	32.4
21-25 years	21.4	25.0	17.2	25.3	17.7	24.2	12.8	20.5
26-30 years	16.4	12.5	22.4	14.0	14.5	18.9	**28.2**	17.8
More than 31 years	22.8	18.7	12.0	**29.5**	16.6	15.7	20.5	20.6

The underlined cells indicate a residual adjustment below –1.9 and above 1.9.

Statistical Appendix

Table I: Factorial Principal Components Analysis: Total explained variance

		Initial autovalues			Total saturations at rotation squared		
		Total	% variance	% accumulated	Total	% variance	% accumulated
Component	1	2.227	20.248	20.248	1.652	15.016	15.016
	2	1.224	11.128	31.376	1.494	13.580	28.597
	3	1.095	9.952	41.328	1.210	11.001	39.598
	4	1.035	9.405	50.734	1.081	9.829	49.426
	5	0.928	8.440	59.173	1.072	9.747	59.173

Table II: Cluster analysis: Distribution

		N	% of combined clusters	% of total
Cluster	1	17	4.1%	2.2%
	2	59	14.1%	7.7%
	3	72	17.3%	9.4%
	4	96	23.0%	12.5%
	5	95	22.8%	12.4%
	6	78	18.7%	10.2%
	Combined	417	100.0%	54.5%
Excluded cases		348		45.5%
Total		765		100.0%

Table III. Cluster analysis: Centroids

	Dissemination and Human Resources		Patents + Spin-off		Commissioned projects and consulting work		Leased facilities and equipment		Mixed centre	
Clusters	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
1	0.110	1.029	0.134	0.975	0.464	0.816	-0.227	1.038	4.508	0.317
2	-0.131	0.996	-0.003	1.089	0.179	0.930	2.121	0.443	-0.325	0.324
3	0.057	1.083	1.592	0.734	0.303	0.819	-0.531	0.513	-0.428	0.431
4	-0.583	0.564	-0.630	0.375	0.769	0.496	-0.436	0.369	-0.203	0.243
5	1.105	0.568	-0.470	0.476	-0.242	0.887	-0.336	0.528	-0.134	0.334
6	-0.607	0.496	-0.149	0.449	-1.169	0.615	-0.119	0.410	0.070	0.323