UNFOLDING THE COMPLEXITY OF INTERACTIONS BETWEEN INDUSTRY AND UNIVERSITY*

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Universities and public research centers are currently considered a key element for increasing innovation performance and improving the competitiveness of firms. Recent studies suggest that enterprises use multiple channels in their relations with universities. Nonetheless, empirical research encounters difficulties for obtaining detailed observations.

This article examines the links between industry and universities, specifically focusing on the diversity of situations in which these interactions occur. To this end, we present a set of hypotheses that try to capture the complexity of this phenomenon. For our analysis we use a survey of 737 enterprises that reflects the variety of innovative profiles of firms in a given region. The questionnaire employs a large set of variables to measure the different types of interaction. The aim of the analyses is that of identifying the most important relations, to determine how these are structured and to draw a map of enterprises according to the links they forge with universities.

1. Introduction

This article examines the links forged between industry and universities, specifically focusing on the diversity of situations in which these interactions occur and the variety of factors that influence them from the point of view of the firms. To this end, we describe specific patterns of university-industry relationships; analyze how these relationships are structured and draw a map of enterprise types according to their links with universities.

The capacity of universities and public research centers is considered a key element for increasing innovation performance and improving the competitiveness of firms. Nonetheless, the difficulties involved in studying these relationships, together with the biased nature of many empirical sources, make it difficult to observe how universities contribute to innovation. Several studies in this field have shown that information is exchanged through a multitude of channels (Arundel and Geuna, 2004; D’este and Patel, 2007). Activities aimed at using codified scientific knowledge, such as patents or spin-offs, account for only a small proportion of this process.

For the majority of firms that have links with universities, the most important interactions are structured around personal relations, mobility and consultancy services. While this is usually the case, even in firms with strong R&D departments and located in knowledge-intensive environments (Etzkowitz and Klofsten, 2005; Florida, 2002), it is especially relevant for other types of firms, for which R&D activities are less important and that are actually more representative of those found in the

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majority of the regions of the developed world (Bonaccorsi and Daraio, 2007).

However, the empirical research conducted in this field typically encounters two types of problems when attempting to make more accurate claims regarding university-industry relationships (Geisler and Rubenstein, 1989). On the one hand, studies that use primary sources usually focus on firms with specific characteristics; normally large firms or those belonging to high-tech sectors. On the other, studies that use secondary sources such as official innovation surveys do not include detailed observations about the various forms of interaction between industry and universities. Thus, the analyses made to date are either difficult to extrapolate to other enterprise scenarios or do not capture the complexity of these relationships (Perkmann and Walsh, 2007).

This paper attempts to overcome some of these limitations by testing a series of hypotheses through the use of a methodology that has been developed for the purpose. Our main assumption is that in order to provide a proper account of the complexity of this phenomenon, it is necessary to examine the full range of channels and mechanisms through which firms forge links with universities. Our main thesis to be defended in this article is that when university-industry relationships are observed in a detailed manner, the variety of links that can be found is structured in accordance to the intensity of the knowledge associated to each concrete type of activity. Thus university-industry relationships are shaped differently according to the absorptive capacity of the firms involved, but also according to the firms’ innovation strategies and the opportunities that exist in the environment in which they operate.

For the analysis we use a survey of 737 firms conducted from November 2007 to February 2008. The questionnaire used in the survey contains a set of variables that reflect various forms of interaction with universities and public research centers. This survey reflects the variety of sectors, size and innovative profiles of firms in Andalusia, the region where the study is located. The Autonomous Community of Andalusia is the biggest region of Spain in terms of population. This region has been traditionally characterized for having an industrial sector with low innovation levels, but which is becoming increasingly heterogeneous due to modernization processes and the emergence of new firms (CES, 2003, 2007). As a result of the economic development over the last three decades and the growing of its extensive university system, Andalusia can be considered now as a catch-up region (Shapira, 2005) in the sphere of the European Union. The diversified economic and social arrangements to be found in the region provide an adequate location for studying different innovation dynamics involving firms and universities.

The paper is divided into four sections. Following the introduction, section two presents the theoretical and empirical background, placing particular emphasis on the methodological problems that arise when studying this topic. Following this, we establish several specific hypotheses regarding the complexity of interactions. Section three describes the data source used, the procedures followed in the fieldwork, the sample characteristics and the indicators employed in the survey. The results are shown in section four. Following a descriptive analysis, three phases are used. In the first phase a factor analysis is made to detect the patterns underlying the variety of relations that are forged with universities. In the second phase a typology of the firms is made by means of a cluster analysis. This gives rise to homogenous groups of firms according to the contacts they have with universities. In the third phase we analyse the profile of each of these clusters taking into account the characteristics of the firms they encompass. Finally, in the conclusions, we highlight the implications of our results to the literature on industry-university links and we also offer some ideas on the policy implications of our analysis for catching-up regions.

2. Theoretical and empirical background

2.1. The complexity of university – industry relationships

Universities are often described as “the driving force behind growth” as they generate educational capacities, skills and research results that are relevant for innovation, particularly in certain industrial sectors (Mansfield, 1991, 1998). For this reason, numerous governments and research agencies are promoting university-industry relationships in the hope that research carried out in universities will have an impact leading to an improvement in the products and processes generated at the regional level (OECD, 1998, 2007).

Although these contributions to economic development are far from immediate, there is widespread agreement on the crucial role of universities for industrial and economic development in general (Mansfield and Lee, 1996; Frits and Schwirten, 1999). Comparative studies highlight the relationship between industrial expenditure on R&D and collaboration between firms and universities (World Economic Forum, 2004). Micro-level research conducted in some countries has also found that university-industry collaboration is a central pillar of national innovation systems (Belderbos et al. 2004; Lööf and Heshmaty, 2002; Faems et al., 2005). Nonetheless, the observed correlations do not allow to make inferences on the causal

† Our study includes public research centers, chiefly institutes of the Spanish Council for Scientific Research (CSIC) located in the region, and the laboratories belonging to the regional government operating mainly in the agrifood (IFAPA) and health (SAS) sectors. The joint size of these centers is much smaller than that of the universities (CICE, 2006). Moreover, the majority of these centers are similar to the university system in terms of their legal status and occupational situation of their workers. For purposes of clarity, we only refer to universities in the text, with the understanding that these relations also include public research centers.

‡ Analysis on this issue in others catch-up regions in Spain can be found at Azagra et al. (2006). For a comprehensive review of industry-university relationships in Spain see Castro-Martínez and Fernández-de-Lucio (2006).
nature of these relations, and have in general led to the conclusion that further research must be done to unveil on how this process is structured and to determine more precisely which are relevant intervening elements.

In spite of the empirical evidence, it is a difficult task to determine the extent to which firms can obtain a competitive advantage by collaborating with universities. There are numerous possible relations that will vary depending on the industrial sector and the scientific field involved (Jacobson, 2002; Autio et al., 1996; Fritsch and Lukas, 2001). Many of the benefits on firms are uncertain and when they do occur, they are distributed in an unequal manner and operate indirectly. The effects are not linear, but often based on iterative processes within different types of mutually reinforced relations (Salter and Martin, 2001). Furthermore, numerous institutions mediate in the relations between both sectors, namely regulations and incentive schemes (Polt et al., 2001). In general, it is very difficult for academic science discoveries to be directly transferred to products or services that are of immediate interest to productive organizations (Pavitt, 2001).

Empirical research in this field has shown that there are numerous factors which have an impact on this relationship. One group has to do with so-called “structural” elements of the firm such as firm size, sector of activity and the age of the firm (Laursen and Salter, 2004). Normally the strongest links are forged in large firms and in those operating in technology-intensive sectors such as health and the life sciences, ICTs or electronics (Arundel and Geuna, 2004). The well-known framework of “absorptive capacity” (Cohen and Levinthal, 1990) suggests that greater dedication to R&D activities enhances opportunities for using knowledge produced in other areas. Thus firms that have stronger links with universities also display a greater absorptive capacity.

A second group of factors points to the important role that a firm’s strategic search processes play in this matter. The most dynamic enterprises are those that introduce management schemes which facilitate the development of an open innovation system (Cyert and Goodman, 1997; Chiesa and Manzini, 1998). According to this viewpoint, firms that introduce organizational routines aimed at capturing new knowledge through alliances with other organizations will also be more open to collaboration, using universities as a source of strategic information and, on occasions, as places for outsourcing R&D activities (Chesbrough, 2003). These are companies which are characterized for employing professionals who are dedicated specifically to these tasks and for acknowledging the importance of elements that facilitate innovation. This is usually associated to an “optimal cognitive” distance which improves absorptive capacity (Nootboon, et al., 2007).

The third type of factors conditioning this interaction has to do with the opportunities firms have for establishing relations with agents from the academic sphere. This third group includes a complex set of factors that could be called “situational factors” and have to do with the configuration of the social or economic structure in which the firm is located. The relations between universities and firms are generally informal and linked to the personal interaction between individuals. They arise from common and overlapping interests of groups from both sectors and frequently take place through informally negotiated exchanges (Mowery, et al., 2001). These relations are often immune to policy measures or to direct intervention by the public sector. Thus relation networks, trust between agents from different sectors (Powell, et al., 1996) and the location of firms in environments with a high concentration of resources that promote interaction are all important factors for producing collaboration between universities and industry (Zucker et al., 1998). This is the case, for example, of technology parks which bring together organizations from a variety of sectors and firms offering specialized services (Löfsten and Lindelöf, 2002).

In addition to the complexity arising from this variety of influential factors, there is a further difficulty due to obstacles to perceiving how the knowledge flow is produced. Much of the literature on technology transfer has centered on the capacity for generating and exploiting intellectual property rights (IPR). Recent research in this field, however, indicates that the knowledge flow takes place through multiple channels. Patents, cooperative research and the creation of spin-offs account for only a small share of the process, especially in those firms characterized by less knowledge-intensive production processes. Finally, it is important to add that in addition to the commercial activities derived from research, the knowledge flow provides many alternative opportunities such as occupational mobility, informal aid and consultancy relations (Hall et al., 2000; Perkmann and Walsh, 2007).

2.2. Methodological caveats

The complexity of factors and the variety of relations have meant that many of the empirical studies conducted in this field encounter notable limitations. Firstly, there is a lack of adequate data sources, making it difficult to determine the causes that aid or hinder firms in establishing links with universities and eventually incorporating them into their innovation strategies. Secondly, there are limitations for specifying the type of relationships that actually exist between the different industrial sectors and universities.

The empirical research specifically designed to study this issue tends to focus on industrial sectors that are closely linked to research, such as biotechnology (Hicks et al., 2001; Owen-Smith and Powell, 2004). Numerous studies are based on firms with particular characteristics, normally firms with R&D departments (Cohen, et al. 2002), start-ups related to high-tech production processes and, in some cases, spin-offs that emerge from a small number of universities with high research levels (Shane, 2002). These studies are found to be highly biased when they are examined outside the intensive-knowledge environments in which these enterprises usually operate. Consequently, their results are difficult to extrapolate to the small and medium-sized innovative firms that are commonplace in much of the developed world.

On the other hand, studies that examine a wider variety
of firms normally utilize data sources that are not designed for the study of university-industry relations. Many of these empirical analyses are based on innovation surveys such as the Community Innovation Survey –CIS- (Stockdale, 2002, for the English version) (PITEC, 2007 for the Spanish version). Although these studies use large samples covering a full range of firms, their measurement tools do not permit detailed information to be gathered on the many and different types of relationships, nor do they account for variables regarding the strategies and expectations of the firms involved. Given that these surveys do not have as their aim to examine this particular type of business behavior, the studies that use them as a data source has to employ summary measures which do not provide insights into the complexity of these relations. Instead, the analyses are usually based on “proxy” variables that reflect, in a very general way, the variety of links and the intensity of such links (Mohnen and Hoareau, 2002).

For example, in studies using general innovation surveys as a data source, the dependent variable is usually constructed from the response to the following question: “Did your enterprise actively cooperate in R&D with a university or public research center?”, which can be answered “yes” or “no” (Bayona-Sáez et al., 2002). Another variable used as a proxy is obtained from the following question: “How important are universities as a source of information and knowledge to your firm’s innovation activities?”, which can be answered on a Likert-type scale from 0 (“not used”) to 4 (“high”) (Laursen and Salter, 2004). Thus although these studies lead to relevant conclusions, they are highly abstract and difficult to translate into practical implications given the diverse situations in which university-industry interactions occur.

Furthermore, this diversity of sources leads to notable differences in the existing empirical studies. While the results obtained in Europe tend to be consistent across countries (OECD, 2002), they contrast notably with studies conducted in North America, making comparisons extremely difficult between countries (Owen Smith, et al. 2002). This variation in the results could be due to the variety of methods used in these studies. When firms are given a specific questionnaire centered on their interactions with universities, the results of the survey are different as some activities emerge, usually because they are not taken into account in more general innovation studies (Laursen and Salter, 2004). In short, the specialized literature on this issue underlines the need for specific and homogeneous indicators that are capable of measuring the wide range of possible relationships (Lepori et al., 2008).

2.3. Hypotheses

Reviews of the literature have shown the lack of a unified analytical framework or a single causal model to explain university-industrial relations (Canton et al., 2005; Perkmann and Walsh, 2007). Moreover, many of the frameworks that have played an influential role in discussions on this topic are normative in character (Shinn, 2002) and award greater importance to one side of the existing relations; a fact that is often reflected in the absence of integrated indicator schemes.

Although it is not our objective to construct a theoretical framework regarding this issue (see, for example, the proposal by Bonaccorsi and Piccaluga, 1994), we do believe that it is convenient for both the measurement system and the analysis strategy to be theoretically oriented. In this paper we will attempt to gain insight from the evidence and the lines of reasoning in this field with a view to including measurement schemes that respond to relevant questions and which will contribute to contrasting the proposed hypotheses.

For this purpose, the design takes into account two viewpoints. On the one hand, our aim is to construct an appropriate data source in terms of both the characteristics of the firms it includes (it should include a variety of firms, not only science-related ones) and the indicators that reflect their modes of interaction with universities (the indicators should cover a wide range of situations). On the other hand, the design is directed at contrasting this diversity and drawing a map of different business practices. The hypotheses are aimed at demonstrating the complexity and identifying specific behavioural features, bearing in mind the innovation possibilities and strategies of firms. In the first of the following points we establish the baseline hypothesis on data sources and indicators, while in the second we establish specific hypotheses regarding complexity.

a) Decomposing complexity

One line of fruitful research emerges from studies on the so-called “third mission” or “third stream” activities. This particular perspective is usually carried out from the side of university organizations, thus including certain academic activities that do not adapt easily to a business rationale, namely dissemination, communication or community services. Nonetheless, it contains lines of reasoning and proposals that are useful for determining the dimensions and indicators that should be taken into account when studying university-industry linkages.

A common critical assumption is that traditional commercial indicators are insufficient for measuring the wide spectrum of potentially productive activities in universities (Gulbrandsen and Slipersaeter, 2007). The proposals are therefore directed at accounting for the largest number of possibilities. These studies underline the importance of considering the full range of university activities as a possible source of innovation, including training and services. Likewise, to gain a proper understanding of this issue it is necessary to understand industry needs and observe industry behavior, while going beyond motivations based on obtaining immediate economic benefits (Klitkou, 2008).

Indicator schemes of this type account for a wide range of possibilities and include dimensions that encompass consultancy services, teaching activities, personnel flows as well as specific activities aimed at research and IPR exploitation (Molas-Gallart et al., 2002). These schemes permit us to develop theoretically-grounded definitions that can serve as a foundation for empirical work. The variety of firm situations and strategies also offers many
opportunities in terms of both the pursuit of sources of innovation and the possibility of establishing links and agreements with other organizations. For this reason, the indicators must take into account different possibilities for interaction, including those that are most active in generating or using R&D results and those that involve utilizing the full range of available university resources; be they human, facility-based, instrumental or expert protocols. In addition, in order to contrast these indicators, observations must be made in firms belonging to various sectors and of different sizes and absorptive capacities.

Our study departs from a baseline assumption that can be considered a “background hypothesis”. In a diversified enterprise environment, different levels of interaction can take place between universities and industry. At one end, we find firms that have no possibility of obtaining competitive advantages due to their lack of capacity. In this type of firms it is unlikely that these relations will occur. At the opposite end, we find highly capacitated enterprises which establish stronger links with universities in all spheres. Both situations, however, encompass a complex range of possibilities in which the various interactions are shaped by factors related to firm structure, strategy or situation. This type of scheme will allow us to observe the rationale behind university-industry relationships and to determine the role they play as sources of innovation.

b) Recombining complexity

When formulating concrete hypotheses, an initial group of relevant questions arises regarding how possible interactions are structured. Do certain types of enterprises have a preference for certain types of interaction? Are these interactions mainly of a single type or are several types used at once? With regard to this last case, what are the patterns of interaction? Or to put it another way, are there groups of interactions that occur conjunctively?

The following hypotheses are aimed at contrasting the structure of university-industry links. Specifically, they deal with the activities of firm and especially with how the combination of different types of interactions is patterned across different types of firms. For this purpose, we differ with the existing literature in that we do not begin with the usual firm traits normally interpreted as independent variables that can have an impact in the behaviour of the firm, mostly related to the absorptive capacities (e.g. Bayona-Saez et. al.2002). Instead, our strategy is to test first a set of specific assumptions about the patterns of interaction. In a second step we use the features of the firms to depict a profile of the different types of behaviour.

One possible scenario is that relationships are structured differently depending on the university’s capacity for meeting the needs of firms. A useful distinction that has long been made in the literature highlights the difference between “knowledge exploration” and “knowledge exploitation” (March, 1991). The first of these usually refers to processes of vigilance aimed at taking advantage of possible opportunities. The second has to do with the active use of a more specific source of knowledge that can be directly appropriated by the firm, be it due to the foreseeable profitability of this knowledge or because it is unprofitable to obtain this knowledge internally.

This distinction can be linked to some of the indicators that account for university-firm relationships. For instance, patent licences and participation in spin-offs are closer to exploitation activities. Personnel flow and subsided joint R&D projects are closer to exploration activities, while contract R&D can be used for both purposes.

Yet both of these scenarios entail different activities. Firms that do not have well-defined innovation needs regarding their production processes, and also firms with insufficient capacity for obtaining knowledge internally, usually are expected to develop exploration strategies involving cooperation activities that differ from those occurring in a knowledge exploitation context. This leads us to formulate the following hypothesis on the structure of university-industry relations:

H1. Intensive activities aimed at generating and exploiting knowledge are patterned differently than activities related to knowledge exploration. Of all the possibilities for interaction that are within reach of firms, one group will correspond to typical exploration strategies, while the other will correspond to exploitation strategies. Strategies of the first type will normally occur conjunctively as will strategies of the second type, regardless of whether some firms develop both types at the same time.

If the types of relationships are structured according to the possibilities for knowledge exploration or exploitation activities with R&D content, enterprise strategies will vary. Consequently, some firms will orient their relations with universities towards certain activities rather than others. Now, it is a widely accepted fact that knowledge exploitation is related to absorptive capacity (Zahra and George, 2002), which in turn has to do with the ability to understand and recombine knowledge with a high R&D content. That is, knowledge exploitation and the generation of new knowledge can go hand in hand. Indeed, some enterprises do not invest in R&D with a view to obtaining direct benefits from it, but to enable them to make use of knowledge that exists in other places (Pavitt, 2001). Thus, as one would expect, the most frequent exploitation activities such as the use of patents, do not occur independently but are undertaken in conjunction with other activities. These are activities that strengthen a firm’s capacity to adapt IPR to the enterprise’s needs or to take advantage of this relationship for subsequent activities. This leads us to formulate our second hypothesis:

H2. Firms with a high capacity for exploiting patents or licenses normally take part in other activities in cooperation with universities. These activities will be chiefly R&D intensive (e.g. R&D projects and consultancy), but also they will maintain a certain amount of exploration-oriented relations, independently of whether these exploration links are the core strategy of the firm.

However, we cannot expect the majority of potentially innovative firms in a given environment to possess all of
The growth of the university system since 1970 largely responds to teaching and research staff (Fernández-Esquinas et al., 2008). Public universities with some 250,000 students and 17,000 of the Higher Education Sector. Andalusia currently has nine Regional Government is in charge of funding and management (Junta de Andalucía, 2003). Additionally, in an attempt to improve interim elements of their production process, some firms may take advantage of the instruments, equipment or facilities that universities offer. This is often the case of firms in very specific sectors of production that find in universities a service that is difficult to obtain in an environment with few knowledge-intensive firms. Moreover, it may be costly to resort to enterprises of this type when they are located in other regions or countries. These activities are not necessarily associated to others related to R&D or to human resources, permitting us to formulate the following hypothesis:

H3. Firms employing exploration strategies will undertake activities which are more closely linked to capturing tacit knowledge and will therefore establish relationships based on human resources.

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3. Methodology

3.1. Data source

This study uses a directory of firms located in the Autonomous Community of Andalusia. The directory was developed by a regional government network that provides innovation assessment (RETA) with offices located across the region. The main purpose of this data set is that of identifying possible innovative firms in the region for getting them involved in networks with other firms as well as in regional innovation programs. The directory contains data on 1898 firms that have received some type of public financial support for innovation during the 2000-2006 period including:

- Subsidies for modernization and innovation from the Regional Innovation Agency.
- Subsidies from the Regional R&D Plan and other R&D programs developed by regional institutions.
- Subsidies and tax deductions from the central government for participation in innovation activities (generally through the National Center for Technological Development-CDTI).
- Subsidies from the EU Framework Program (1998-2002) or any other European Union program related to innovation.

In addition, the RETA network has added to their data set those firms that have been identified as more prone to innovation due to the activities they develop or because the positive feedback they show when contacted by RETA local offices.

The data source used for the study has a series of advantages and drawbacks related to the typical dilemma between “representativeness” and “specificity” that often arises in studies of this kind. For example, one of the key decisions to be taken when defining our population of firms is whether observations should be made of all the existing firms in the region or only firms with specific characteristics, namely those with a potential for innovation. A limitation of our data source is that it does not represent all of the firms in the region, but only those with a more innovative profile. Thus our data source is biased with respect to the entire population of firms.

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§ Andalusia is a region located at the South of both Spain and Europe. The region has almost 9 million inhabitants and covers an area of 87,000 square km. It is geographically diverse with large rural enclaves and several metropolitan areas. A traditionally underdeveloped region, Andalusia has undergone a rapid process of change, bringing it practically on a par with European standards. In the early 20th century, parameters on wellbeing were similar to those of the rest of the country. Nonetheless, the region differs from others in the country in terms of its lower competitiveness (73.5% of the per capita GDP of Spain in 2001) (CES, 2003, 2007). Family-owned SMEs account for a large portion of the production sector. This firm structure implies that important industry sectors are oriented towards local markets and dedicated to low knowledge-intensive activities (only 33% of R&D expenditure of the region is made by the firms, INE, 2006). Nonetheless, regional firms are becoming increasingly heterogeneous as a result of the process of economic modernization promoted by the European Union and regional policies for the creation and diversification of firms (Junta de Andalucía, 2003).

Regional Government is in charge of funding and management of the Higher Education Sector. Andalusia currently has nine public universities with some 250,000 students and 17,000 teaching and research staff (Fernández-Esquinas et al., 2008). The growth of the university system since 1970 largely responds to training needs in the region (upper level of the vocational training is inside the university system), leading to an organizational model traditionally centred on teaching. Investment in the acquisition of scientific capacity in recent years has led to the concentration in universities of a large part of regional R&D resources (universities account for 45% of R&D expenditure, while 61% of the researchers in the region are employed by universities) (INE, 2006). An important change has occurred in recent years as a result of the reorganization of R&D and higher education policy in 2003. Andalusia is a good example of the rapid transition from traditional policies based on a linear model of innovation to policies aimed at interaction between the public administration, the educational system and industry (CICE, 2006). A useful illustration of the more interactive policies is the RETA network - Red de Espacios Tecnológicos de Andalucía [www.reta.es] - that provides innovation support and collects information from the firms that have been used in this study.

** It should be noted that the bias is unidirectional. The majority of very small firms in the region that operate in very low-level technology sectors are not represented. However, practically all the technology-intensive firms, as well as those that conduct significant R&D activities - including both small and large companies - have received some type of public aid, at least tax deductions. For this reason they are included in the data file we use as a source.
Nonetheless, this source permits us to conduct analyses aimed at examining the characteristics of cooperation. If we were to use a sample of firms chosen randomly from among all of those registered in the region, we would obtain only a very small percentage of them that have had some type of interaction with universities. It would therefore be pointless to ask about the different forms of interaction and we would encounter a similar situation to that which occurs with more general innovation surveys. By choosing our data in this way, we obtain an “operational population” that fits in with the objectives of our study as it represents the portion of the production sector that is more prone to collaboration.

On the other hand, the use of this data source provides additional advantages. Firstly, it includes firms with varying innovation capacities that have obtained different types of financial support. There are firms that have obtained non-R&D related aid for innovation (e.g. a computer network or a web marketing system) as well as firms that engage in highly scientific activities (e.g. R&D projects conducted by aeronautic firms). This also means that only some of them have a department specifically dedicated to R&D. Secondly, the sample includes a wide range of business activities and sizes ranging from SMEs to large companies. Thirdly, the firms studied are not only concentrated in industrial areas or in technology parks near universities, but dispersed geographically throughout urban and rural areas of the region. In short, our data source is appropriate for observing the different patterns of interaction and the possible factors that operate in them.

3.2. Sample, fieldwork and questionnaire

Using this population, we have designed a sample of 800 enterprises. Selection was random, with a proportional distribution between strata formed by the sector of activity and the province where the enterprise is located. The fieldwork was conducted by means of personal interviews in the headquarters or offices of the firms. The fieldwork was carried out in the following sequence. The enterprises that were selected in the initial phase were contacted first by post mail and later by telephone to request their participation in the study. If the enterprise accepted, the appropriate person employed by the firm was chosen to respond to the questionnaire. An appointment was then arranged and a professional survey taker traveled to the firm’s headquarters to conduct the survey.

For the firms that refused to answer the survey, a randomly selected substitution sample was used following the same criteria. The acceptance rate in the first wave was 76%, while in the second wave it was 72%. A total sample of 737 enterprises was obtained. The main characteristics of the firms included in the sample can be found in the Total column of Table 5. The firms are chiefly independent, with less than one-fourth belonging to a business group. The number of employees reflects the size of the enterprises in the region: 52% employ ten workers or less, while only 14% have more than 50 workers. A large part of the firms can be considered startups: 18% were created after the year 2000. Their geographical location varies throughout the region, as does their sector of activity. As regards innovation capacity, 21.3% have an R&D department on the premises, while 3.8% have off-site R&D departments.

The information collected has been grouped into four main categories: a) characteristics of the enterprise, b) factors having to do with innovation capacity and processes, c) interaction with the university sector and d) geographical location and firm relationships. Special importance was given in the survey to section c). Decisions regarding survey design were inspired in recent specific studies (Cohen et al., 2002) as well as in the report on third stream indicators by Molas-Gallart et al. (2002). Nonetheless, in this last case the indicators were not designed in an operational manner, making it necessary to develop a specific measurement system. Moreover, the indicators were adapted to the context of the region where the firms are located. The indicator set was developed using an activity-based approach. In other words, the survey focused on what the enterprises do in relation to the universities, rather than on the impact that this interaction may have in economic terms.

The set of indicators includes twelve possibilities for interaction, ranging from R&D contract and consultancy to training and mobility of personnel, including also commercialization of IPR-related activities (see Chart 1). For each of these items, the respondent was asked if the firm had engaged in such activities during the 2000-2006 period and the number of times they occurred.

Chart 1: Types of interaction

1. Consultancy provided by a university or public research center
2. Contracts of R&D projects (commissioning of projects financed exclusively by the enterprise)
3. Joint R&D projects (jointly financed or funded with public aid)
4. Use of university facilities or equipment
5. Exploitation of a patent or an industrial design
6. Training of university personnel by the enterprise
7. Temporary exchange of personnel
8. Specific training of enterprise personnel by the university
9. Participation in a joint-venture, with the university as one of the partners.

†† In the national innovation survey, 8% of the innovative enterprises surveyed stated that they had collaborated, in some way, in R&D activities with a university or a public research center in 2005 (PITEC, 2005).
‡‡ The person who has been selected to respond to the survey depends on the size and internal organization of the firm. Each firm was allowed to select the most appropriate person to answer the questionnaire, albeit the choices were restricted to the following positions: the owner of the firm, the executive director, the head of the R&D or innovation department or the person in charge of the department most closely related to innovation strategy.
10. Creation of or collaboration in the creation of a new enterprise (spin-offs or start-ups)§§
11. Informal relations with university personnel
12. Other types of collaboration activities (open question coded afterward as: dissemination, conferences, encounters, seminars, joint trips and other unspecific links.)

4. Results

4.1. Descriptive results

Table 1 includes the different interactions that firms have with universities. It should be noted that informal relationships obtain the highest value (32% of the firms stated that they engaged in this type of interaction) followed by training of university personnel inside the firm (27.5%). This last case is especially significant due to regional government programs to promote the training of university postgraduates in enterprises (CICE, 2006). Moreover, this is a common mechanism for identifying future employees and lowering the risks involved in the selection of personnel. The rest of the interactions can be divided into three groups:

- 15%-25% of the firms engage in consultancy, joint research projects and university training programs for their employees.
- 5%-15% of the firms contract R&D projects, lease or use university facilities and engage in the exchange of personnel.
- Less than 5% of the enterprises have participated in the creation of spin-offs or start-ups, the sale or transfer of patents and joint ventures.

Other less frequent modes of interaction such as participation in encounters, seminars, dissemination or publications have been grouped in the same category given that less than 2% of the enterprises engage in these activities.

It should be highlighted that interaction related to training and personnel as well as consultancy carry an important weight, while the exploitation of intellectual property rights is given less importance even in firms regarded as being the most innovative in the region.

To give an overview of the results, 421 firms (57% of the sample) stated that they engaged in no type of interaction.

4.2. Mapping university-industry interactions

The second part of the analysis consists of drawing a map of the firms according to the interactions they engage in with universities. To this end, we conduct a cluster analysis with the firms that have collaborated with universities in some way. The analysis is carried out on ten variables, with the exception of informal relations and those included in the miscellaneous category containing unspecific links. Given that the correlations between variables may distort the results of a cluster analysis (Hair et al. 1999), as a first step we opted for a data reduction technique using factor analysis whose underlying dimensions can be utilized as normalized variables.

From the results of the factor analysis, we chose 5 dimensions. Table 2 shows the underlying structure of university-industry relationships and indicates the existence of common interaction patterns. Interactions related to R&D projects and consultancy are grouped together as are those related to the training and exchange of personnel. The same occurs with participation in the creation of a new enterprise or a joint-venture, although joint-ventures are also associated to the training of university personnel in the premises of the firms. Finally, there are two specific activities that are clearly separated; the exploitation of patents and the use of university facilities or equipment.

The 5 resulting dimensions are listed according to the characteristics of the activities they include:

- F1. “Activities linked to the generation and adaptation of knowledge” (R&D projects and consultancy)
- F2. “Participation in the creation of a new organization” (joint-venture, start-ups or spin-offs)
- F3. “Training and exchange of human resources”
- F4. “Exploitation of intellectual property results”
- F5. “Use of facilities or equipment”

The cluster analysis with the variables generated by these factors gives rise to six groups that are homogeneous in terms of their internal composition. The results show the aggregation patterns of the interactions. These are types of firms which are characterized for engaging in certain cooperation activities rather than in others. On the one end, we find the large group in the sample that has not engaged in any type of interaction (this group was not included in the cluster analysis and is labeled as C0). On the opposite end we find groups of very active firms which engage in knowledge-intensive activities. This map

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§§ Including firms that are spin-offs or star-ups themselves

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*** For purposes of the analysis, the firms which stated that they only engaged in informal relationships or in other types of unspecified links have been aggregated to the group that engages in no type of interaction.

††† The factor analysis was conducted using dichotomous variables that indicate if each type of interaction exists or not, with values of 0 and 1. The first five factors explain 70% of the variance. Three have eigenvalues higher than 1, while two of them have eigenvalues above 0.95. On the other hand, 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.
of firms reflects concrete patterns of interaction with universities (Table 3 shows the cluster distribution, while Table 4 indicates what type of relationships each cluster of firms has engaged in).

In what follows, we briefly describe the groups, labelling each one according to its identifying characteristics, the activities it engages in and its weight in the whole sample.

C1. “Firms engaged in exploiting intellectual property”. This group is mainly characterized by the exploitation of patents (58.5% of the firms have engaged in this type of activity). As compared to the others, it includes firms which have participated in the creation of a new firm (30.2%), although it also shows high scores for receiving specialized training from universities, as well as for exchange of personnel, consultancy and participation on R&D projects. This confirms again that exploitation of IPR needs specialized knowledge that is facilitated by the others channels. This group is comprised of 53 cases, accounting for 7.2% of the sample.

C2. “Firms engaged in institutionalized cooperation”. This group is characterized for participation in a joint-venture (97.5% of the firms with this relationship), mostly technology centers where a university has a formal involvement. High cooperation is also found for the creation of spin-off or start-up firms (31.8%), in addition to consultancy, R&D projects and activities related to human resources, mostly receiving trainees. This is the smallest group with 22 cases and accounts for 3% of the sample.

C3. “Firms that use university facilities”. This group is characterized for the instrumental use of the physical capital of universities. 100% of the firms in this cluster have used university facilities or equipment, either through leasing, concessions or an expert protocol. Consultancy is also an important activity (63.4%). This group shows moderate values in terms of participating in projects and activities related to human resources. It should be highlighted that there is not a single case of a firm in this group that has utilized a patent or participated in the creation of a joint-venture. This group comprises 41 cases, representing 5.6% of the sample.

C4. “Firms that receive trainees”. The firms in this cluster are characterized for the training of university personnel (100% of the cases), mostly postgraduates, which is usually their only activity. This is the group that engages least in the other activities, for which it shows very low values close to zero. This group comprises 68 cases and accounts for 9.2% of the sample. This group and the one that follows are the most numerous.

C5. “Firms engaged in generating and using embedded tacit knowledge”. This group shows high scores for all types of activities related to human resources, being much more active in all of these issues than the previous group. It also shows high scores for activities related to the creation and utilization of knowledge (participation range from around 72% of firms in consultancy and joint R&D projects to 45% in contract R&D projects). The group is characterized also for its lack of use of IPR results. No firm in this group use patents. Therefore, tacit knowledge seems to be the key feature for engagement in those R&D activities that require close collaborations with university personnel. This group includes 66 cases and represents 9% of the sample.

C6. “Firms engaged in generating and using less embedded tacit knowledge”. This group has important relationships with regard to consultancy (49%) and both kind of R&D projects (40% of the firms participate in contract R&D, 56% participate in joint R&D projects) although at a less intensive level than the previous one. An important feature of this cluster is that it has practically inexistent engagement with universities in the training and exchange of human resources as well as in the rest of the activities. That is why engagement for generating tacit knowledge seems to be less embedded in the relationships with university personnel. There are 45 cases in this group, which account for 6.1% of the sample.

4.3. Characterizing firms according to their type of involvement in university-industry interactions

The third part of the analysis consists in the characterization of each of the groups of firms obtained in the cluster analysis. For this purpose, we use a set of variables that can be classified in three groups according to the dimensions we labelled in section 2.1 above as “structural”, “strategy” and “situational” components of the firm.

The variables in the first group refer to two types of characteristics of the firm. The first group has to do with the background of the firm, such as sector of activity (coded following the technology-intensity classification by OECD, 2003), age, number of workers, turnover, scope of the market (regional, national and international) and integration in a corporate business group. The second deals more directly with the absorptive capacities of the firm. They include the existence of an R&D department on the premises of the firm, the size of the R&D department and the qualification of firm workers. For the innovation performance of the firm, we use two survey questions that enquire whether the firm has introduced either a product or a process innovation into the market in the last 5 years.

A second group of variables can be interpreted as indicators of strategy in terms of the openness of the firm toward external sources. Since this dimension is usually difficult to grasp, we have decided to build two compound variables that reflect the role that different external sources play in the innovation process of the firm. The first compound variable is formed by the number of times a firm states that an external organization is ‘important’ or ‘very important’ as a source for innovation. For this operation we use a list of 11 types of organizations, ranging from R&D intensive to local organizations (see Table I in the Annex). The second compound variable is formed by the number of times a firm states that a knowledge intensive business service (KIBS), usually provided by another specialized firm, is important or very important as a source for innovation. For this variable we use a list of 11 KIBS. Both compound variables show internal consistency (Cronbach
alpha=0.61 and 0.69). They reflect the extent to which the firm is prone to an open innovation strategy aimed at capturing different kind of knowledge from the environment.

A third group of variables has to do with some situational attributes regarding the geographical environment where the firm is located or to the different kind of links the firm has with other organizations. For the first dimension we use a classification of the type of location of the firm, distinguishing between technology parks, industrial, urban and rural areas. For the second one we use the membership of the firm to several types of associations. These links can be interpreted as a reflection of the social capital of the firm.

By using a cross-tabulation of the three sets of variables, the basic characteristics of each cluster are provided. Table 5 includes in rows the categories of the variables. The table shows in columns, for each cluster, the percent of firms in each value (for nominal and ordinal variables) or the mean (for interval variables). Residual analysis for qualitative measurements and mean differences for quantitative ones are used when applicable, and highlighted in the table. Although the aim of this analysis is exploratory, it provides substantive insights on the factors that can influence the different kind of relationships firms have with universities. In addition, the findings can serve to refine the usual assumptions in this field when using variables in causal analysis. The sequence we follow for describing the profile of the clusters starts by showing common patterns in the more similar ones, and then by highlighting the main differences between them.

The clusters we found to be more similar in terms of the collaboration patterns with universities also show some common features in the kind of firms they encompass. Clusters 1 and 2 are the more similar in terms of the types of relationships with universities, as shown in 4.2. They also share some of the basic characteristics of the firms they contain. In general, firms to be found in these clusters are bigger, more oriented to the national and international market instead to the local market, and also more of them belong to a corporate group. More than a half of the firms in these groups have R&D departments, and the number of workers at these departments is also bigger when compared with the other clusters. Activities reflecting innovation are more frequent, especially product innovation.

However, there are some differences between C1 and C2. Firms in C1 (engaged in exploiting IPR) are younger and smaller, and have more workers with higher education degrees than C2. Instead, C2 (firms engaged in institutional cooperation) is formed by bigger firms, and more of them are in the manufacturing sector. Firms in C2 give less importance to external organization as sources for innovation than C1, although not to external KIBS. Moreover, they are more concentrated in some locations, especially in technology parks, and consequently more of them belong to certain kind of associations, especially regional technology centres and firm associations related to innovation. In sum, C2 has some distinctive characteristics in addition to C1, reflecting bigger firms with more absorptive capacities in terms of the internal organizational arrangements for in house R&D.

Clusters 5 and 6 show some, though not very marked differences in the background of their firms when compared to C1 and C2. Bigger differences are found in indicators related to absorptive capacities. C5 (firms engaged in generating and using embedded tacit knowledge) includes less firms with R&D department than C1 and C2, and also the departments are smaller, although these values are high when compared to the whole sample and also to the rest of the clusters. Numbers of firms with product and process innovation are also smaller than in the previous clusters. In C5 only slight differences are found in the compound variables referred to the importance paid to external sources when compared to C1 and C2, although the network of relationships is less tight, especially with innovation-related associations. In contrast, C6 (firms engaged in generating and using less embedded tacit knowledge) is some steps lower in the background and absorptive capacities. It includes older and smaller firms than the three previous groups. It also has less workers with university degree, less firms with R&D department, and also less product innovation activities. More of the firms in this cluster are located in places other than technology parks, and some of them are in rural areas. In sum, it can be said that there is a down grade of innovation-related features between C1 and C2 firstly, and then between C5 and C6, reflecting different levels of modernization and organizational arrangements. Different kinds of firms are found in C3 and C4, in accordance to the specific interactions with universities they have. C3 (firms that use university facilities) is formed by bigger firms. They also have more firms with an important part of the workers with a university degree, as well as with an R&D department. However, C3 has fewer firms with product or process innovation. Few differences are encountered in the strategy towards open innovation. The main feature regarding the situational variables is that a quarter of them are located in technology parks (second in importance after C2), and that more of them belong to firm associations related to innovation. On the other hand, C4 (firms that receive trainees) shows a profile of smaller firms, older, more oriented to the regional market, with practically no PhD. Few of them has an R&D department, as well as less of them do product or process innovation. Only few are located in technology parks, and most of their relationships are with local or sector based associations.

Finally, a mention to firms in Cluster 0; the one formed by firms with no interactions with universities. This group encompasses firms that show important differences when compared to the rest of the clusters, especially with the ones with more intense cooperation. It includes smaller, independent, locally oriented firms. They are less innovative, have few workers with HE degree, and few of them have R&D departments. The importance that they give to external organizations and services is also smaller. Their links are more concentrated in local or sector associations. Although few of them are in technology parks, geographical distributions does not show a clear pattern when compared to the other clusters, as most of
the firms in C0 are located in industrial districts and central urban areas.

5. Conclusions

The results of this study provide relevant insights on university-industry relationships. In the first step of the analysis we illustrate the complexity of collaboration between firms and universities by presenting the variety of forms it can take. The variables commonly used in innovation surveys do not usually capture this complexity. When detailed indicators are employed, a wide range of interactions emerge which. On many occasions, they are found to be unrelated to R&D or IPR activities. In our survey more than half of the firms do not engage in any type of cooperation, in spite of having an innovative profile. In the remaining firms, however, some university-industry relationships are clearly found to play an important role. The most frequent activities are those having to do with the training and exchange of human resources as well as consultancy. In-house R&D projects and the use of university facilities are found to be of less common. The least frequent activities include the exploitation of patents, the creation of spin-offs and participation in joint-ventures. These results support the thesis that universities are an important source of tacit knowledge related to the human resources needed for both recruitment of skilled workers and for enhancing the use of results from collaborative projects and consultancy.

With the second step of the analysis involving factor and cluster procedures the results clearly show how the different possibilities for cooperation are structured, permitting the proposed hypotheses to be tested. The interactions studied reveal an aggregation pattern. Groups of activities are correlated and undertaken in a conjunctive manner. Some activities correspond to “exploration strategies” associated to human resources. Others, such as patents and spin-offs, are more closely linked to “knowledge exploitation strategies”. Nonetheless, the diversity of activities makes it difficult to confirm our first hypothesis if we take it as a marked division between exploitation and exploration. Although this is a useful analytical distinction, it is not yet sufficiently operationalized if the aim is to study this phenomenon empirically.

We find confirmation for our second hypothesis, which sustains that the use of patents is linked to other activities aimed at both knowledge exploitation and exploration. The firm cluster characterized for using patents largely engages in many of the other activities, particularly in the exchange and training of personnel and in a variety of research projects. Our third hypothesis can only be confirmed to a certain degree given that there are various clusters of firms characterized for human resources-related cooperation involving different levels of expertise. This hypothesis needs some refinement as there are groups of firms that engage in training postgraduates as well as in activities aimed at exploiting and generating knowledge. Finally, our fourth hypothesis is clearly corroborated by the existence of a group of enterprises which uses university facilities and services but is not very active in the other areas, albeit this group of firms accounts for a very small part of the sample.

The third step of the analysis aimed at providing a profile of the clusters does not always show a completely clear distinction in the kind of firms they encompass when looking at the structure, the strategy, or the situation variables. First, we observe that there are several factors that create a kind of threshold for interacting with universities, which is different depending on the kind of relationship we look at. On the one hand, there is a very important part of the productive sector that, in spite of having some innovative capacities relative to the population of firms (our sample comes from the population of firms in the region that are more prone to innovation), inhabits a world that is quite alien to most of the activities that have to do with universities and public research organizations, as well as with R&D related innovation. This is the usual situation for a majority of firms in catch-up regions, and also for most of SMS firms in developed regions. On the other hand, once this barrier is trespassed, the situation of the firms that can be found in the landscape is far from homogeneous.

In the lower side, there are different kinds of firms that are able to cooperate with exchange of personnel, specialized training, some consulting or some joint R&D projects, especially when public support is available. Skilled human resources and a certain degree of innovation seem to be the minimum requirements the firm. In the upper side, the firms very actively engaged in using IPR and contract research are the ones with HE workers, some of them with a PhD, and organizational structure and routines aimed at generating as well as capturing new knowledge. Moreover, science related engagements do not go alone because these firms are also very active in personnel exchange and consultancy. Other typical cases for interacting with universities, such as the use of university facilities or the engagement in joint centres, are shaped by the specific features of the firm and the productive process they are involved in, e.g. if the productive process of the firm is akin to the facilities university provide. Although some capabilities are required, mostly the existence of a stable and structured productive process and the presence of personnel that is able to exchange with and to process information from other organizations.

Second, it seems to be another threshold in the upper side that in some circumstances can go the other way round for tight relationships with universities. The firms that have strong capabilities, as well as the firms well positioned in the market, usually have develop a core business competence that provide strategic advantage. These firms usually don’t need to collaborate with universities for creating their core competences, nor is frequent for them to subcontract or ask for consultancy related to this strategic advantage. Instead, they get involved with universities mainly in order to make use of some of the facilities, for recruiting human resources or for obtaining information that can be useful for detecting new business opportunities. So firms with high absorptive capacities frequently do not interact with universities in producing or exploiting knowledge, but rather in activities...
related to exploration.

From this point of view, the thesis of absorptive capacities needs additional research that takes into account the varied species of firms in the landscape for collaboration. The structure of the firm usually sets the basic capabilities for making possible the starting of relationships with knowledge-intensive actors. The type of sector or activity, education of workers, the presence of a specialized department, and to some extent, the presence of innovation processes are probably the factors that define the probabilities to get in the landscape for cooperation. But once this minimum level is reached, possibilities expand and readapt according to the strategies firms adopt for enhancing innovation, and also according to the access to relevant actors through networks and contacts.

Therefore, it is necessary to look at the organizational culture of the firm, at the possibilities for establishing networks in the institutional environment, and then to put them in context with the core competences of the firm. However, according to our data, evidence is less strong when looking at these variables. Strategies aimed at capturing external knowledge are appreciated only between the groups that differ the most (the ones with no relationships and the ones with many relationships), but only slight differences are found when looking at different types of cooperation patterns reflected by the clusters. Unfortunately, our data set has limitations due to the number of firms in the groups, making difficult to detect differences. Our data is also limited regarding the variables reflecting the open innovation strategy of the firms due to limitations of Likert-type scale responses when applied in a short time interview scheme. More research is needed to overcome the difficulties of measuring the open strategy of the firm. Finally, variables related to location and networks show also some differences in specific clusters, indicating that specific situation and contacts are an important issue for some firms. Location in technology parks and links to innovation related associations are the more relevant, but not definite features of the most active clusters of firms, although it is difficult to grasp if this situational features are a constituent part of the strategy of the firm and whether if they are decided before, during, or after cooperation arrangements with universities start.

Notwithstanding, these results must be interpreted with a certain amount of caution. This is an exploration of the map that emerges when observing university-industry relations under a complex framework. Inferences made come from analyses aimed at mapping enterprise types. It is therefore necessary to study in greater detail the causal mechanisms (or the independent variables that reflect the strategy, structure and situation) that lead an enterprise to belong to one or another of the groups identified here.

To conclude, the findings have important policy implications. They are especially relevant from the viewpoint of catch-up regions, although they can also be extended to other more knowledge-intensive environments since our data source includes numerous enterprises with a high innovative profile that are active in R&D. Universities are important organizations for the productive sector and are used by enterprises to obtain resources. Nonetheless, these resources are extremely varied and respond to very different rationales depending on the possibilities and strategies of the firm. It is necessary to take into account that R&D-related activities do not play a major role in most of the firms, even in those more prone to innovation. This is especially important for universities and public research organizations which are not located in knowledge-intensive environments and surrounded of high-tech firms. R&D-intensive activities, particularly IPR exploitation, are possibly just the tip of the iceberg that emerges only when firms have absorptive and exploitation capacities that have been acquired through a wide range of previous interactions with universities.

Then policy options for facilitating university-firm collaboration, including incentives and rewards for academics and units, should consider opening up to the majority of less R&D intensive activities that firms are able to get involved with in reality. First, because they enhance the capabilities of local firms, and second, because these activities usually go hand in hand with higher level of absorption of the knowledge generated by universities.

6. References


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CIF- Consejo Económico y Social de Andalucía (2003, 2007) Informe sobre la situación socioeconómica de Andalucía, Sevilla: CES.


PITEC (2005): La innovación en la empresa española, Madrid: FECYT-SISE.
# Tables

Table 1: Types of interactions with universities

<table>
<thead>
<tr>
<th>% answering &quot;yes&quot; in each type of interaction</th>
<th>% Do not know / No answer</th>
<th>Collaborative intensity (number of interactions)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>N&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
<tr>
<td>Consultancy work</td>
<td></td>
<td>124</td>
</tr>
<tr>
<td>Commissioning of R&amp;D projects to universities</td>
<td></td>
<td>87</td>
</tr>
<tr>
<td>Joint R&amp;D projects</td>
<td></td>
<td>145</td>
</tr>
<tr>
<td>Use or renting of facilities</td>
<td></td>
<td>48</td>
</tr>
<tr>
<td>Patent exploitation</td>
<td></td>
<td>28</td>
</tr>
<tr>
<td>Training of university postgraduates and internships at the firm</td>
<td></td>
<td>158</td>
</tr>
<tr>
<td>Exchange of personnel</td>
<td></td>
<td>40</td>
</tr>
<tr>
<td>Training of firm workers by the university</td>
<td></td>
<td>93</td>
</tr>
<tr>
<td>Joint-ventures with universities</td>
<td></td>
<td>22</td>
</tr>
<tr>
<td>Participation in spin-offs and start-ups</td>
<td></td>
<td>27</td>
</tr>
<tr>
<td>Informal networks</td>
<td></td>
<td>147</td>
</tr>
<tr>
<td>Other types of collaborative Activities</td>
<td></td>
<td>1.9</td>
</tr>
</tbody>
</table>

<sup>1</sup>Base: Firms displaying at least one type of interaction

<sup>2</sup>Base: Total of firms
Table 2: Factor analysis of interaction types. Rotated component matrix

<table>
<thead>
<tr>
<th>Components*</th>
<th>F1</th>
<th>F2</th>
<th>F3</th>
<th>F4</th>
<th>F5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consultancy work</td>
<td>0.766</td>
<td>-0.049</td>
<td>0.249</td>
<td>0.117</td>
<td>0.184</td>
</tr>
<tr>
<td>Commissioning of R&amp;D projects to universities</td>
<td>0.783</td>
<td>0.096</td>
<td>-0.002</td>
<td>-0.061</td>
<td>0.062</td>
</tr>
<tr>
<td>Joint R&amp;D projects</td>
<td>0.715</td>
<td>0.166</td>
<td>0.133</td>
<td>0.189</td>
<td>-0.141</td>
</tr>
<tr>
<td>Use or renting of facilities</td>
<td>0.072</td>
<td>0.121</td>
<td>0.087</td>
<td>0.002</td>
<td>0.933</td>
</tr>
<tr>
<td>Patent exploitation</td>
<td>0.161</td>
<td>0.198</td>
<td>0.213</td>
<td>0.720</td>
<td>-0.137</td>
</tr>
<tr>
<td>Training of university postgraduates and internships at the firm</td>
<td>-0.037</td>
<td>0.284</td>
<td>0.365</td>
<td>-0.644</td>
<td>-0.244</td>
</tr>
<tr>
<td>Exchange of personnel</td>
<td>0.070</td>
<td>0.415</td>
<td>0.609</td>
<td>0.113</td>
<td>0.095</td>
</tr>
<tr>
<td>Training of firm workers by the university</td>
<td>0.246</td>
<td>-0.077</td>
<td>0.838</td>
<td>-0.025</td>
<td>0.046</td>
</tr>
<tr>
<td>Joint-ventures with universities</td>
<td>0.214</td>
<td>0.833</td>
<td>-0.054</td>
<td>-0.152</td>
<td>0.015</td>
</tr>
<tr>
<td>Participation in spin-offs and start-ups</td>
<td>-0.038</td>
<td>0.626</td>
<td>0.252</td>
<td>0.329</td>
<td>0.163</td>
</tr>
</tbody>
</table>

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: 68.8%
### Table 3. Distribution of firm clusters

<table>
<thead>
<tr>
<th>N</th>
<th>% collaborative firms</th>
<th>% total</th>
</tr>
</thead>
<tbody>
<tr>
<td>C0</td>
<td>432</td>
<td>58.6</td>
</tr>
<tr>
<td>C1</td>
<td>53</td>
<td>17.4</td>
</tr>
<tr>
<td>C2</td>
<td>22</td>
<td>7.2</td>
</tr>
<tr>
<td>C3</td>
<td>41</td>
<td>13.4</td>
</tr>
<tr>
<td>C4</td>
<td>68</td>
<td>22.3</td>
</tr>
<tr>
<td>C5</td>
<td>66</td>
<td>21.6</td>
</tr>
<tr>
<td>C6</td>
<td>45</td>
<td>14.8</td>
</tr>
<tr>
<td>Excluded cases</td>
<td>10</td>
<td>3.3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>737</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

Optimal division of collaborative firms in six cluster according to the following criteria:

- Schwarz's Bayesian Criterion (BIC minimum): 834.3
- Ratio of Distance Measures (maximum): 1.6

### Table 4. Types of interactions with universities in firm clusters (% of firms of the clusters that have the stated relationship with a university)

<table>
<thead>
<tr>
<th></th>
<th>C0</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
<th>C6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consultancy work</td>
<td>0.0</td>
<td>67.9</td>
<td>72.7</td>
<td>63.4</td>
<td>7.4</td>
<td>74.2</td>
<td>48.9</td>
</tr>
<tr>
<td>Commissioning of R&amp;D projects to universities</td>
<td>0.0</td>
<td>41.5</td>
<td>68.2</td>
<td>31.7</td>
<td>2.9</td>
<td>45.5</td>
<td>40.0</td>
</tr>
<tr>
<td>Joint R&amp;D projects</td>
<td>0.0</td>
<td>69.8</td>
<td>86.4</td>
<td>43.9</td>
<td>11.8</td>
<td>71.2</td>
<td>55.6</td>
</tr>
<tr>
<td>Use or renting of facilities</td>
<td>0.0</td>
<td>13.2</td>
<td>31.8</td>
<td>100.0</td>
<td>0.0</td>
<td>0.0</td>
<td>2.2</td>
</tr>
<tr>
<td>Patent exploitation</td>
<td>0.0</td>
<td>58.5</td>
<td>9.1</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>2.2</td>
</tr>
<tr>
<td>Training of university postgraduates and internships at the firm</td>
<td>0.0</td>
<td>39.6</td>
<td>90.9</td>
<td>58.5</td>
<td>100.0</td>
<td>93.9</td>
<td>2.2</td>
</tr>
<tr>
<td>Exchange of personnel</td>
<td>0.0</td>
<td>32.1</td>
<td>40.9</td>
<td>17.1</td>
<td>1.5</td>
<td>19.7</td>
<td>0.0</td>
</tr>
<tr>
<td>Training of firm workers by the university</td>
<td>0.0</td>
<td>67.9</td>
<td>45.5</td>
<td>41.5</td>
<td>0.0</td>
<td>71.2</td>
<td>0.0</td>
</tr>
<tr>
<td>Joint-ventures with universities</td>
<td>0.0</td>
<td>5.7</td>
<td>95.5</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Participation in spin-offs and start-ups</td>
<td>0.0</td>
<td>30.2</td>
<td>31.8</td>
<td>12.2</td>
<td>1.5</td>
<td>0.0</td>
<td>0.0</td>
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</table>
## Table 5: Profile of firm clusters (*percent in columns, **mean)

<table>
<thead>
<tr>
<th>Activity Sector*</th>
<th>C0</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
<th>C6</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low and Medium-Low-Technology Manufacturing</td>
<td>15.3</td>
<td>19.6</td>
<td><strong>38.1</strong></td>
<td>12.2</td>
<td>20.9</td>
<td>19.7</td>
<td>22.7</td>
<td>17.5</td>
</tr>
<tr>
<td>Medium-High-Technology Manufacturing</td>
<td>13.9</td>
<td>13.7</td>
<td>14.3</td>
<td>19.5</td>
<td>11.9</td>
<td>13.6</td>
<td>19.5</td>
<td>14.4</td>
</tr>
<tr>
<td>High-Technology Manufacturing</td>
<td>5.8</td>
<td>3.9</td>
<td>4.8</td>
<td>12.2</td>
<td>0.2</td>
<td>4.5</td>
<td>9.8</td>
<td>4.5</td>
</tr>
<tr>
<td>Technical Services</td>
<td><strong>19.9</strong></td>
<td>17.6</td>
<td>9.5</td>
<td>17.1</td>
<td>23.9</td>
<td>21.2</td>
<td>11.4</td>
<td>19.3</td>
</tr>
<tr>
<td>Info-Tech Services</td>
<td>5.3</td>
<td>11.8</td>
<td>0.2</td>
<td>12.2</td>
<td>0.2</td>
<td>9.8</td>
<td>13.4</td>
<td>6.1</td>
</tr>
<tr>
<td>Professional and Financial and Services</td>
<td>16.9</td>
<td>9.9</td>
<td>4.8</td>
<td>12.2</td>
<td>0.2</td>
<td>4.5</td>
<td>2.3</td>
<td>19.5</td>
</tr>
<tr>
<td>Transport Services</td>
<td>8.6</td>
<td>3.9</td>
<td>4.8</td>
<td>9.8</td>
<td>9.0</td>
<td>15.2</td>
<td>9.1</td>
<td>10.8</td>
</tr>
<tr>
<td>Wholesale, Retail and Personal Services</td>
<td>39.7</td>
<td>2.9</td>
<td>4.8</td>
<td>12.2</td>
<td>0.2</td>
<td>9.8</td>
<td>13.4</td>
<td>6.1</td>
</tr>
<tr>
<td>Others</td>
<td>39.7</td>
<td>2.9</td>
<td>4.8</td>
<td>12.2</td>
<td>0.2</td>
<td>9.8</td>
<td>13.4</td>
<td>6.1</td>
</tr>
<tr>
<td><strong>% of the business in the regional market</strong></td>
<td>82.4</td>
<td>48.1</td>
<td>52.0</td>
<td>62.5</td>
<td>66.1</td>
<td>55.8</td>
<td>55.8</td>
<td>73.2</td>
</tr>
<tr>
<td><strong>% of the business in the national market</strong></td>
<td>94.3</td>
<td>75.2</td>
<td>79.0</td>
<td>81.9</td>
<td>92.7</td>
<td>84.5</td>
<td>83.6</td>
<td>90.1</td>
</tr>
<tr>
<td><strong>% of the business in the international market</strong></td>
<td>3.8</td>
<td>15.3</td>
<td>16.4</td>
<td>18.1</td>
<td>4.3</td>
<td>10.9</td>
<td>9.8</td>
<td>6.9</td>
</tr>
</tbody>
</table>

### 1b. ABSORPTIVE CAPACITY VARIABLES

| % of workers with PhD** | 0.3 | 3.3 | 2.1 | 3.2 | 1.1 | 0.6 | 1.9 | **1.0** |
| % of workers with other HE degree** | 12.7 | 39.6 | 29.7 | 53.3 | 28.0 | 86.5 | 31.8 | 22.1 |
| R&D department* | Yes, in this location | 8.1 | 54.7 | 54.5 | 48.8 | 26.5 | 40.0 | 24.4 | 20.8 |
| Yes, in other location | 3.2 | 1.9 | 4.5 | 2.4 | 4.4 | 4.4 | 3.6 |
| No | 86.7 | 43.4 | 40.9 | 45.8 | 69.1 | 53.8 | 71.1 | 75.6 |
| Numbers of workers at the R&D department** | 0.5 | 5.1 | 6.5 | 5.4 | 2.0 | 3.4 | 1.6 | 1.8 |

### 2. STRATEGY VARIABLES

| Product innovation in the last 5 years* | 44.2 | 81.1 | 86.4 | 68.3 | 67.6 | **77.3** | 68.9 | 56.3 |
| Process innovation in the last 5 years* | 35.2 | 56.6 | 95.5 | 65.9 | 50.7 | 59.1 | 60.0 | 45.5 |

### 3. SITUATIONAL VARIABLES

| Location of the firm ** | Science or technology park | 36.6 | 17.3 | 18.2 | 22.0 | 32.4 | 25.8 | 22.2 | 28.7 |
| Urban area – city centre | 46.3 | 17.3 | 18.2 | 41.5 | 26.5 | 33.3 | 33.3 | 39.2 |
| Urban area – suburbs | 14.2 | 19.2 | 13.6 | 2.4 | 20.6 | 16.7 | 20.0 | 15.1 |
| Rural area | 7.2 | 13.5 | 9.1 | 7.3 | 4.4 | 7.6 | 17.8 | 8.1 |
| Others | 0.5 | 1.9 | 4.5 | 2.4 | 2.4 | 2.4 |

| Membership with other organizations* | Associated to a technology centre | 2.6 | 7.3 | 32.9 | 6.9 | 19.9 | 8.8 | 11.6 | **10.8** |
| Associated to a regional innovation network (CIT-Regional centres for innovation) | 0.7 | 9.8 | 4.8 | 3.4 | 3.6 | 3.8 | 3.1 | 4.1 |
| Associated to a research centre | 0.4 | 2.4 | 10.1 | 3.4 | 1.9 | 2.6 | 3.1 | 3.0 |
| Member of firm associations related to innovation activities | 14.9 | 24.4 | 14.3 | 14.7 | 35.2 | 24.5 | 21.9 | 29.4 |
| Member of employers associations | 15.2 | 19.5 | 9.5 | 6.9 | 16.7 | 15.1 | 12.5 | 14.8 |
| Member of other firm associations (sector or trade associations, local associations, local chambers of commerce, etc.) | 59.5 | 34.1 | 28.6 | 37.6 | 42.6 | 47.2 | 43.8 | 50.1 |

Highlighted cells for qualitative variables (*): adjusted residuals under -1.9 and above 1.9
Highlighted cells for means (**): significant differences for above 0.05.
Annex.

Table I. Firm strategy on open innovation: information for the compound variables
% of firms that answer that the proposed activity or organization is important or very important as a source of innovation

<table>
<thead>
<tr>
<th>Knowledge intensive business services</th>
<th>% in “important” or “very important”</th>
<th>External Organizations</th>
<th>% in “important” or “very important”</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Business development advise</td>
<td>44.6</td>
<td>1. Specialized suppliers</td>
<td>81.7</td>
</tr>
<tr>
<td>2. Planning advise</td>
<td>40.5</td>
<td>2. Others firms in the same sector</td>
<td>68.3</td>
</tr>
<tr>
<td>3. Marketing and promotion advise</td>
<td>49.3</td>
<td>3. Technological consultants</td>
<td>42.4</td>
</tr>
<tr>
<td>4. Marketing and product research</td>
<td>60.9</td>
<td>4. Commercial laboratories</td>
<td>38.6</td>
</tr>
<tr>
<td>5. Accounting and financial advise</td>
<td>70.9</td>
<td>5. Universities and public research centers</td>
<td>49.6</td>
</tr>
<tr>
<td>6. Information Technologies Services</td>
<td>58.4</td>
<td>6. Regional technology and innovation centers</td>
<td>49.8.</td>
</tr>
<tr>
<td>7. Human resources training</td>
<td>73.6</td>
<td>7. Conferences and specialized events</td>
<td>69.8</td>
</tr>
<tr>
<td>8. Recruitment</td>
<td>54.8</td>
<td>8. Local government</td>
<td>32.4</td>
</tr>
<tr>
<td>9. Accreditation</td>
<td>48.5</td>
<td>9. Regional government</td>
<td>39.9</td>
</tr>
<tr>
<td>10. Legal services</td>
<td>45.8</td>
<td>10. Firm associations</td>
<td>53.6</td>
</tr>
<tr>
<td>11. E-commerce</td>
<td>35.0</td>
<td>11. Informal networks</td>
<td>37.3</td>
</tr>
</tbody>
</table>