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# R&D cooperation between Spanish firms and scientific partners: what is the role of tertiary education?

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XARXA DE REFERÈNCIA EN ECONOMIA APLICADA

# *R&D cooperation between Spanish firms and scientific partners: what is the role of tertiary education?*

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**Abstract**

*This paper explores the factors that determine firm's R&D cooperation with different partners, paying special attention on the role of tertiary education (degree and PhDs level) in facilitating the connection between the firms and the to scientific bodies (technology centres, public research centres and universities). Here, we attempt to answer two questions. First, are innovative firms that carry out internal and external R&D activities more likely to cooperate on R&D projects with other partners? Second, do Spanish innovative firms with a high participation of researchers with degrees or PhDs tend to cooperate more with scientific partners? To answer both questions we apply a three-dimensional approach on a firm level Panel Data with a sample of 4.998 manufacturing and services Spanish firms. First, we run a complementary test between external R&D acquisition and skilled research workers and find that firms which carry out external R&D activities obtain a greater return on R&D cooperation when they have skilled workers in R&D, especially in high-tech manufactures and KIS services. Second, we carry out a 2-step tobit model to estimate, in the first stage, the determinants that explain whether Spanish innovative firms cooperate or not; and in the second stage the factors that affect the choice of partners. And third, we apply an ordered probit model to test the marginal effects of explanatory variables on the different partners. Here we contrast some of the most interesting empirical hypotheses of previous studies, and which emphasize the role of employees with degrees and PhDs in facilitating cooperative R&D between firms and scientific partners.*

**JEL classification: O31, O33, O38**

**Key words: Determinants R&D cooperation, industry-university flows, PhD research workers**

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## 1. Introduction

In recent years the determinants and effects of R&D cooperation have become an important research topic, and the empirical literature has increasingly focused on R&D cooperation between innovative firms and universities (Hervas-Oliver et al, 2011; Barge-Gil, 2010; Segarra & Arauzo, 2008; Belderbos et al, 2004; Becker & Dietz, 2004, Laursen & Salter, 2004.). The previous literature shows that firms tend to cooperate on R&D activities with universities and scientific bodies when they know their needs in a particular field of knowledge and have researchers with the appropriate skill endowment. But if innovative firms do not have staff qualified to absorb and adapt external knowledge, the likelihood that individual firms will cooperate with scientific partners decreases greatly. In this context the presence of research staff with a degree or a PhD in the firm plays a determining role in reducing the factors that hinder cooperation between innovative firms and scientific partners.

This paper explores the role of graduate and PhD employees' research as a source of absorptive capacity for firms as regards R&D cooperation with external partners, especially technology centres and universities. The role of higher manpower skills has been looked into by many researchers in the literature and in general the results are conclusive: the better a firm's skill and qualification endowments, the higher the level of R&D investment (Piva & Vivarelli, 2009) and the higher the level of productivity (Freeman, 1987). This process is not unidirectional in the sense that qualified workers facilitate R&D activities and increase productivity, but recursive, in that the intensity of R&D at firm and country level offers more incentives to PhD holders and graduates to migrate from less industrialized to more industrialized countries (De Grip et al, 2010; Hall et al, 2010). In addition, the presence of qualified personnel in organizations encourages positive spillovers with the rest of the staff, although at the same time it may accelerate the obsolescence of knowledge among non-qualified and ageing workers.

Our starting hypothesis emphasizes the central role of tertiary education –degrees and PhDs employees- in enhancing a firm's ability to recognize and provide new knowledge generated outside innovative firms. In particular we are interested in the role played by two stages of tertiary education: the first concerns the programs that prepare students for the labour market, and the second stage refers to tertiary studies that lead to an advanced research qualification or a PhD.

Analysing the impact of tertiary education on firm cooperation performance, especially with universities and other public centres, has become extremely important in countries like Spain. Indeed, Spain now faces the difficult task of finding a new path to growth under the ambitious framework of the Sustainable Economy Law. Under this law, university reform and the presence of PhD staff in firms are two basic areas in the new economic model. In this context the complementarity between a high educational level and R&D cooperation with technological and scientific partners is related to the firm's absorptive capacity to adapt external knowledge.

Despite the increasing share of services in European economies, few studies have analyzed firms' cooperation in R&D with the manufacturing and services industries. This point is relevant because the sources of innovation and R&D cooperation strategies are very different between manufacturing and service firms. In the empirical analysis our data is taken from the Spanish Technological Innovation Panel for the period 2004-2009. Our panel data present a sample of 4,998 innovative Spanish firms and the econometric work offer better empirical results than with cross-sectional data. This paper analyses both manufacturing and service industries, but this approach is extremely rare in the literature on R&D cooperation (exceptions are Belberbos et al., 2004, for the Netherlands and Segarra & Arauzo, 2008, for Spain).

Here we use an extensive sample of innovative firms to identify the determining factors for R&D cooperation agreements with three types of partner: private partners (firms belonging to the same group, customers, suppliers and competitors), technology centres, and universities (public research institutes and university research groups)[1]. This empirical analysis focus on the determining factors for R&D cooperation between innovative firms and scientific partners (technology centres and universities)[2]. In particular we are interested in measuring the presence of complementary effects between tertiary educated workers and the ability of firms to cooperate with technology centres and universities.

The empirical strategy proposed here consists in estimating an ordered probit models (OPM), because it is better suited than the widely-used regression technique to work with ordinal variables that reflect the intensity of the firms' efforts in innovation. Our results show that a firm's cooperation activities are closely linked to industry characteristics and firm profile. These include aspects such as R&D intensity, size, product and process innovation, and access to public grants for R&D activities. Internal R&D and external R&D acquisition also increase a firm's propensity towards R&D cooperation with universities. The most notable results are related to the existence of a learning process in the field of R&D cooperation between manufacturing firms but not between services, and also to the critical role played by PhD research in facilitating communication and cooperation between firms and universities.

This paper is organised as follows. In the second section we review preliminary contributions on the factors that determine innovative firms' capacity to cooperate in R&D projects. In the third section we present the firm dataset used here and we run a complementary test between external R&D and skilled research personnel. 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.

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[1] The R&D partners selected differs in the empirical literature, for example, Belderbos et al (2004) explore the determinants of innovating firms' decisions to engage in R&D cooperation between four types of partners: competitors, suppliers, customers, and universities and research institutes (institutional cooperation).

[2] This approach was rare in this literature until a few years ago: see, for example, Belderbos et al. (2004), Veugelers & Cassiman (2005), Kaiser (2002), Becker & Dietz (2004), Bönte & Keilbach (2005), Schmidt (2005) and López (2008).

## 2.- Why do firms cooperate on R&D projects with other partners?

The economic literature offers a vast number of arguments about the incentives for innovative firms to cooperate on R&D with other partners. Most empirical studies deal with formal R&D cooperation (Cassiman & Veugelers, 2002; Miotti & Sachwald, 2003; Lopez, 2006; Segarra & Arauzo, 2008), but informal R&D cooperation also plays an important role (Bönte & Keilbach, 2005). This paper provides empirical evidence regarding the determinants of formal R&D cooperation for a wide sample of Spanish firms in the manufacturing and service sectors, with special attention paid to the role of research staff qualifications in innovative firms. The case of Spain is interesting because it has fewer R&D activities than other European countries, innovative firms have a traditionally low absorptive capacity, and the traditional barriers to R&D cooperation activities between firms and scientific bodies are high.

In recent years many papers have been published on the determining factors of R&D cooperation (Miotti & Sachwald, 2003). In order to simplify the situation, we have grouped these factors into two main groups: elements related to protection and absorptive capacity, and elements related to the complementary needs of external knowledge.

The first group of factors concerns a firm's ability to protect and capture internal and external knowledge. Cohen & Levinthal (1989, 1990) introduced the term “absorptive capacity”, and in a later study noted the dual role of R&D as a source of new information and as a tool that makes it easier for a firm to absorb existing information. They argue that absorptive capacity increases a firm’s ability to identify, assimilate and exploit knowledge from the environment. A firm with a high absorptive capacity should thus be able to access a larger amount of knowledge than a firm with a lower capacity.

To protect the results of their R&D activities, firms can invest in appropriation tools, and to absorb external knowledge they can develop specific skills. Innovative firms with high absorptive capacities are more likely to cooperate in R&D with scientific bodies. Using this argument, Cassiman & Veugelers (2002) distinguished between incoming spillovers, which affect a firm’s innovation rate, and appropriability, which affects a firm’s ability to appropriate the returns from innovation. And Lopez (2008) finds empirical evidence in Spanish manufacturing firms that incoming spillovers and appropriability affect the probability of R&D cooperation.

The second group of factors is related to the firm’s lack of specific knowledge and its need for R&D cooperation with outside partners. Hagedoorn (1993) finds that technological complementarities are one of the most important reasons for firms to cooperate on R&D. When an innovative firm requires external knowledge and skills to complement its internal knowledge, and when its needs cannot be satisfied via the market, its incentive to cooperate increases. When innovative firms cooperate on R&D projects, especially with public bodies, they benefit from the complementary knowledge generated by other agents and share the risks on projects and access to public grants.

The empirical literature shows that the incentives and returns involved for firms in cooperative R&D projects with scientific bodies differ across firms and universities. A recent trend in firm performance in innovation is to increase R&D cooperation with customers and suppliers, competitors, universities and public research organizations (Segarra & Arauzo, 2008; Veugelers, 1997; Fritsch & Lukas, 2001; Arora et al., 2001; Tether, 2002).

Empirical studies by Cassiman & Veugelers (2002), Belderbos et al. (2004), Bönte & Keilbach (2004) and Dachs et al. (2004) investigated R&D cooperation and found that the meaning of theoretically important factors like incoming spillovers and appropriability depends on the type of cooperation partner. Higher incoming spillovers, for instance, positively affect the probability of cooperating with public research institutions, while better appropriability results in a higher propensity to cooperate with customers and/or suppliers (see Cassiman & Veugelers 2002). R&D contracts (buy) and in-house activities (make) have also been the subject of several empirical investigations. Beneito (2001), Veugelers & Cassiman (1999) and Veugelers (1997) have detected several determinants that are responsible for a firm's decision to 'make' and/or 'buy' innovations. Beneito (2003) found that an intensive competitive environment, a firm's sound financial basis, large markets and medium firm size are decisive characteristics for organizing R&D in-house. Piga & Vivarelli (2004), meanwhile, found that the decision to acquire external R&D is related to the prior decision to engage in some form of R&D, and that external R&D generates significantly higher returns than internal R&D. For German CIS manufacturing firms, Schmidt (2005) found that firms with high intramural R&D budgets are more likely to cooperate with universities and research institutions than with suppliers and customers.

This paper shows that firms with high intramural R&D budgets are more likely to cooperate with universities and research institutions than with suppliers and customers. Our evidence is in line with Schmidt (2005), who found a direct link between the amount of internal R&D and the propensity of German firms to cooperate with universities. Similar results are given by Hall et al. (2003), who reported that firms are likely to collaborate with universities on basic research projects and when it is difficult for them to appropriate benefits from joint research.

**The relationship between firms and universities**

Since the 1960s, a third mission related to economic growth and territorial development has been added to the two traditional missions of modern universities, teaching and research[3]. The concept of the 'triple-helix' has been the most widely accepted conceptual framework for public policy makers (Etzkowitz et al, 2000) in the second academic revolution. However, the ambiguous nature of the concept of the 'triple-helix' has usually been interpreted by universities themselves as a new challenge that will open up new contacts with the outside world without first internally transforming its three missions: teaching, research, and knowledge transfer.

[3] In 1810 Wilhelm von Humboldt founded a Berlin university that integrated teaching and research.

The new challenge for universities has a high profile in countries such as Spain, located at some distance from the technological frontier. Spanish universities are modifying the traditional roles of a Humboldt-style university (i.e. higher education and research) in order to generate and disseminate knowledge directly connected with economic development. This connection is partly due to university-industry links such as technology transfer centres, research institutes, science parks and spin-off incubators. Spain is also interesting because university policy is dependent on regional government, and public support for promoting firm innovation and cooperation projects between universities and public research centres, especially SMEs, has increased considerably in recent years.

Moreover, the commercialization of university knowledge (especially knowledge from university-based technologies) has increased considerably due to patenting, joint ventures in research and firm creation (spin-offs from universities). Several factors explain this phenomenon. First, the creation of structures that promotes relations between universities and business, such as science parks and other property-based institutions (Link and Scott, 2003). Second, the development of intellectual property laws that encourage researchers to patent their discoveries, and this helps to commercialize the results of university research. Third, Spanish public subsidy programmes that promote R&D cooperation between SMEs and universities have increased in the last few years. Finally, closer R&D cooperation between firms and universities together with public funding for the creation of joint ventures have directed university research activities towards the demands of business.

The role of universities is particularly relevant in a regional context where this industrial mix is specialized in industries with low and middle technological intensity. In the Spanish innovation system overall investment in R&D is below the EU average, more money goes into R&D in the public sector than in the private sector, and the presence of innovative firms is smaller. In 2009 Spanish investment in R&D was 1,38% of GDP (GERD) front 2,01% in the EU-27; public R&D expenditure was 0,66% of GDP front 0,74% in the EU; business R&D expenditure was 0,72% of GDP versus 1,25% in the EU; and the contribution of high-tech and medium-high-tech manufactured goods to the trade balance was 0,3% of total trade front 5,1% in the EU. During the period 2000-2009 Spain's R&D intensity has grown from 0.91% of GDP to 1.38 %, which is one of the highest increases of all EU members. Spain record during this period an intense process of convergence towards EU member located on the technological frontier.

## 3.-Data and descriptive analysis

In the empirical analysis the data source is the Spanish Technological Innovation Panel (henceforth PITEC). This dataset is jointly developed by the Spanish National Statistics Institute (INE) and the COTEC foundation with the aim of providing data from the Community Innovation Survey (CIS) for Spain in a panel structure. After an intensive consolidation process – firms with more than three employees, firms with more than three annual observations, etc – the panel data present 4,998 innovative Spanish firms -4,004 manufacturing firms and 994 services firms- and 21,467 annual observations.

The main advantage of the PITEC is that it is the best instrument for observing the innovation activities of Spanish firms over time (Barge-Gil, 2010). We use PITEC panel data from some waves that cover the period 2004-2009, and we can therefore track the performance of innovative Spanish firms over five years.

The descriptive analysis of innovative firms offers an interesting scenario which becomes even more attractive when the main subjects of manufacturing and service firms are viewed separately. If we consider that our purpose is to analyse the determinants of cooperation agreements, then descriptive tables will distinguish between firms that do not cooperate and firms that cooperate with universities, technology centres and private partners.

**Table 1**
**Descriptive statistics for innovative manufacturing firms**

| | **No cooperation** | **Other Partners** | **Technology centres** | **Universities** |
|---|---|---|---|---|
| **Industry variables** | | | | |
| MANUFAC-HT % | 45.09%<br>(0.4976) | 44.76%<br>(0.4974) | 41.54%<br>(0.4930) | 57.87%<br>(0.4939) |
| **Firm variables** | | | | |
| SIZE<br>(employees) | 126.22<br>(317.34) | 213.64<br>(727.66) | 193.70<br>(697.55) | 283.72<br>(633.87) |
| AGE<br>(years) | 27.54<br>(19.00) | 28.82<br>(20.75) | 28.63<br>(17.84) | 30.77<br>(21.13) |
| R&D INTENSITY<br>(thousands) | 5,030.58<br>(12,416.72) | 6,534.08<br>(15,353.19) | 7,016.99<br>(14,255.58) | 9,805.35<br>(15,463.71) |
| PARK % | 1.74%<br>(0.1306) | 1.69%<br>(0.1289) | 1.88%<br>(0.1357) | 4.46%<br>(0.2064) |
| GROUP % | 32.41%<br>(0.4681) | 50.52%<br>(0.5001) | 43.10%<br>(0.4954) | 52.53%<br>(0.4995) |
| PRD % | 8.10%<br>(0.1216) | 8.84%<br>(0.1367) | 11.18%<br>(0.1744) | 13.52%<br>(0.1655) |
| PRDDOC % | 1.83%<br>(8.4742) | 1.84%<br>(8.1845) | 1.87%<br>(8.7142) | 4.68%<br>(11.0845) |
| PRDLI % | 29.96%<br>(33.0844) | 33.98%<br>(32.6813) | 40.52%<br>(32.3763) | 42.74%<br>(29.1244) |
| **Innovation determinants** | | | | |
| PROD&PROC | 52.08%<br>(0.4996) | 67.48%<br>(0.4685) | 70.42%<br>(0.4566) | 73.56%<br>(0.4411) |
| R&DIN | 67.50%<br>(0.4684) | 76.24%<br>(0.4258) | 85.60%<br>(0.3512) | 90.24%<br>(0.2968) |
| R&DEX | 23.07%<br>(0.4213) | 41.86%<br>(0.4934) | 60.19%<br>(0.4897) | 68.06%<br>(0.4663) |
| Number observations | 11,423 | 2,205 | 1,153 | 2,511 |

A growing number of empirical studies have estimated complementarity versus substitutibility among innovation-sourcing strategies. Arora & Gambardella (1990) analyse the external linkage of large firms in the bio-technology industry using data for a sample of large EU, US and Japanese manufacturing firms. Their results suggest that external and internal activities are complementary in large firms, but this is not clear in small and medium firms.

The relation between internal R&D and external R&D is clear in that the empirical literature shows, in general, a positive effect on the returns of each activity if the other one is performed at the same time. The complementarities between internal R&D and external R&D can be found for example in Arbussà & Coenders (2007) for Spain, Lokshin et al. (2008) for Holland, Cassiman & Veugelers (2006) for Belgium, Nakamura & Odagiri (2005) for Japan, Love & Roper (2002) for the UK, and Segarra & Teruel (2011) for Catalonia.

**Table 2**
**Descriptive statistics for innovative services firms**

| | **No cooperation** | **Other partners** | **Technology centres** | **Universities** |
|---|---|---|---|---|
| **Industry variables** | | | | |
| KIS % | 60.64%<br>(0.4887) | 41.48%<br>(0.4931) | 70.91%<br>(0.4563) | 84.22%<br>(0.3647) |
| **Firm variables** | | | | |
| SIZE<br>(employees) | 259.81<br>(876.83) | 574.42<br>(1.118.67) | 224.89<br>(497.27) | 279.87<br>(1.101.64) |
| AGE<br>(years) | 22.24<br>(23.88) | 30.91<br>(34.29) | 16.86<br>(11.86) | 16.41<br>(16.52) |
| R&D INTENSITY<br>(thousands) | 9,185.18<br>(27,996.31) | 9,510.63<br>(51,247.70) | 14,690.01<br>(19,547.88) | 45,036.50<br>(158,619.9000) |
| PARK % | 5.95%<br>(0.2366) | 4.56%<br>(0.2088) | 20.00%<br>(0.4034) | 26.86%<br>(0.4436) |
| GROUP % | 33.32%<br>(0.4715) | 56.56%<br>(0.4961) | 20.91%<br>(0.4085) | 34.22%<br>(0.4747) |
| PRD % | 16.70%<br>(0.2548) | 13.56%<br>(0.2393) | 30.59%<br>(0.3220) | 50.40%<br>(0.4010) |
| PRDDOC % | 2.12%<br>(8.7221) | 2.25%<br>(10.0438) | 2.08%<br>(7.0201) | 7.19%<br>(12.6319) |
| PRDLI % | 35.00%<br>(38.2868) | 30.59%<br>(35.6040) | 46.43%<br>(32.9534) | 55.25%<br>(30.2552) |
| **Innovation determinants** | | | | |
| PROD&PROC | 45.40%<br>(0.4980) | 64.25%<br>(0.4796) | 61.82%<br>(0.4881) | 63.59%<br>(0.4814) |
| R&DIN | 59.45%<br>(0.4911) | 57.47%<br>(0.4948) | 82.73%<br>(0.3797) | 93.34%<br>(0.2493) |
| R&DEX | 19.74%<br>(0.3982) | 35.44%<br>(0.4787) | 55.45%<br>(0.4993) | 54.56%<br>(0.4982) |
| Number observations | 2,350 | 663 | 110 | 1,052 |

As far as the relationship between R&D activities and R&D cooperation is concerned, the empirical results in the research are less conclusive at this stage. On the influence of internal R&D on R&D cooperation, for instance, Abramovsky et al. (2005) find a positive impact of internal R&D on the probability of R&D cooperation for four European countries, confirming previous empirical results; Arora & Gambardella (1994) analyse pharmaceutical firms in the US and find a positive correlation between both; and Colombo & Garrone (1996) observe the cooperation agreements of high-tech startups in Italy and find a significant correlation between internal R&D and R&D cooperation. Schmiedeberg (2008) looks at German manufacturing firms and finds that internal R&D and R&D cooperation are positively correlated and that the productivity of each activity increases if the other one is performed. Similar findings can be found in Cassiman & Veugelers (2002) for Belgium, Bönte & Keilbach (2004) and Schmidt (2005) for Germany, and López (2008) for Spanish manufacturing.

Another aspect of innovation activities is that they are heterogeneous, asymmetric and complementary (Benedetti, 2009). Firstly, innovation activities are heterogeneous in the sense that some firms do not innovate, some concentrate on specific types of innovation – product, process, organizational or marketing innovation – and others develop various types of innovation. Secondly, innovation strategies are asymmetric – the distribution of innovation and its impact on a firm's productivity and growth is asymmetric, with its distribution being more skewed towards the right. Thirdly, innovations are complementary and it frequently happens that innovation increases when a firm has already introduced other innovations. Using an adoption approach, Cassiman & Veugelers (2006) found that different innovation activities are strongly positively correlated and they identified basic R&D as a source of complementarity between internal and external innovation activities.

The empirical analysis of the complementarities between R&D sources at firm level has received increasing attention from researchers in recent years. In general the evidence shows a strong complementarity between the three dimensions of R&D at firm level – making, buying and cooperating.

In order to determine this, we analyse the complementarities between external R&D and PhDs researchers using the theory of supermodularity, which is a useful instrument (Milgrom & Roberts, 1990). We assume that a firm can make two binary decisions related to R&D external activities ($A_1$) and PhD workers ($A_2$), and that each activity can either be done by the firm ($A_i = 1$) or not ($A_i = 0$) and $\in \{1, 2\}$. The function $\Pi(A_1, A_2)$ is supermodular and $A_1$ and $A_2$ are complementary if,

$$\Pi(1, 1) - \Pi(0, 1) \geq \Pi(1, 0) - \Pi(0, 0)$$

i.e. adding an activity while already performing the other activity has a higher incremental effect on performance ($\Pi$) than when doing the activity in isolation (Cassiman & Veugelers, 2004). Here the complementary test measures whether, when an individual firm decides both to carry out R&D external activities ($A_1$) and employ PhD workers ($A_2$), its propensity to cooperate with universities increases more than when doing the activity in isolation.

Our data from the Spanish version of PITEC show that increasing numbers of managers in innovative Spanish firms regard choices on external R&D strategies and skilled research personnel as complementary activities. In this setting, complementarities imply that firms which carry out external R&D activities will obtain a greater return on R&D cooperation when those firms have skilled workers in R&D.

**Table 3**
**Complementary Test**

| | $Chi^2$ | Prob. |
|---|---|---|
| High-tech manufacturing industries | 56.54 | 0.0000 |
| Low-tech manufacturing industries | 29.01 | 0.0000 |
| Knowledge-intensive services | 97.35 | 0.0000 |
| Other services | 9.20 | 0.0024 |

*Note: the equation test is: R&D external – PhD research + R&D external & – PhD research*

The table above presents the complementarity test classified by sector into four groups. The results show that carrying out R&D outsourcing and employing PhD research staff has a positive impact on firms' propensity to cooperate with universities, especially in knowledge-intensive services (KIS) and high-tech manufacturing industries.

**4.- Econometric tools and R&D cooperative determinants**

Here the main goal is to analyse how a vector of internal R&D and external R&D determinants of Spanish innovative firms affect their ability to cooperate and the nature of their partners, distinguishing between private partners, technology centres and universities. In our firm data panel, as is usual in studies of this kind, the dependent variable presents problems of censorship: in this case, the data following the distribution of the sample are a mixture of continuous and discrete distributions. The appropriate methodology in similar multiple-choice studies is the so-called ordered probit model. This was developed by Aitchison & Silvery (1957) and Ashford (1959), and was recently updated by Maddala (1983) and McCullagh (1980).

We applied a model based on the following specification,

$$Y_i = \beta X_i + \epsilon_i$$

where $Y_i$ is the firm's degree of R&D cooperation, $X_i$ are the explanatory variables and β are the parameter values of these variables.

In our ordered probit model there is a continuous and unmeasured latent variable $Y^*$, whose values determine what the observed ordinal variable $Y$. The continuous latent variable $Y^*$ has various threshold points. The value of the observed variable $Y$ depends on whether or not a particular threshold has been crossed. For example, if we are interested in studying the determinants of R&D cooperation with three types of partners, we apply the following stratification,

$$\begin{aligned} Y_i &= 0 \text{ if } Y^*_i = 0 \\ Y_i &= 1 \text{ if } Y^*_i \le \kappa_1 \\ Y_i &= 2 \text{ if } \kappa_1 \le Y^*_i \le \kappa_2 \\ Y_i &= 3 \text{ if } Y^*_i \ge \kappa_2 \end{aligned}$$

When Spanish innovative firms do not cooperate with external partners, $Y_i$ is nil if they don't cooperate with anyone; when they cooperate with other firms $Y_i = 1$; when they cooperate with technology centres $Y_i = 2$; and when they cooperate with public research centres and universities $Y_i = 3$. The categorical variable takes on increasing values depending on the scientific level of the external partners.

| ***Table 4*** <br> ***Definitions of the independent variables*** | |
|---|---|
| **Dependent variables** | |
| **COOPERA** | *Dichotomous variable: 1 if the firm has R&D cooperation with other agents, 0 otherwise* |
| **PARTNER** | *Categorical variable: 1 if the firm has R&D cooperation with private partners, 2 if the firm cooperates with technology centres, 3 if the firm cooperates with universities, 0 otherwise* |
| **Industry variables** | |
| MANUFAC-HT | *Dichotomic variable: 1 if the firm is in the high-tech manufacturing industry, 0 otherwise* |
| SERV-KIS | *Dichotomic variable: 1 if the firm is in KIS services, 0 otherwise* |
| **Firm variables** | |
| SIZE | *Number of employees in the firm* |
| AGE | *Firm's age in years* |
| R&D INTENSITY | *R&D investment per employee in euros in current year* |
| PARK | *Dichotomic variable: 1 if the firm is in a technology park; 0 otherwise* |
| GROUP | *Dichotomic variable: 0 if the firm does not belong to a group; 1 otherwise* |
| PRD% | *R&D personnel as % of total employees* |
| PRDPhD% | *% of R&D personnel with PhD* |
| PRDGD% | *% of R&D personnel with degree* |
| ***Innovation determinants*** | |
| PROD&PROC | *Dichotomic variable: 1 if the firm made both product and process innovations in 2006-2008; 0 otherwise* |
| R&DIN | *Dichotomic variable: 1 if the firm carried out internal R&D in 2006-2008; 0 otherwise* |
| R&DEX | *Dichotomic variable: 1 if the firm acquired external R&D services in 2006-2008; 0 otherwise* |
| **Public funds** | |
| Regional public funds | *Dichotomic variable: 1 if the firm accessed public resources from local or regional governments for innovation activities in 2006-2008; 0 otherwise* |
| Spanish public funds | *Dichotomic variable: 1 if the firm accessed public resources from the Spanish government for innovation activities in 2006-2008; 0 otherwise* |
| *European public funds* | *Dichotomic variable: 1 if the firm accessed public resources from the EU for innovation activities in 2006-2008; 0 otherwise* |

In the empirical analysis we first use a 2-step tobit model to estimate two equations that relate the decision to cooperate and partner choice with the other variables of interest. We model firms' R&D cooperation decisions as a two-stage process. In first stage, firms decide either to be R&D cooperative or not, and then in the second stage we observe the technology level of the partners. Here we applied the Raymond et al (2010) econometric proposition that studies the persistence of innovation and the dynamics of innovation output in the Dutch manufacturing sector using company data from three waves of CIS.

We present new econometric evidence related to the R&D cooperative decision and choice of partners. In the first stage we observe the factors that affect the likelihood that a Spanish firm will cooperate in R&D activities with other partners, while in the second stage we can observe specifically the role of human and skill endowments in promoting R&D cooperation with scientific partners.

| Table 5<br>Results of the dynamic type 2 tobit model | | |
|---|---|---|
| | **Manufacturing** | **Services** |
| **Type of partner (1 private partners, 2 technology centres, 3 universities)** | | |
| MANUFAC-HT / SERVICE-KIS | 0.1706 (0.0438)* | 0.2722 (0.0836)* |
| SIZE (log) | 0.0144 (0.0146) | 0.0097 (0.0167) |
| AGE (log) | 0.0007 (0.0008) | -0.0025 (0.0012)** |
| R&D INTENSITY (log) | -0.0129 (0.0040)* | 0.0088 (0.0057) |
| PRD% | 0.4611 (0.0881)* | 0.2341 (0.0832)* |
| PRDDOC% | 0.0072 (0.0016)* | 0.0061 (0.0017)* |
| PRDLI% | 0.0017 (0.0005)* | 0.0044 (0.0008)* |
| **Cooperation decision (1 R&D cooperation with partners, 0 no cooperation)** | | |
| R&D INTENSITY (log) | 0.0145 (0.0031)* | 0.0105 (0.0051)** |
| R&DIN | 0.1672 (0.0461)* | 0.3880 (0.0798)* |
| R&DEX | 0.6875 (0.0317)* | 0.6210 (0.0585)* |
| GROUP | 0.3067 (0.0300)* | 0.2696 (0.0557)* |
| Regional public funds (log) | 0.9490 (0.2050)* | 0.1010 (0.0823) |
| Spanish public funds (log) | 0.0655 (0.0626) | 0.2020 (0.1090)*** |
| European public funds (log) | -0.0940 (0.0859) | 1.3700 (0.4300)* |
| Note: The variables for regional public funds, Spanish public funds and European public funds are in thousands euros.<br>* significant at 1%, ** significant at 5%, *** significant at 10% | | |

In this two step estimation we can see that internal R&D intensity (R&D investment per employee), the carrying-out of internal and external R&D and whether the firm belongs to a group have a direct effect on the propensity of innovative firms to cooperate on R&D activities with partners. Furthermore, in the field of public policy, support for innovative firms from regional grants increases the propensity of Spanish manufacturing firms to cooperate, whereas regional and European grants increase this propensity in Spanish firms in the service sector.

When it comes to choosing between different partners, Spanish firms in high technology sectors (manufacturing and services) tend to cooperate more in R&D external activities, and in particular with scientific partners (Segarra & Arauzo, 2008, Vega-Jurado & Manjarrés, 2010). The technology level of the sector to which the firm belongs is particularly relevant in the services, since Spanish firms in knowledge-intensive services tend to cooperate more with universities. In addition, R&D intensity does not seem to be a relevant factor when innovative firms choose a partner, but the proportion of researchers on the firm's staff and the proportion of PhD workers on the R&D staff play a critical role in R&D cooperation with scientific partners and especially with universities.

## 5.- Main Hypotheses and Empirical Results

In this section, we profile innovative firms that cooperate with other firms, technological centres and universities. We start with the results of the probit model on the propensity to cooperate with other partners, where in order to control the possible endogeneity problems we apply lagged explanatory variables during the econometrics estimations. In line with the previous literature, we propose eight main hypotheses.

| Table 6<br>**Main Hypotheses** | |
|---|---|
| H1 | The propensity to engage in R&D cooperation is higher for firms that operate in sectors with high R&D intensity |
| H2 | R&D cooperation increases with firm's size |
| H3 | R&D cooperation exhibits a dynamic learning process and is related to firm's age |
| H4 | Intramural R&D activities increase the propensity to engage in R&D cooperation agreements |
| H5 | The presence of staff educated to PhD and graduate level in innovative firms promotes the firm's absorptive capacity and facilitates R&D cooperation with universities and public research centres |
| H6 | Firms that perform both product and process innovation have a high propensity to engage in R&D cooperation agreements |
| H7 | Public funding programmes affect the propensity to engage in R&D cooperation agreements |
| H8 | Firms located in technology or science parks show more capacity for cooperation with scientific partners (technology centres and universities) |

Our results show that most of our main hypotheses have been confirmed.

H1. The propensity to engage in R&D cooperation is higher for firms that operate in sectors with high R&D intensity, especially KIS services.

This hypothesis is only partially satisfied since the two groups included in the dichotomous variable belonging to a high-technology sector have the expected sign but do not reach the statistical level. However, the effect of R&D intensity in the sector is more important between services firms, where 84% of firms in KIS services have R&D agreements with universities, but only 57% of firms in high-tech manufacturing cooperate with universities.

H2. R&D cooperation increases with firm size

This hypothesis is satisfied in all types of cooperation partner, especially when firms cooperate with universities. These results are in line with previous studies, for instance Bayona et al. (2003), Veugelers and Cassiman (2005), Colombo and Garrone (1998) and Hagedoorn and Schakenraad (1994) found that size has a positive influence on cooperation. In general, small firms are more likely to restrict their innovation strategy to an exclusive make or buy strategy, while large firms are more likely to combine internal R&D, external knowledge acquisition and cooperative R&D activities. In addition, larger firms tend to cooperate with various R&D partners simultaneously and obtain scale and scope returns, since small firms when applied multiple R&D cooperation strategies incurs in higher costs (Belderbos et al, 2006)

H3. R&D cooperation exhibits a dynamic learning process and is related to firm age.

Our results show a positive link with a firm's age in manufacturing sectors, especially when the firm cooperates with universities, but this relationship does not take the expected sign in the service sectors. These results reveal the existence of a dynamic learning process between manufacturing firms which establish a stable relationship with universities, while in services firms this learning process does not appear, and younger firms collaborate more intensively with universities than mature firms.

| *Table 7*<br>***Determinants for cooperation with universities and technology centres in manufacturing industries***<br>***Ordered logit model*** | | | | | | |
|---|---|---|---|---|---|---|
| | | | ***Marginal effects*** | | | |
| | **Coefficients** | **Standard deviation** | **No cooperation** | **Other partners** | **Technology centres** | ***Universities*** |
| ***Industry variables*** | | | | | | |
| MANUFAC-HT | 0.0026 | 0,0433 | -0.0009 | 0.0002 | 0.0002 | 0.0005 |
| ***Firm variables*** | | | | | | |
| SIZElog | 0.1099 | 0,0182* | -0.0389 | 0.0097 | 0.0078 | 0.0215 |
| AGElog | 0.0020 | 0,0009** | -0.0007 | 0.0002 | 0.0001 | 0.0004 |
| R&D INTENSITYlog | 0.0055 | 0,0038 | -0.0020 | 0.0005 | 0.0004 | 0.0011 |
| PARK | 0.2502 | 0,1128** | -0.0931 | 0.0195 | 0.0175 | 0.0560 |
| GROUP% | 0.1893 | 0,0383* | -0.0676 | 0.0164 | 0.0134 | 0.0378 |
| PRD% | 1.0299 | 0,1474* | -0.3648 | 0.0908 | 0.0728 | 0.2012 |
| PRDDOC % | 0.0086 | 0,0019* | -0.0030 | 0.0008 | 0.0006 | 0.0017 |
| PRDLI% | 0.0007 | 0,0006 | -0.0003 | 0.0001 | 0.0001 | 0.0001 |
| ***Innovation determinants*** | | | | | | |
| PROD&PROC | 0.2475 | 0,0348* | -0.0867 | 0.0220 | 0.0174 | 0.0473 |
| R&DIN | 0.1219 | 0,0626** | -0.0426 | 0.0110 | 0.0086 | 0.0230 |
| R&DEX | 0.6981 | 0,0356* | -0.2550 | 0.0525 | 0.0472 | 0.1553 |
| ***Public funds*** | | | | | | |
| Regional public funds | 0.2670 | 0,1130** | -0.0945 | 0.0235 | 0.0189 | 0.0521 |
| Spanish public funds | 0.0770 | 0,0681 | -0.0273 | 0.0068 | 0.0054 | 0.0150 |
| European public funds | -0.0873 | 0,1040 | -0.0309 | -0.0077 | -0.0062 | -0.0170 |
| Number of cases | 6,302 | | | | | |
| Sectoral dummies | Yes | | | | | |
| Temporal dummies | Yes | | | | | |
| $R^2$ | 0.1007 | | | | | |
| *The regional public funds, Spanish public funds and European public funds variables are expressed in millions of euros.*<br>** significant at 1%, ** significant at 5%, *** significant at 10%* | | | | | | |

H4. Intramural R&D activities increase the propensity to engage in R&D cooperation agreements.

This hypothesis is satisfied in all types of cooperation agreement, mainly for cooperation with public centres and universities. Intramural R&D and external R&D play an important role in service sectors, especially when R&D cooperation is with universities.

H5. The presence of staff educated to PhD and graduate level in innovative firms promotes the firm's absorptive capacity and facilitates R&D cooperation with universities and public research centres.

As we might expect, Spanish innovative firms with a high percentage of research staff establish more contracts with other partners, this being the result obtained especially in the service sector. However, the presence of PhD-qualified research staff in the firm is also directly related to its propensity to collaborate on R&D projects, especially with universities.

| *Table 8*<br>***Determinants for cooperation with universities and technology centres in service industries. Ordered logit model*** | | | | | | |
|---|---|---|---|---|---|---|
| | | | ***Marginal effects*** | | | |
| | **Coefficients** | **Standard deviation** | **No cooperation** | **Other partners** | **Technology centres** | ***Universities*** |
| ***Industry variables*** | | | | | | |
| SERVICE-KIS | 0.0929 | 0.1088 | -0.0369 | 0.0061 | 0.0019 | 0.0289 |
| ***Firm variables*** | | | | | | |
| log SIZE | 0.1264 | 0.0309* | -0.0503 | 0.0080 | 0.0026 | 0.0397 |
| AGE | -0.0015 | 0.0016 | 0.0006 | -0.0001 | -0.0000 | -0.0005 |
| log R&D INTENSITY | 0.0103 | 0.0068 | -0.0041 | 0.0006 | 0.0002 | 0.0032 |
| PARK | 0.5112 | 0.1159* | -0.2002 | 0.0132 | 0.0078 | 0.1792 |
| GROUP | 0.1258 | 0.0741*** | -0.0501 | 0.0076 | 0.0025 | 0.0399 |
| PRD% | 0.8961 | 0.1618* | -0.3565 | 0.0565 | 0.0184 | 0.2817 |
| PRDDOC | 0.0049 | 0.0035 | -0.0019 | 0.0003 | 0.0001 | 0.0015 |
| PRDLI | 0.0003 | 0.0014 | -0.0001 | 0.0001 | 0.0001 | 0.0001 |
| ***Innovation determinants*** | | | | | | |
| PROD&PROC | 0.1992 | 0.0669* | -0.0791 | 0.0127 | 0.0041 | 0.0623 |
| R&DIN | 0.0726 | 0.1219 | -0.0288 | 0.0047 | 0.0015 | 0.0226 |
| R&DEX | 0.4565 | 0.0721* | -0.1806 | 0.0226 | 0.0085 | 0.1494 |
| ***Public funds*** | | | | | | |
| Regional public funds | 0.0007 | 0.0987 | -0.0003 | 0.0001 | 0.0001 | 0.0002 |
| Spanish public funds | 0.3380 | 0.1630* | -0.1350 | 0.0213 | 0.0069 | 0.1060 |
| European public funds | 0.5500 | 0.3310 | -0.2190 | 0.0347 | 0.0113 | 0.1730 |
| Number of cases | 1,522 | | | | | |
| Sectoral dummies | Yes | | | | | |
| Temporal dummies | Yes | | | | | |
| $R^2$ | 0.1444 | | | | | |
| *The regional public funds, Spanish public funds and European public funds variables are expressed in millions of euros.*<br>** significant at 1%, ** significant at 5%, *** significant at 10%* | | | | | | |

H6. Firms that perform both product and process innovation have a high propensity to engage in R&D cooperation agreements.

This hypothesis is satisfied in all types of cooperation agreement, but the effect is greater for cooperation with firms from the same group and with customers and suppliers. If we consider that product and process innovation are the main outputs of the innovation process, the results show that innovative firms have more R&D contracts with different types of external partner.

H7. Public funding programmes affect the propensity to engage in R&D cooperation agreements.

This hypothesis is partially satisfied (especially for Spanish and European public funds), but some additional explanations are needed. In our estimations we are testing the use of public funds from several public administrations. However, the amount of these funds differs considerably: regional programme funds provide little budgetary support while Spanish funds and (mainly) European funds are of great importance. Public funding for innovative manufacturing firms is low, especially among firms that do not cooperate on R&D projects, whereas it reaches higher levels in the service sectors, especially in firms that cooperate as technology centres or universities. According to our results, access to public funds is a determining factor in promoting cooperation with public institutions.

H8. Firms located in technology or science parks show more capacity for cooperation with scientific partners.

In recent years, both regional and State governments have supported the creation of structures that promote relations between the universities and business, such as science parks and other property-based institutions. Technology and science parks are areas that facilitate the interrelations between the academic world and business. In Spain's technology and science parks promote cooperation between innovative firms and scientific partners, particularly in the service sector.

## 6. Concluding remarks

The main goal of this paper is to analyse the factors determining the ability of firms to cooperate on innovative R&D activities in Spain. The external partners have been distributed in three groups: private partners (firms belonging to the same group, customers and suppliers), technology centres and universities. This reflects the nature of the R&D projects as well as the barriers to cooperation between firms and universities. Our main interest is to analyse the role of skilled and qualified researchers as a factor affecting a firm's capacity to cooperate with external partners and the propensity to cooperate with research groups and public institutions that has emerged among Spanish universities.

In this regard, the case of Spain is of great interest because the proportion of innovative firms that have stable R&D agreements with external partners is lower that among other EU members. However, the last two decades have seen a change in Spanish universities and the growth in relationships between universities and firms has been remarkable. To carry out the empirical study of the two main contributions from the literature we used firm data from three waves of Community Innovation Surveys, covering the period 2004-2009. This panel data offers information on 4,998 manufacturing and services Spanish firms. This dataset facilitates more consistent results regarding the role of skilled workers in the R&D cooperation decisions of Spanish innovative firms.

The main result of this paper shows the role played by graduate and PhD-qualified research staff in Spanish innovative firms in facilitating stable R&D cooperation with scientific partners. These results have relevant implications for policy makers and the universities themselves in so far as training good professionals is the best tool for promoting collaboration with innovative firms, and also for reducing the traditional distance that has separated firms and universities in the past.

## References


Abramovsky, L., Kremp, E., López, A., Schmidt, T., Simpson, H., 2005. Understanding cooperative R&D Activity: evidence from four European Countries. IFS Working Paper 05-23

Aitchison, J., Silvery, S.D., 1957. The generalization of probit analysis to the case of multiple responses. Biometrika 44, 131-150.

Arbussà, A., Coenders, G., 2007. Innovation activities, use of appropriation instruments and absorptive capacity: Evidence from Spanish firms. Research Policy 36, 1545-1558.

Arora, A., Gambardella, A., 1990. Complementarity and external linkages: the strategies of the large firms in biotechnology. The Journal of Industrial Economics 38 (4), 361–379.

Arora, A., Gambardella, A., 1994. The changing technology of technological change: general and abstract knowledge and the division of innovative labour. Research Policy 23, 523-532.

Arora, A., Fosfuri, A., Gambardella, A. (2001). Markets for Technology and their Implications for Corporate Strategy. Industrial and Corporate Change 10(2), 419-451.

Ashford, J.R., 1959. An Approach to the Analysis of Data for Semi-Quantal Responses in Biological Assay. Biometrics 15 (4), 573-581.

Barge-Gil, A., 2010. Cooperation-based innovators and peripheral cooperators: An empirical analysis of their characteristics and behaviour. Technovation 30 (3), 195-206.

Bayona, C., García, T., Huerta, E., 2003. ¿Cooperar en I+D? Con quién y para qué. Revista de Economía Aplicada XI (31), 103-134.

Becker, W., Dietz, J., 2004. R&D cooperation and innovation activities of firms—evidence for the German manufacturing industry. Research Policy 33 (2), 209-223.

Belderbos, R., Carree, M., Diederen, B., Lokshin, B., 2004. Cooperative R&D and firm performance. Research Policy 33(10), 1477-1492.

Belderbos, R., Carree, M., Diederen, B., Lokshin, B., 2006. Complementary in R&D Cooperation Strategies. Review of Industrial Organization 28(4), 401-426.

Benedetti, C. (2009). Product and Process Innovation in a Growth Model of Firm Selection. EUI Working Papers ECO 2009/30. European University Institute, Florence, Department of Economics.

Beneito, P. (2001). R&D Productivity and Spillovers at the Firm Level: Evidence from Spanish Panel Data. Investigaciones Económicas XXV(2), 289-313.

Beneito, P. (2003): Choosing among Alternative Technological Strategies: An Empirical Analysis of Formal Sources of Innovation. Research Policy 32, 693-713.

Bönte, W., Keilbach, M., 2004. Concubinage or Marriage? Informal and Formal Cooperations for Innovation. ZEW Disussion Paper No. 04-11.

Bönte, W., Keilbach, M., 2005. Concubinage or Marriage? Informal and Formal Cooperations for Innovation. International Journal of Industrial Organization 23, 279-302.

Cassiman, B., Veugelers, R., 2002. R&D cooperation and spillovers: some empirical evidence from Belgium. American Economic Review 92 (4), 1169–1184.

Cassiman, B., Veugelers, R. 2006. In Search of Complementarity in Innovation Strategy: Internal R&D and External Knowledge Acquisition. Management Science 52(1), 68-82.

Cohen, W.M., Levinthal, D.A. 1989. Innovation and learning: The two faces of R&D. Economic Journal 99, 569–596.

Cohen, W.M., Levinthal, D.A. 1990. Absorptive-capacity – A new perspective on learning and innovation. Administrative Science Quarterly 35 (1), 128–152.

Colombo, M.G., Garrone, P., 1996. Technological cooperative agreements and firm's R&D intensity. A note on causality relations. Research Policy 25 (6), 923–932.

Colombo, M., Garrone, P., 1998 . A simultaneous equations model of technological agreements and infra-mural R&D", En M. Colombo (ed.), *The changing boundaries of the firm,* Routledge, London, págs. 140-157.

De Grip, A., Hall, B.H., Smits, W., 2010. Empirical studies of employment and performance of scientists and engineers. Economics of Innovation and New Technology 19 (5), 387-391.

Etzkowitz, H., Webster, A., Gebhardt, Ch., 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.

Freeman, C. (1987), *Technology Policy and Economic Performance*, London: Pinter.
Fritsch, M., Lukas, R., 2001. Who cooperates on R&D?. Research Policy 30, 297-312.
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., Schakenraad, J., 1994. The effect of strategic technology alliances on company performance. Strategic Management Journal 15, 291-309.
Hall, B.H., Link, A.N., Scott, J.T., 2003. Universities as Research Partners. Review of Economics and Statistics 85 (2), 485–491.
Hall, B., de Grip, A., Smits, W., 2010. The labour market for scientists and engineers: introduction, Economics of Innovation and New Technology 19 (5), 1-7 Special issue.
Hervas-Olivera, J.L., Albors-Garrigosa, J., Baixaulia, J.J., 2011. Beyond R&D activities: the determinants of firms' absorptive capacity explaining the access to scientific institutes in low–medium-tech contexts. Economics of Innovation and New Technology, DOI:10.1080/10438599.2011.555113
Kaiser, U. 2002. An empirical test of models explaining R&D expenditures and R&D cooperation. International Journal of Industrial Organisation 20(6), 747-774.
Laursen, K. and Salter, A., 2004. 'Searching high and low: what types of firms use universities as a source of innovation?', Research Policy 33 (2004) 1201–1215.
Link, A.N., Scott, J.T., 2003. The growth of research triangle park. Small Business Economics 20, 167-175.
Lokshin, B., Belderbos, R., Carree, M. 2008. The Productivity Effects of Internal and External R&D: Evidence from a Dynamic Panel Data Model. Oxford Bulletin of Economics and Statistics 70 (3), 399-413.
López, A., 2008. Determinants of R&D cooperation: evidence from Spanish manufacturing firms. International Journal of Industrial Organization 26 (1), 113–136.
Love, J.H., Roper, S., 2002. Internal Versus External R&D: A Study of R&D Choice with Sample Selection. International Journal of the Economics of Business 9(2), 239-255.
Maddala, G.S., 1983. Limited-Dependent and Qualitative Variables in Econometrics. Cambridge University Press, Cambridge.
McCullagh, P., 1980. Regression Models for Ordinal Data. Journal of the Royal Statistical Society. Series B (Methodological) 42 (2), 109-142.
Milgrom, P., Roberts, J., 1990. The Economics of Modern Manufacturing: Technology, Strategy, and Organization. American Economic Review 80, 511-528.
Miotti, L., Sachwald, F., 2003. Cooperative R&D: Why and with Whom? An Integrated Framework Analysis. Research Policy 32, 1481-1499.
Nakamura, K., Odagiri, H., 2005. R&D boundaries of the firm: an estimation of the double-hurdle model on commissioned R&D, joint R&D, and licensing in Japan. Economics of Innovation and New Technology 14 (7), 583-615.
Piga, C.A., Vivarelli, M., 2004. Internal and External R&D: A Sample Selection Approach. Oxford Bulletin of Economics and Statistics 66 (4), 457–482.
Piva, M., Vivarelli, M., 2009. The role of skills as a major driver of corporate R&D. International Journal of Manpower 30, 835-852.
Raymond, W., Mohnen, P., Palm, F., Schim van der Loeff, S., 2010. Persistence of Innovation in Dutch manufacturing: Is it Spurious?. Review of Economics and Statistics 92, 495-504.
Schmiedeberg, C., 2008. Complementarities of innovation activities: An empirical analysis of the German manufacturing sector. Research Policy 37, 1492–1503.
Schmidt, T., 2005. Knowledge Flows and R&D Co-operation: Firm-level Evidence from German. Discussion Paper No. 05-22, ZEW.
Segarra, A., Arauzo, J.M., 2008. Sources of innovation and industry-university interaction: Evidence from Spanish firms. Research Policy, 37(8), 1283-1295.
Segarra, A., Teruel, M., 2011. Productivity and R&D sources: evidence for Catalan firms. Economics of Innovation and New Technology, Forthcoming.
Tether, B., 2002. Who cooperates for innovation, and why: An empirical analysis. Research Policy 31(6), 947-967.

Vega Jurado, J., Manjarrés Henríquez, L., 2010. Cooperation with scientific agents and firm's innovative performance. INGENIO, Spain.

Veugelers, R., Cassiman, B. 1999. Make and buy in innovation strategies: evidence from Belgian manufacturing firms .Research Policy 28, 63-80.

Veugelers, R., 1997. Internal R&D expenditures and external technology sourcing. Research Policy 26, 303-315.

Veugelers, R, Cassiman, B., 2005. R&D cooperation between firms and universities. Some empirical evidence from Belgian manufacturing. International Journal of Industrial Organization 23(5-6), 355-379.

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“Innovation sources and productivity: a quantile regression analysis”
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**Segarra-Blasco, A.** (GRIT);
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**Bermúdez Morata, Ll.** (RFA-IREA); **Guillén Estany, M.** (RFA-IREA), **Solé Auró, A**. (RFA-IREA)
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