UNIVERSITAT ROVIRA I VIRGILI

WORKING PAPERS

Col·lecció "DOCUMENTS DE TREBALL DEL DEPARTAMENT D'ECONOMIA"

"External sources of innovation and industry-university interaction: evidence from Spanish firms"

Agustí Segarra-Blasco
Josep Maria Arauzo Carod

Document de treball nº -1- 2005

DEPARTAMENT D'ECONOMIA
Facultat de Ciències Econòmiques i Empresarials

UNIVERSITAT
ROVIRA I VIRGILI

Edita:

Departament d'Economia
http://www.fcee.urv.es/departaments/economia/public_html/index.html
Universitat Rovira i Virgili
Facultat de Ciències Econòmiques i Empresarials
Avgda. de la Universitat, 1
432004 Reus
Tel. +34 977 759 811
Fax +34 977 300 661

Dirigir comentaris al Departament d'Economia.

Tots els treballs publicats a la col·lecció *"Documents de Treball del Departament d'Economia"* han superat un procés d'avaluació externa.

Dipòsit Legal: T-1025-2006
ISSN 1576 - 3382

DEPARTAMENT D'ECONOMIA

Facultat de Ciències Econòmiques i Empresarials

External sources of innovation and industry-university interaction: evidence from Spanish firms

Agustí Segarra-Blasco (♣): agusti.segarra@urv.net

Josep-Maria Arauzo-Carod (♣): josepmaria.arauzo@urv.net

Abstract

This paper is about the firm innovation process and the cooperation of the innovative firms with other firms and public institutions. A special attention is paid to the cooperation with universities. We use the Technological Innovation Survey (TIS) from the *Instituto Nacional de Estadística* (Spain) in order to obtain data for 4,159 innovative firms. Our results show that firm's cooperation activities are closely linked to the characteristics of the industry and the firm as well as to the origin of public funds for R&D activities.

Key words: Innovation, universities, Spanish economy

JEL code: O31, I20, L60

(♣) Grup de Recerca d'Indústria i Territori (GRIT)
Department of Economics (Universitat Rovira i Virgili)
Av. Universitat,1; 43204 – Reus
Phone + 34 977 759 800 Fax + 34 977 759 810

This research was partially funded by CICYT: SEJ2004-05860/ECON and CICYT: SEJ2004-07824/ECON. We would like to acknowledge the helpful and supportive comments of participants at the *Workshop on Local Development and Territorial Governance* (Toulouse) and the *XXX Reunión de Estudios Regionales* (Barcelona) and those of an anonymous referee. The usual disclaimer applies.

1. Introduction

Universities are devoted to higher education and research. They are also called upon to participate actively in areas that directly affect the economy. Since the nineteenth century, when the university was enclosed within its "ivory tower", the changes have been spectacular, so much so, in fact, that universities are becoming an increasingly high-profile stakeholder in the generation and dissemination of knowledge with a direct impact on economic activities. In addition to the traditional roles of a Humboldt-style university (i.e. higher education and research), they are increasingly taking on a third mission that is connected with economic development.

Universities participate actively in the generation and transfer of knowledge from academic institutions to innovation in entrepreneurship. The relations between university and firms cover a wide range (technology transfer centres, research institutes, science parks, technology springboards, etc.), which in practice aim to bring the academic world and the business world closer together.

In modern societies, where knowledge management is a key factor in social well-being, universities not only fulfil the role of providing higher education and research, but also aspire to being drivers of the economy. In addition to educating and producing knowledge, therefore, universities must also contribute to the development of their regions. There is a growing public desire for universities to take an active role in disseminating new knowledge, new skills and new ideas to firms and institutions (Branscomb et al., 1999). The universities themselves share this desire. Departments, research institutes, research groups and the managers of universities are establishing a wide range of relationships with businesses and public institutions. These new demands on universities to play an active role in regional development are opening up new opportunities for the academic world, but at the same time they are creating tensions within their structures.

The commercialisation of university knowledge (especially knowledge from university-based technologies) has increased considerably due to patenting, joint ventures in research and firm creation. Several factors explain this phenomenon. First is the creation of structures that promote relations between the universities and business, such as science parks and other property-based institutions (Link et al., 2003). Second is the development of laws on intellectual property, while researchers' increasing interest in patenting their discoveries has helped to commercialise the results of university research. Finally, closer R&D cooperation between firms and universities and public funding for the creation of joint ventures have oriented universities' research activities towards the demands of business.

A key issue about this process is the innovation system concept (Lundvall, 1992). This can be defined as the set of elements that in a certain sphere (geographical or sectorial) act and interrelate in the processes of creating and disseminating economically useful knowledge. Following COTEC (2002), the innovation system is made up of five subsystems: firms, public administrations, innovation support infrastructures, public R&D system (universities, public research centres, laboratories, etc.) and the subsystem made up of the financial system, the educational system and the behaviour of demand. As well as these subsystems it is important to consider the market mechanisms where economic agents interact and where market failures (knowledge externalities) are generated by activities of research and knowledge transfer.

In the innovation system, agents and institutions come together and participate in the processes of creating and disseminating knowledge until the innovation is carried out by firms. In short, the public R&D system includes the universities and public institutions that participate in applied and basic research. With public resources, administrations promote the research and foster entrepreneurial innovation via a process that regulates the markets of goods and technology (competition policy, science and technology policy, fiscal incentives, copyright, etc). Infrastructure and scientific equipment help to transfer knowledge from the technological market to business, and firms are active agents in the innovation process. Finally, the markets are where the various agents interrelate.

To measure the activities carried out during the innovation process, a wide range of indicators are needed. Most research on entrepreneurial innovation has concentrated on indicators related to inputs (Geroski, 1990) or outputs (Griliches, 1979; Jaffe, 1989). However, just as important as the elements that participate in the innovation system are the relationships between them. Another important way of transmitting knowledge and innovation is the R&D relationship between firms and external agents.

Traditionally, technology policies have been directed at financing the R&D of firms and public research centres. This is the linear model of technological innovation. However, during the nineties there was a certain change in the policies aimed at reinforcing national and regional systems of innovation. Central governments and supranational applications (the European Commission), as well as the regional governments, use technology policy instruments to improve the competitiveness of economic agents. This improvement is achieved by strengthening the abilities of the various areas in the system to interrelate, obtaining a more appropriate supply and demand of technology, increasing the ability to absorb new and existing knowledge, making infrastructure available for innovation and promoting a smooth flow of knowledge (Meyer-Krahmer, 1990).

In this paper we use the *Encuesta de Innovación Tecnológica* (Technological Innovation Survey) as a source of information of firm cooperation in R&D activities at the Spanish level. The Spanish innovation system is of high interest, because of the reduced expense in R&D and the importance of public sector in those activities (Bayona et al., 2001).

This paper is structured as follows. In the second section we review some contributions on the external sources of the innovation process. In the third section we analyse the characteristics of the cooperation and innovation process. In the fourth section we present the model and the variables. In the fifth section we discuss our results and in the sixth section we summarise our main conclusions.

2. External sources of the innovation process

At the university level there are formal and informal relations between institutions, firms and individuals, and new scientific knowledge is transmitted to the innovative agents. However, the process for transmitting knowledge, involving intervening agents and the creative process itself, is very complex. Until the late 1970s, the innovation process was thought to follow a linear model that began with basic and applied research and ended with entrepreneurial innovation. On the basis of this linear model, R&D activities were the main manifestation of entrepreneurial innovation. However, the relationship between R&D expenditure and entrepreneurial innovation is not so direct and other important factors influence the innovative capacity of a firm.

The fact that some countries that were not located on the technological border achieved high levels of innovation indicates that organizational changes and human assets are important factors in the development of innovations. Landau (1991) states that three factors (physical assets, human assets and intangible assets) are important for the innovative process of firms. At the same time, scientific knowledge does not flow in only one direction (towards innovation). There is feedback, and these interactions between science and technology are intense and unforeseen. In effect, innovative firms often benefit indirectly from scientific advances via multiple external sources, such as their relationships with their customers and suppliers, the recruitment of qualified staff, and contact with the public research centres. A firm's innovative process takes place when it has an accumulation of technological knowledge and easy access to external knowledge. To achieve a successful innovative process a firm needs to combine internal and external knowledge (Freeman, 1998).

Until recently the innovation process was thought to follow a linear model in which the main indicator of innovation activities was R&D. Unfortunately, since the mid-1970s it has not been possible to verify (at the firm or at the national level) whether there is a direct relationship between the increase in R&D expenditure and the increase in competitiveness. This situation has led to the development of new models in which R&D activities are not a precondition for innovation but are used in a phase of the process when existing knowledge is not enough. This new innovation model provides information about the structure of the technological innovation process, describes the relationship between this process and a firm's technological strategy, and highlights the factors that influence (or obstruct) both its capacity to innovate and its economic performance.

The decentralized system of university funding created strong incentives for public universities to pursue research that was interesting for local firms (Mowery and Sampat, 2001). However, the recent rise in university-industry partnerships has stimulated an important public-policy debate on how these relationships affect fundamental research (Poyago-Theotoky, Beath and Siegel, 2002), given that firms' relationships with other agents involved in the innovation system play a key role in their innovation processes.

To analyse the external relations of Spanish firms linked to their innovative behaviour, an interesting data source is available at a firm level. The *Encuesta de Innovación Tecnológica* (hereafter TIS: Technological Innovation Survey) contains much information about the strategies and performance of business innovation between 1998 and 2000[1]. This survey asks firms which sources they have used in their innovation process. The sources of innovation include the collaboration agreement with other firms and public institutions during three-years period.

The TIS began in 1994 and is performed every two years. The survey used in this paper was performed in 2000. In this fourth edition, the datebase contained data on

---

[1] In coordination with the OECD, the Statistical Office of the European Union (EUROSTAT) has carried out several studies to collect data on innovation in its member States. In 1993 it carried out the Community Innovation Survey (CIS), which used a harmonised questionnaire to collect data on business innovation in the European Community. The method was based on that of the OECD's Oslo Manual. In 1997 a new Community survey was carried out. Data from the first Spanish and European surveys concerned the years 1992 and 1993 and were made public in 1997. This analysis is of little use, therefore, for business or public-policy decision making.

11,887 firms. These data were for a stratified random sample whose strata were defined by a combination of the branch variables of activity, size (number of employees) and R&D activity. The method for collecting the information was a mixed system that included questionnaires and interviews backed up by phone calls. For countries such as Spain, which have a high level of development and limited R&D resources, is essential to know the characteristics of the innovation process of its firms. Greater knowledge of the sources of innovation provides important information for designing technological and scientific policies and this data source is interesting because it provides direct qualitative indicators of innovation.

The TIS questionnaire asks questions about the nature and sources of innovations carried out by Spanish firms and about their performance in various innovative fields. For the years between 1998 and 2000, the firms indicated whether they carried out product and process innovations (radical or incremental innovations). The questionnaire paid special attention to conventional sources of innovation (R&D activities, R&D expenditure, patent registration), external sources of innovation (the purchase of external services related to innovative activity, the acquisition of incorporated technology and technical assistance) and cooperation agreements with others agents.

In manufacturing and services, 11,015 firms were interviewed, 4,150 of which carried out at least one innovation between 1998 and 2000. The survey defines three types of innovations depending on the intensity and nature of the change:

- *Total product innovations* refer to the development of an entirely new product based on new technology or new uses of existing technology;
- *Progressive product innovations* refer to marginal improvements to the components or subsystems of a product;
- *Process innovations* refer to the adoption of new or appreciably improved methods of production.

Of the 4,150 innovative firms, 2,697 carried out at least one product or process innovation (1,523 firms carried out radical product innovation and 1,174 firms carried out incremental product innovation), 2,738 firms carried out at least one process innovation, and 1,616 firms carried out both product and process innovations.

The development of these technological innovations is related to R&D activities, industrial design, manufacturing equipment and manufacturing engineering, the commercialisation of new products and the acquisition of material and immaterial technologies. A firm's R&D activities are developed at their own facilities or via agreements with other agents[2]. Internal expenses of R&D include current and capital expenses linked to research and technological development activities within the firm as well as expenses incurred outside the firm in support of their R&D activities. External expenses of R&D, on the other hand, include contracts for the acquisition of R&D services made by other firms, universities or public research centres.

The main features of innovation-related activities are given in Table 1. In accordance with the OECD classification for the technological intensity of industries, the firms are divided into four groups according to the sector (manufacturing and services) and to the technological intensity (high-technology sectors and medium and low-technology sectors). Here we can see that the innovative processes and performances of manufacturing industries and service industries are different. Also different are the innovative processes and performances of industries with a low-medium technological level and industries with a high technological level.

Several stylised facts emerge from Table 1. Between 1998 and 2000, firms in high-technology industries carried out intensive innovative activity aimed at totally or partially incorporating related innovations into their products or services. In high-technology manufacturing industries, 46.2% of the firms carried out at least eleven radical product innovations and 29.9% of the firms carried out at least one incremental product innovation. In high-technology services, 57.8% of the firms carried out at least one radical product innovation and 21.0% carried out at least one incremental product innovation. The innovative activity of the industries of average and below-average technological intensity was much more moderate and more orientated to partial changes in the products or services.

Table 1
Main indicators of innovation by sectors

	High-tech manufacturing	Other manufacturing	High-tech services	Other services
Product innovations	313 (76.2)	1583 (65.3)	289 (78.7)	512 (54.1)
Radical	190 (46.2)	865 (35.7)	212 (57.8)	256 (27.0)
Incremental	123 (29.9)	718 (29.6)	77 (21.0)	256 (27.0)
Process Innovation	237 (57.7)	1668 (68.8)	195 (53.1)	638 (67.4)
Product and process innovation	177 (43.1)	998 (41.1)	149 (40.6)	292 (30.8)
Innovative activities in progress	302 (73.5)	1328 (54.7)	273 (74.4)	441 (46.6)
Frustrated innovative activities*	144 (35.0)	561 (23.1)	84 (22.9)	110 (11.6)
Internal R&D activities*	310 (75.4)	1176 (48.5)	264 (71.9)	209 (22.1)
The company has acquired external services of R&D*	123 (29.9)	517 (21.3)	68 (18.5)	169 (17.8)
Cooperation with other companies or institutions in R&D activities*	130 (31.6)	401 (16.5)	131 (35.7)	117 (12.4)
The company has requested a patent*	122 (29.7)	402 (16.6)	66 (18.0)	33 (3.5)
Has the company some current patent at the end of 2000	152 (37.0)	533 (22.0)	64 (17.4)	54 (5.7)
Number of firms	411	2426	367	947

Notes: * during the period 1998-2000. Rates in brackets.
Source: Survey of Technological Innovation, INE

However, medium- and low-technology industries were more active in process innovations. Between 1998 and 2000, 68.8% of medium- and low-technology manufacturing firms carried out at least one innovation process, which was higher than the 57.7% for high-technology firms. We also found this pattern among services: 67.4% of medium- and low-technology service industries carried out at least one process innovation, against only 53.1% in the high-technology service industries.

---

[2] The cooperation in R&D includes R&D projects joined together with other institutions and the own projects linked officially to the projects of other institutions. A special form of cooperation in R&D consists of the participation in national and international programs destined to encourage research.

The differences in the intensity and nature of the innovations carried out by Spanish firms reflect their different innovating strategies. Firms operating in markets with intense competition, fast technological change and a short product life cycle, are forced to continuously introduce new technological knowledge and product or process innovations. On the other hand, firms operating in mature markets where prices are a determinant of market quota dedicate more resources to making organizational and technological changes that reduce distribution and production costs. We must highlight also an important group of firms that make process and product innovations simultaneously. In fact, between 30% and 40% of innovating firms make as many process innovations as product innovations, both in the manufacturing industry as in the high- or low- technology services industry.

There are great differences in the origins of business innovation, either for the accomplishment in the firm or in firms of the same group of R&D activities, in the external acquisition of services related to innovation and in cooperation with other firms or public institutions to develop innovations, and these depend on the technological intensity of the industry. In high-technology industries, the innovative firms that develop internal R&D activities and cooperate with firms, universities and public research institutions predominate. On the other hand, the internal development of R&D activities and external cooperation is less frequent in other industries, and especially in the service industries.

Finally, patenting, as an instrument for protecting innovations, is not very deep-rooted among Spanish firms. This is a critical aspect of the innovation process because firms need to be able to appropriate the results of their innovations to create innovation incentives (Cohen et al., 2002). The level of appropriability is lower and unpatented products and processes are more common among Spanish firms. This poor tradition in patenting the results of one's innovations is particularly apparent in services and especially in low-technology services. Between 1998 and 2000, only 3.5% of these firms requested a patent and by the end of 2000 only 5.7% had a registered patent.

3. Cooperation and innovation process

The innovation process is not created only by the individual actions of firms. Firms' relationships with other agents involved in the innovation system are an important dimension of business innovation. About the determinants of cooperation agreements with other firms, Bayona et al. (2001) consider the following hypothesis:

- Cooperative R&D agreements between firms are more frequent in sectors with a high technological complexity than in sectors with a low technological complexity.
- Those firms which consider that undertaking innovation activity carries very high risks are more likely to enter into cooperative R&D agreements than firms which do not hold this view.
- Firms which consider that they lack finance to carry out innovation activities infra-mural will be more willing to establish cooperative relationships in this area.
- Firms which seek to improve their knowledge of the market and their access to the same through extending their range of products or increasing their domestic or foreign market share will have a higher propensity for cooperative R&D.

Most innovation activities are characterized by a significant division of functions between the agents involved (Fritsch and Lukas, 1999). Moreover, in these activities spillovers are very important. At the sectorial level, some spillovers are intraindustrial and others are interindustrial. Also, the local size of spillovers is extremely important in certain industries. Some empirical studies show that innovation activities tend to be clustered in space (Audretsch and Feldman, 1996; Aoki and Takizama, 2002) but there are different types of knowledge flows. The research results are published in journals or registered in patents and knowledge flows use the market mechanism or the knowledge spillovers. When knowledge flows through the market mechanisms, the effects of spillovers tend to be more concentred in space (Audretsch and

Stephan, 1996), but when knowledge spillovers are predominant the spatial effect is smaller.

We shall now pay special attention to the external sources used by innovative firms during their innovation process. The TIS contains interesting information about cooperative strategies with other agents and institutions between 1998 and 2000.

Table 2
Share of firms with a cooperative relationship in R&D activities by industries

	All firms		High technology manufacturing		Other manufacturing		High technology services		Other services	
	Firms	%	Firms	%	Firms	%	Firms	%	Firms	%
Total firms with a cooperative relationship in R&D during 1998-2000, COOP	819	19.0	130	31.6	401	16.5	131	35.7	117	12.4
Cooperative partners										
Other firms of the group, COOP1	383	8.9	63	15.3	197	8.1	56	15.3	50	5.3
Customers, COOP2	351	8.1	62	15.1	157	6.5	81	22.1	37	3.9
Suppliers of component, equipment and software, COOP3	467	10.8	65	15.8	221	9.1	82	22.3	72	7.6
Competitors and others firms, COOP4	294	6.8	51	12.4	134	5.5	59	16.1	32	3.4
Experts and consultancy firms, COOP5	380	8.8	53	12.9	178	7.3	69	18.8	62	6.5
R&D firms or laboratories, COOP6	315	7.3	60	14.6	157	6.5	54	14.7	30	3.2
Universities or centres of higher education, COOP7	503	11.7	93	22.6	237	9.8	101	27.5	48	5.1
Public and non-profit research organisations, COOP8	465	10.8	83	20.2	237	9.8	85	23.2	34	3.6
Number of firms	4.312	---	411	---	2426	---	367	---	947	---

Sources: Survey of Technological Innovation, 2000. INE

In these years, of the 4,150 innovative firms in our sample only 819 had a formal cooperation agreement with other firms or institutions. About 19% of Spanish innovative firms had external channels of collaboration (2000) on R&D activities. Collaboration with external agents is different depending on the industry to which the firm belongs. In high-technology services, 35.7% of innovative firms cooperated with other agents and in the high-technology manufacturing the cooperation rate was 31.6%. In the other manufacturing and services industries, the cooperation agreements are quite smaller.

Table 2 reveals several interesting facts. Firstly, cooperation agreements with other firms or public institutions are still rare among Spanish innovative firms. *Intramuros* R&D activities and external R&D services related to innovation activities are still the main sources for the innovative process of the Spanish firm. However, it appears that collaboration with other agents is beginning to become a part of the innovation strategies of certain firms, especially those that operate in high-technology markets[3]. About 31.6% of the high technology manufacturing firms and 35.7% of high technology service firms set up relations for technological cooperation with other firms or public institutions between 1998 and 2000. In these firms agreements with universities and public research organisations predominate over collaboration with other firms, customers or suppliers. There is less vertical cooperation (customers and suppliers) and horizontal cooperation (competitors) than in other European countries.

Firms at the low- and medium-technology level cooperate with external agents less. Relationships between these firms and universities and public research organizations are very scarce: 9.8% of the manufacturing firms and 5.1% of the services firms established cooperation agreements with universities, and 9.8% of manufacturing firms and 3.6% of service firms cooperated with public research organizations.

4. The Model

Cooperation agreements of innovative firms with other firms or public institutions are an important source for the innovative process. In this section we use a logistic model to determine the profile of the Spanish innovative firms that use formal

[3] The R&D cooperation agreements with customers and suppliers are an example of the importance of those new innovation strategies (Gemünden et al., 1992; Mason and Wagner, 1999). By this kind of collaboration firms can develop new products that can be tested by their customers and, at the same time, they can test new products of their suppliers and work together to improve their quality.

agreements with other agents as a key element of its innovative strategy. The formal collaboration with other agents (e.g. customers, suppliers, competitors, universities and public research centres) is an important source for a firm's innovative output. Spanish firms carry out few formal agreements with others agents in the innovative fields, but external cooperation is increasing between the more innovative industries.

4.1 The determinants of cooperation

Collaboration with external agents is included in our model through a dichotomous variable whose value is 1 when the firm cooperates with other agents and null otherwise. We consider five types of firms: firms that cooperate with other firms in the same group; firms that carry out vertical cooperation with customers and suppliers, firms that carry out horizontal cooperation with their competitors, firms that have cooperation agreements with universities, and firms that cooperate with public research centres.

In our logistic model we define the dependent binary variable $y_n=1$ if the firms cooperate with the agent "j" and 0 otherwise. The collaborative strategies of the innovative firm can be modelled by four different vectors of explanatory variables: x_1, x_2, x_3 and x_4. These sets of explanatory variables define the profile of the innovative Spanish firms. Vector x_1 includes three explanatory variables related to the firm's industrial characteristics. Vector x_2 includes six variables related to the firm's individual characteristics. Vector x_3 includes four variables that show the innovation sources of the firm. Finally, vector x_4 includes three variables that represent access to public funds for the innovative activities. The econometric specification is the following:

$$y_{j,i} = X_{1,j,i}\,\beta_{j,1} + X_{2,j,i}\,\beta_{j,2} + X_{3,j,i}\,\beta_{j,3} + X_{4,j,i}\,\beta_{j,4} + \varepsilon_{j,,i}$$

where $X_{1,j,i}$, $X_{2,j,i}$, $X_{3,j,i}$ and $X_{4,j,i}$ are the matrices of explanatory variables of dimension k_0, k_1, k_2, k_3 and k_4; $\beta_{j,1}$, $\beta_{j,2}$, $\beta_{j,3}$ *and* $\beta_{j,4}$ are the vectors of the parameters, and $\varepsilon_{j,i}$ is the vector of stochastic error term.

Additionally, we analyse the cooperation behaviour with Spanish and foreign universities using five different vectors of explanatory variables: x_1, x_2, x_3, x_4 and x_5. Vector x_1 includes two explanatory variables related to the firm's industrial characteristics. Vector x_2 includes five variables related to the firm's individual characteristics. Vector x_3 includes four variables that show the innovation sources of the firm. Vector x_4 includes three variables that show the origin of the public funds for the innovative activities. Finally, vector x_5 shows the cooperation with other firms and public institutions. The econometric specification is the following:

$$y_{j,i} = X_{1,j,i}\ \beta_{j,1} + X_{2,j,i}\ \beta_{j,2} + X_{3,j,i}\ \beta_{j,3} + X_{4,j,i}\ \beta_{j,4} + X_{5,j,i}\ \beta_{j,5} + \varepsilon_{j,,i}$$

4.2 Explanatory variables

We have divided the independent variables into five categories: industry variables, firm variables, innovation sources, public founds and cooperation. Industry variables involve characteristics shared by all firms in the same industry. Firm variables involve specific characteristics of each firm, such as size, sales or patent registration. Innovation sources involve whether innovation activity came from internal or external R&D activities and whether the firm acquires machinery or immaterial technology. Public funds involves the origin of public founds used for innovative activities. Finally, cooperation involves cooperation relations with other firms (customers and suppliers, competitors or firms of the same group) or public research centres.

Table 3
Definitions of the independent variables

Industry variables	
MANUFAC-HT	Dichotomic variable: 1 if the firm is in the high-tech manufacturing industries, 0 otherwise
SERV-HT	Dichotomic variable: 1 if the firm is in the high-tech service industries, 0 otherwise
AVERAGE	Mean expenditure on innovation by firm in the SIC-2 digits sector
Firm variables	
WORKERS	Categorical variable: 1 if firm employees in 2000 less than First Quartile; 2, if firm employees in 2000 less than Median; 3 if firm employees in 2000 less than Third Quartile; 4 if firm employees in 2000 more than Third Quartile
SALES	Categorical variable: 1 if firm sales in 2000 less than First Quartile; 2, if firm sales in 2000 less than Median; 3 if firm sales in 2000 less than Third Quartile; 4 if firm sales in 2000 more than Third Quartile
R&D INTENSITY	Categorical variable: 1 if firm innovation cost in 2000 less than First Quartile; 2, if firm innovation cost in 2000 less than Median; 3 if firm innovation cost in 2000 less than Third Quartile; 4 if firm innovation cost in 2000 more than Third Quartile
GROUP	Categorical variable: 0 if the firm does not belong to a group; 1 if the firm belongs to a group located in Spain; 2 if the firm belongs to a group located in another country of the EU; 3 if the firm belongs to a group located outside EU
PROD&PROC	Dichotomic variable: 1 if the firm made both product and process innovations in 1998-2000; 0 otherwise
PATENTS	Dichotomic variable: 1 if the firm had some patent registered by the end of 2000; 0 otherwise
Innovation sources	
R&DIN	Dichotomic variable: 1 if the firm carried out internal R&D activities related to innovations made in 1998-2000; 0 otherwise
R&DEX	Dichotomic variable: 1 if the firm acquired external R&D services depending on innovative activities carried out in 1998-2000; 0 otherwise
EQUIP	Dichotomic variable: 1 if the firm acquired machinery or equipment for doing innovative activities in 1998-2000; 0 otherwise
TECNO	Dichotomic variable: 1 if the firm acquired immaterial technology (use of patents, licenses, know-how, etc.) used for innovative activities carried out in 1988-2000; 0 otherwise
Public founds	
FOUND1	Dichotomic variable: 2 if the firm accessed public resources of the local or autonomous administrations for innovative activities in 1998-2000; 1 otherwise
FOUND2	Dichotomic variable: 2 if the firm accessed public resources of the state administration for innovative activities in 1998-2000; 1 otherwise
FOUND3	Dichotomic variable: 2 if the firm accessed public resources of the EU for innovative activities in 1998-2000; 1 otherwise
Cooperation	
COOP1	Dichotomic variable: 1 if the firm cooperated with other firms of the same group in 1998-2000; 0 otherwise
COOP23	Dichotomic variable: 1 if the firm cooperated with clients and suppliers in 1998-2000; 0 otherwise
COOP4	Dichotomic variable: 1 if the firm cooperated with competitors in 1998-2000; 0 otherwise
COOP8	Dichotomic variable: 1 if the firm cooperated with public research centres in 1998-2000; 0 otherwise

4.3 The geographical dimension of university-firm cooperation

Researchers discuss their achievements in forums, workshops and congresses. The publication of results in working papers and scientific journals allows for an open debate between researchers working in a particular area and access (for agents interested in the scientific and technological development) to the basic sources of the knowledge. Quotations and bibliographical references in scientific journals indicate that beneficiaries from one research field developed in one university are often a long way from where the basic knowledge was generated. Also, the increasing specialisation of technological development and the universities themselves forces innovative firms to cooperate with the research centres of other countries.

Between 1998 and 2000, Spanish firms registered 453 stable collaboration agreements with Spanish universities, 102 agreements with other universities of the European Union and 52 agreements with universities in other countries. It is important to note that few collaboration agreements (only 10) were carried out by Spanish firms with U.S. institutions.

Public support can take on several forms, including government subsidies for projects funded by private firms, the supply of laboratory services, incentives for creating joint ventures for research, and collaborative research with the universities. The end result is an increasing interest by firms in carrying out more collaborative research, especially in formal research collaboration agreements between firm and universities (Link et al., 2003).

5. Results

In this section, we present a profile of the innovative firms that cooperate with other firms, universities or public research centres. Firstly (Table 4), we show the results of the logit model about the propensity to cooperate with other firms. Secondly (Table 5), we show descriptive statistics about cooperative relationship in R&D activities with universities. And thirdly (Table 6), we show the cooperation with Spanish and foreign universities.

If we look at Table 4, there it is shown that specific industrial characteristics affect the propensity of innovative firms to collaborate with other agents in their innovative activity. Generally speaking, firms from industries where the incumbent firms spend large amounts of money on R&D activities tend to collaborate with other external agents. Also, firms operating in manufacturing and (mainly) service industries, with a high-technological level are more likely to enter into formal cooperation agreements with external agents. Those results are quite similar to other obtained by Bayona et al. (2001, 2003), García (1995), Hagedoorn (1993), Robertson and Gatignon (1998) and Wang (1994).

The individual characteristics of innovative firms show a more ambiguous result than the one observed for the industry determinants. For example, firm size (measured by the number of employees) is positively related to cooperation strategies with other firms of the same group and with public research centres, but is not statistically significant for cooperation with customers, suppliers, competitors or universities. If we consider all partners, the number of employees affects positively the cooperation agreements. However, when firm size is measured by volume of sales, the results are very different: a higher size affects positively cooperation with all partners, customers and suppliers, competitors and universities, and a smaller size affects negatively cooperation with group firms. Those mixed results are in line with others obtained by other researchers. For instance, Bayona et al. (2003, 2001), Cassiman and Veugelers (1998), Colombo and Garrone (1998) and Hagedoorn and Schakenraad (1994) find a positive influence of size over cooperation, while Pisano (1990) and Robertson and Gatignon (1998) did not find any relationship.

Our results show, as well how firm size affects external cooperation, that an innovative firm that belong to a corporate group carries out product and process innovations simultaneously, has at least one patent registered and enters into more formal cooperation agreements with other agents.

If we consider other characteristics, such as innovation sources, our results show that the propensity to cooperate with other firms depends positively on the firm's internal R&D activities and the acquisition of external R&D services, but not on the acquisition of machinery or immaterial technology. Specifically, firm’s internal R&D

activities are necessary for cooperate on R&D activities with external agents (Bayona et al., 2003). Finally, the effect on cooperation of public funding, especially from the European Union, is clearly positive.

The incidence of the variables that act over cooperation decisions is not the same for all kind of cooperation partners. From table 4 we can conclude that cooperation with other firms and public institutions could be explained also with other variables not included here. This is true for all kinds of cooperation, but especially for group firms and for competitors.

Table 4
Propensity to cooperate with other firms and public institutions
Logit model

	All partners	Group Firms	Customers and suppliers	Competitors	Universities	Public Centres
Industry variables						
MANUFAC-HT	0.538 (0.146)*	0.356 (0.181)**	0.248 (0.173)	0.409 (0.199)**	0.546 (0.168)*	0.383 (0.175)**
SERV-HT	0.826 (0.158)*	0.596 (0.195)*	0.914 (0.173)*	0.844 (0.197)*	1.037 (0.179)*	0.741 (0.186)*
AVERAGE	0.583 (0.176)*	0.401 (0.196)**	0.498 (0.189)*	0.523 (0.197)*	0.432 (0.193)**	0.541 (0.196)*
Firm variables						
WORKERS	0.156 (0.080)**	0.190 (0.109)***	0.083 (0.096)	0.081 (0.121)	0.149 (0.102)	0.264 (0.108)**
SALES	0.181 (0.084)**	-0.005 (0.114)	0.116 (0.102)***	0.154 (0.129)***	0.189 (0.108)***	0.061 (0.112)
R&D INTENSITY	-0.002 (0.055)	0.098 (0.074)	0.137 (0.067)**	-0.066 (0.085)	-0.030 (0.070)	-0.093 (0.074)
GROUP	0.472 (0.105)*	1.326 (0.146)*	0.357 (0.124)*	0.432 (0.154)*	0.511 (0.130)*	0.372 (0.136)*
PROD&PROC	0.241 (0.100)**	0.486 (0.130)*	0.324 (0.117)*	0.318 (0.146)**	0.213 (0.122)***	0.273 (0.128)**
PATENTS	0.212 (0.114)***	0.178 (0.140)	0.252 (0.128)**	0.396 (0.151)*	0.494 (0.128)*	0.305 (0.135)**
Innovation sources						
R&DIN	0.604 (0.111)*	0.561 (0.155)*	0.633 (0.138)*	0.849 (0.186)*	1.015 (0.155)*	1.282 (0.170)*
R&DEX	1.295 (0.103)*	1.100 (0.129)*	0.994 (0.119)*	0.793 (0.148)*	1.182 (0.123)*	1.138 (0.129)*
EQUIP	-0.171 (0.105)	-0.130 (0.134)	0.027 (0.123)	-0.027 (0.149)	-0.074 (0.126)	-0.149 (0.131)
TECNO	0.082 (0.112)	0.013 (0.142)	0.154 (0.127)	0.022 (0.158)	-0.011 (0.136)	-0.166 (0.144)
Public funds						
FUND1	0.446 (0.112)*	-0.074 (0.152)	0.211 (0.131)***	-0.096 (0.165)	0.355 (0.134)*	0.640 (0.134)*
FUND2	0.725 (0.117)*	0.340 (0.154)**	0.486 (0.132)*	0.455 (0.168)*	0.686 (0.135)*	0.956 (0.138)*
FUND3	1.345 (0.159)*	0.905 (0.184)*	1.471 (0.160)*	1.415 (0.181)*	1.179 (0.169)*	1.419 (0.168)*
Constant	-9.641 (0.408)*	-8.296 (0.470)*	-9.314 (0.437)*	-8.875 (0.518)*	-10.629 (0.487)*	-10.783 (0.508)*
Model summary						
Chi-square for covariates	1110.43*	589.37*	774.86*	424.55*	907.65*	896.99*
Pseudo R^2	0.277	0.238	0.253	0.209	0.305	0.320
Number of cases	4,150	4,150	4,150	4,150	4,150	4,150

Notes: Standard error in brackets; (*) significance at 1%, (**) significance at 5% and (***) significance at 10%.

If we go further on cooperation analysis, we can deep into how is the cooperation with universities. Table 5 shows as cooperation patterns differs according industries and technological levels. That is, high technology firms (both manufacturing and services) shows a higher degree of cooperation with universities, but these cooperative behaviour is mainly with Spanish universities: 453 of the 503 firms that had cooperative relationship in R&D activities with universities had those relationships with Spanish universities (90,1% of them).

Table 5
Share of firms with cooperative relationship in R&D activities with universities

	All firms		High technology manufacturing		Other manufacturing		High technology services		Other services	
Country of partners	Firms	%	Firms	%	Firms	%	Firms	%	Firms	%
Universities or centres of higher education, COOP7	503	11.7	93	22.6	237	9.8	101	27.5	48	5.1
Spain, COOP71	453	10.5	89	21.7	211	8.7	89	24.3	42	4.4
E/EFTA countries,COP72U	102	2.4	17	4.1	40	1.6	34	9.3	1	0.1
Countries candidate to EU, COOP73	6	0.1	0	0.0	2	0.1	4	1.1	0	0.0
USA, COOP74	10	0.2	2	0.5	2	0.1	6	1.6	0	0.0
Japan, COOP75	2	0.0	0	0.0	1	0.0	1	0.3	0	0.0
Other countries, COOP76	34	0.8	2	0.5	15	0.6	12	3.3	5	0.5
Total firms	4,312	---	411	---	2,426	---	367	---	947	---

Sources: Survey of Technological Innovation, 2000. INE

Table 6 shows the determinants of cooperation of individual firms with universities. Generally speaking, these are fairly similar for all partners. However, we consider that cooperation is not the same with Spanish universities as it is with non-Spanish universities. It seems that cooperation with Spanish universities is linked to a higher degree of innovation activities. For example, firms in the high-tech manufacturing industries are positively influenced to cooperate with Spanish universities, but this variable is not significant for cooperation with foreign universities. There are also firm characteristics that act over cooperation: if the firm belongs to a group, this enhances cooperation with Spanish universities, and diminishes cooperation with foreign universities. Also, the internal R&D activities and the acquisition of external R&D services favour cooperation with Spanish universities.

Table 6
Cooperation with Spanish and foreign universities
Logit model

	Spanish universities		Foreign universities	
	Model 1	Model 2	Model 1	Model 2
Industry variables				
MANUFAC-HT	0.681 (0.166)*	0.720 (0.215)*	0.339 (0.305)	0.164 (0.350)
SERV-HT	1.170 (0.174)*	0.914 (0.222)*	1.370 (0.259)*	1.195 (0.325)*
Firm variables				
WORKERS	0.288 (0.079)*	0.287 (0.097)*	0.377 (0.145)*	0.402 (0.176)**
R&D INTENSITY	-0.045 (0.072)	-0.108 (0.090)	0.048 (0.134)	0.091 (0.160)
GROUP	0.617 (0.132)*	0.329 (0.170)***	0.376 (0.230)	-0.551 (0.284)***
PROD&PROC	0.207 (0.126)	0.040 (0.160)	0.173 (0.223)	-0.051 (0.262)
PATENTS	0.618 (0.130)*	0.671 (0.168)*	0.424 (0.223)***	0.264 (0.258)
Innovation sources				
R&DIN	1.089 (0.165)*	0.730 (0.199)*	1.288 (0.350)*	0.284 (0.416)
R&DEX	1.172 (0.126)*	0.736 (0.162)*	0.499 (0.226)**	-0.199 (0.260)
EQUIP	-0.087 (0.130)	-0.147 (0.164)	-0.028 (0.223)	-0.052 (0.265)
TECNO	0.003 (0.139)	0.043 (0.177)	-0.077 (0.236)	0.064 (0.275)
Public funds				
FUND1	0.408 (0.136)*	0.222 (0.177)	0.163 (0.233)	0.071 (0.274)
FUND2	0.784 (0.139)*	0.391 (0.185)**	0.659 (0.251)*	0.050 (0.300)
FUND3	0.986 (0.173)*	-0.141 (0.237)	2.040 (0.230)*	1.348 (0.278)*
Cooperation				
COOP1		0.881 (0.218)*		0.822 (0.338)**
COOP23		1.776 (0.200)*		1.051 (0.433)**
COOP4		-0.150 (0.248)		1.055 (0.308)*
COOP8		2.033 (0.194)*		2.577 (0.460)*
Constant	-10.289 (0.486)*	-7.967 (0.590)*	-12.145 (0.892)*	-9.927 (1.059)*
Model summary				
Chi-square for covariates	811.27	1449.01	360.85	631.24
Significance Chi-square	0.000	0.000	0.000	0.000
Pseudo R^2	0.293	0.523	0.322	0.563
Number of cases	4,150	4,150	4,150	4,150

Notes: Standard error in brackets; (*) significance at 1%, (**) significance at 5% and (***) significance at 10%.

The cooperation agreements of firms also can help to explain cooperation with universities. That is, for instance, the cooperation with competitors or with public research centres increases cooperation with foreign universities.

Our preliminary results are not clear, but they show that cooperation with Spanish universities is greater. The main exceptions may be the firms that receive public resources from the European Union: these firms show a greater level of cooperation with foreign universities. At the same time, founds coming from regional and national level show a bigger influence of cooperation with Spanish universities than with foreign universities.

6. Conclusions

Our results show that firm's cooperation activities are closely linked to the characteristics of the industry and the firm as well as to the origin of public funds for R&D activities. That is, a firm's cooperation behaviour can be explained from certain characteristics of the firm's innovative activity. However, from a public policies point of view, we believe that public administrations have a key role in promoting cooperation and innovation activities by offering public funds to innovative firms. This appears to be one of the most effective ways of stimulating innovation.

Our results also highlight the fact that cooperation with Spanish universities is more intense than cooperation with other universities. This limits a firm's competitive capacity because it is prevented from cooperating with major universities and acquiring potential benefits from this cooperation. This is partially due to the origin of the innovation: when the funding is domestic the cooperation is also domestic and when the funding is from the European Union, the cooperation may be more international. This means that firms must follow a strategy for joining EU research programs in order to benefit from participating in superior innovation networks, where the expectations for innovation are also greater.

References

Aoki, M. and Takizama, H. (2002): “Information, Incentives and Option Value: The Silicon Valley Model”, *Journal of Comparative Economics* **30**: 759-786.

Audretsch, D. and Feldman, M.P. (1996): "R&D Spillovers and the Geography of Innovation and Production" *American Economic Review* **86 (3)**: 630-640.

Audretsch, D. and Stephan, P.E. (1996): ”Company–scientist locational links: the case of biotechnology”, *American Economic Review* **86**: 641–652.

Bayona, C.; García-Marco, T. and Huerta, E. (2003): “¿Cooperar en I+D? Con quién y para qué”, *Revista de Economía Aplicada* **31**: 103-134.

Bayona, C.; García-Marco, T. and Huerta, E. (2001): “Firms’ motivations for cooperative R&D: an empirical analysis of Spanish firms”, *Research Policy* **30**: 1289-1307.

Branscomb, L.M.; Kodama, F. and Florida, R. (1999): *Industrializing Knowledge. University-Industry Linkages in Japan and the United States*, Massachussetts: The MIT Press.

Callejón, M. (dir.) (2001): *Tecnologia i Política Industrial*, Barcelona: Associació d’Amics de la UPC.

Cassiman, B. and Veugelers, R. (1998): “R&D cooperation and spillovers: some empirical evidence”, *Working Paper* **328** (Department of Economics and Business, Universitat Pompeu Fabra).

Cohen, W.M. ; Goto, A.; Nagata, A.; Nelson, R.R. and Walsh, J.P. (2002): “R&D spillovers, patents and the incentives to innovate in Japan and the United States”, *Research Policy* **31**: 1349-1367.

Colombo, M. and Garrone, P. (1998): “A simultaneous equations model of technological agreements and infra-mural R&D”, in M. Colombo (ed.), *The Changing Boundaries of the Firm*, London: Routledge.

COTEC (2002): *Informe COTEC 2002. Tecnología e Innovación en España*, Madrid: COTEC.

Edquist, C. (ed.) (1997): *Systems of Innovation. Technologies, Institutions and Organizations*, London: Pinter.

Etzkowitz, H., Webster, A., Gebhardt, Ch. and Cantisano, B.R. (2000): “The future of the university and the university of the future: evolution of ivory tower to entrepreneurial paradigm”, *Research Policy* **29**: 313-330.

Etzkowitz, H. and Leydesdorff, L. (1997): *Universities and the Global Knowledge Economy. A Triple Helix of University-Industry-Government Relations*, London: Pinter.

Freeman, C. (1998): “The economics of technical change”, in D. Archibugi, and J. Michie (eds.), *Trade, Growth and Technical Change*, Cambridge: Cambridge University Press.

Fritsch, M. and Lukas, R. (1999): “Innovation, Cooperation, and the Region” in D. Audretsch and R. Thurik (eds.), *Innovation, Industry Evolution and Employment*, Cambridge: Cambridge University Press, 157-181.

García, E. (1995): “Acuerdos de cooperación en I+D en España: un análisis empírico”, *Revista Asturiana de Economía* **4**: 195-207.

Gemünden, H.G.; Heydebreck, P. and Herden, R. (1992): “Technological interweavement: a means of achieving innovation success”, *R&D Management* **22 (4)**: 359-375.

Geroski, P. (1990): “Innovation, technological opportunity, and market structure”, *Oxford Economic Papers* **42**: 586–602.
Griliches, Z. (1979): “Issues in assessing the contribution of R&D to productivity growth”, *Bell Journal of Economics* **10**: 92–116.
Hagedoorn, J. (1993): “Understanding the rationale of strategic technology partnering: interorganizational modes of cooperation and sectoral differences”, *Strategic Management Journal* **14**: 371-385.
Hagedoorn, J. and Schakenraad, J. (1994): “The effect of strategic technology alliances on company performance”, *Strategic Management Journal* **15**: 291-309.
Jaffe, A.B. (1989): “Real effects of academic research”, *American Economic Review* **79 (5)**: 957–970.
Karlsson, C. and Zjang, W. (2001): “The role of universities in regional development. Endogenous human capital and growth in a two-region model”, *Annals of Regional Science* **35**: 179-197.
Landau, R. (1991): “How competitiveness can be achieved: fostering economic growth and productivity” in *Technology and economics,* Washington, D.C.: National Academy Press.
Link, A.; Scott, J.T. and Siegel, D.S. (2003): “The economics of intellectual property at universities: an overview of the special issue”, *International Journal of Industrial Organization* **21**: 1217-1225.
Lundvall, B.-Å., (Ed.) (1992): *National Systems of Innovation. Towards a Theory of Innovation and Interactive Learning*. London: Pinter.
Mason, G. and Wagner, K. (1999): “Knowledge transfer and innovation in Germany and Britain: “Intermediate institution” models of knowledge transfer under strain?”, *Industry and Innovation* **6 (1)**: 85-110.
Meyer-Krahmer, F. (1990): “The Determinants of Investment in R&D and the Role of Public Policies: An Evaluation”. In Deiaco, E.; Hornell, E. and Vickery, G. (eds.), *Technology and investment: Crucial issues for the 1990s*, London: Pinter.
Pisano, G. (1990): “The R&D boundaries of the firm: an empirical analysis”, *Administrative Science Quarterly* **35**: 153-176.
Poyago-Theotoky, J., Beath, J. and Siegel, D. (2002): “Universities and Fundamental Research: reflections on the Growth of University-Industry Partnerships”, *Oxford Review of Economic Policy* **18 (1)**: 10-21.
Robertson, T. and Gatignon, H. (1998): “Technology development mode: a transaction cost conceptualization”, *Strategic Management Journal* **19**: 515-531.
Rosenberg, N. and Nelson, R.R. (1994): “American universities and technical advance in industry”, *Research Policy* **23**: 323-348.
Wang, J.C. (1994): “Cooperative research in a newly industrialized country: Taiwan”, *Research Policy* **23**: 697-711.