What Drives the Choice of the Type of Partner in R&D Cooperation? Evidence for Spanish Manufactures and Services

Erika Raquel Badillo[a*]
Rosina Moreno[a]

[a] AQR Research Group-IREA, Department of Econometrics, Statistics and Spanish Economy, University of Barcelona, Av. Diagonal 690, 08034 Barcelona, Spain (e-mail: ebadillo@ub.edu, rmoreno@ub.edu)

[*] Corresponding author. Department of Econometrics, Statistics and Spanish Economy, University of Barcelona, Av. Diagonal, 690, 08034, Barcelona (Spain). Tel.: +34 934021412; fax: +34 934021821.
E-mail address: ebadillo@ub.edu (E. Badillo).

Acknowledgements

Erika Badillo wishes to acknowledge the financial support from the AGAUR (Generalitat de Catalunya) through "the grant for universities and research centres for the recruitment of new research personnel (FI-DGR 2011)". Rosina Moreno acknowledges financial support provided by the Ministerio de Economía y Competitividad for the project entitled "Innovation and territory. Technological collaboration, international competitiveness and location factors", ECO2014-59493-R, as well as for the project "Redes de colaboración tecnológica e innovación. Determinantes y efectos sobre la competitividad de las empresas españolas" funded by the Fundación BBVA Ayudas a Proyectos de Investigación 2014. Thanks are also due to the Program ICREA Acadèmia.

What Drives the Choice of the Type of Partner in R&D Cooperation? Evidence for Spanish Manufactures and Services

Abstract

We analyse the heterogeneity in firms' decisions to engage in R&D cooperation, taking into account the type of partner (competitors, suppliers or customers, and research institutions) and the sector to which the firm belongs (manufactures or services). We use information from the Technological Innovation Panel (PITEC) for Spanish firms and estimate multivariate probit models corrected for endogeneity which explicitly consider the interrelations between the different R&D cooperation strategies. We find that placing a higher importance to publicly available information (incoming spillovers), receiving public funding and firm size increase the probability of cooperation with all kind of partners but the role is much stronger in the case of cooperative agreements with research institutions and universities. Our results also suggest that R&D intensity and the importance attributed to the lack of qualified personnel as a factor hampering innovation are key factors influencing positively R&D cooperation activities in the service sector but not in manufactures.

Keywords: R&D cooperation; Choice of partners; Industrial sector; Service sector; Innovative Spanish firms; Multivariate probit model

JEL classification: O32; L24; C35; L60; L80

1. Introduction

The relevance of collaborative research networks has been highlighted in the literature on innovation economics. The development of new products and processes in firms largely depends on the firms' ability to build networks and partnerships as a way to incorporate external knowledge for innovation (Lundvall, 1988, 2007; Tether, 2002; Powell and Grodal, 2005; Vega-Jurado et al., 2009; Trigo and Vence, 2011). Specifically, collaborative agreements have become a strategy of knowledge sharing and transfer across firms which is largely recognised as an important (quasi-market) mechanism to access such external knowledge (Schilling, 2008).

It is becoming increasingly important for firms to cooperate with other organizations to carry out their R&D activities. According to the Community Innovation Survey, the percentage of cooperative innovative firms in EU members increased from 25% in 2004 to 31% in 2012 (Figure 1). In particular, Spain, despite its low proportion of cooperative firms, presents one of the highest increases in such proportion, from 18% in 2004 to 29% in 2012. Indeed, from a policy perspective, an important part of EU and national public funding for R&D is addressed at stimulating cooperation between firms, and between firms and public institutions (López, 2008). The European Commission, for instance, recognizes partnerships between businesses, public entities and knowledge institutions as essential for success (European Commission, 2012).

[Insert Figure 1 around here]

Given the relevance and the growing interest of both academics and policy-makers in this phenomenon, the main objective of this paper is to examine the determinants in the choice of different R&D cooperation partners as a strategy to carry out innovation activities. Although a growing number of studies have analysed the motivations of cooperation in R&D according to its various forms, namely, with suppliers and/or customers, research institutions and competitors (Tether, 2002; Miotti and Sachwald, 2003; López, 2008; Arranz and Arroyabe, 2008; Segarra-Blasco and Arauzo-Carod, 2008; Abramovsky et al., 2009), less attention has been paid to the possible interrelation between these different types. The evidence shows that firms make simultaneous agreements with different types of partners (Belderbos et al., 2004, 2006), and consequently, the decisions on the type of cooperation partner may not be independent from each other. In this paper we will therefore study how the motivations for carrying out R&D cooperation agreements may differ according to the type of partnership chosen while controlling for the possible correlation between such R&D cooperation strategies.

Additionally, most of the previous empirical literature on the determinants of R&D cooperation rarely considers the service sector in their analyses, either because of lack of data or because services have long been considered to innovate scarcely. However, given the current increasing importance of this sector in most industrialized countries and the distinct nature of the innovative processes between manufacturing and service firms (Hoffman et al., 1998; Vega-Jurado et al., 2009) we explore and deep on the differences between manufacturing and service firms in relation to the driving factors forcing the formation of cooperation agreements.

We use data from the Technological Innovation Panel (PITEC), a comprehensive database of Spanish companies which mainly provides information on innovative activities. The longitudinal structure of the PITEC database allows us to perform a cross-section analysis taking into account the simultaneity bias inherent in this kind of analysis via the inclusion of lagged explanatory variables as well as via corrections for endogeneity through a control function approach.

After this introduction, Section 2 proceeds with the literature review. Section 3 describes the database and shows some descriptive statistics. Section 4 details the estimation methodology and Section 5 presents the empirical results. Finally, we present the major conclusions.

2. Literature Review

The **literature on industrial organization** emphasizes knowledge spillovers, both incoming and outgoing, as main determinants of R&D cooperation (Katz, 1986; D'Aspremont and Jacquemin, 1988; Kamien et al., 1992). *Incoming spillovers* are the flows of external knowledge that a firm is able to capture, while *outgoing spillovers* reflect the firm's ability to control the knowledge that flows outside it. The idea is that in order to internalize the information flows that may occur in the processes of innovation, and in order to manage these flows more effectively, firms decide to participate in cooperative agreements. But, do they do it differently depending on the type of partnership?

In an empirical study using data from the Community Innovation Survey (CIS) for Belgian industrial companies, Cassiman and Veugelers (2002) find that incoming spillovers and the firm's ability to appropriate returns from innovations have a positive and significant effect on the probability of R&D cooperation of any kind. These authors also show that the larger the incoming spillovers, the greater the likelihood of cooperation with research institutions and universities but that the extent of incoming spillovers has no effect on cooperation with suppliers and customers. Similar results are found in Veugelers and Cassiman (2005), López (2008), Abramovsky et al. (2009), Serrano-Bedia et al. (2010) and Chun and Mun (2012). With regard to outgoing spillovers it is concluded that a greater ability to appropriate the results of innovation through protection increases the likelihood of vertical cooperation and has no effect on agreements with research institutions. However, some works also argue that an excessive protection may hinder the internalization of the flows shared by the partners and may thus have a negative effect on R&D cooperation in general (Hernán et al., 2003; López, 2008).

Another determinant of R&D cooperation strategies, which is related to the flows of knowledge, is the firm's *absorptive capacity*. As point out by Cohen and Levinthal (1989) the absorptive capacity is required to assimilate and exploit knowledge in the environment; a company with more absorptive capacity is able to access a greater amount of knowledge than another with lower capacity, and will derive greater benefit from cooperation agreements in R&D. Absorptive capacity has been identified by many studies as an important feature of the firms that are more likely to cooperate (Bayona et al., 2001; Fritsch and Lukas, 2001; Miotti and Sachwald, 2003; Hernán et al., 2003; Belderbos et al., 2004; Röller et al., 2007; Arranz and Arroyave, 2008). However, distinguishing between types of cooperation, there is no clear conclusion of the effect of internal R&D effort on the decision to take part in cooperation of one type or another. Miotti and Sachwald (2003), using data for France, found a significant positive impact on the likelihood of agreements with research institutions and found no effect on the probability of vertical cooperation, but López (2008)'s conclusion for Spain was the opposite.

According to the **strategic management literature**, companies use research alliances with the idea of accessing complementary knowledge such as, *market knowledge or qualified personnel*, or in order to share *risks or costs* of R&D activities (Hagedoorn, 1993). However, empirical studies show mixed results regarding the effects of these factors on R&D cooperation (Chun and Mun, 2012). Sakakibara (1997) shows that access to complementary knowledge is one of the main motivations for cooperating in R&D. Bayona et al. (2001) report that both risks and costs of innovation activities are significant determinants of cooperation. In contrast, Miotti and Sachwald (2003) find that neither of these factors influence the likelihood of cooperation. Distinguishing between R&D cooperation according to type of partner, Belderbos et al. (2004) finds that the risk factors involved in innovation positively affect the likelihood of cooperation with competitors and suppliers, while cost-sharing is only relevant for the decision to cooperate with research institutions.

By distinguishing between different types of cooperation, Arranz and Arroyabe (2008), for the case of Spain, analyse the determinants of cooperation from a resource-based perspective. For example, they argue that *firm size* has a negative effect on cooperation with universities: that is, smaller firms tend to cooperate more with universities due to their limited technological resources. In this sense it is argued that firms need to have certain structure and resources to be able to face the commitment required in parnerships and to benefit from cooperation agreements. Likewise, following this line of thinking, these authors find evidence supporting the idea that when firms obtain public *R&D subsidies* they may be more likely to establish cooperation agreements with another firm or with institutions given that this way they have the resources to do the research. Among others, Miotti and Sachwald (2003), Belderbos et al. (2004), Busom and Fernández-Ribas (2008) and Abramovsky et al. (2009) also provide evidence supporting this argument.

Most empirical analyses have assumed that the strategies of cooperation with different types of partners in R&D activities are independent; however, the existence of simultaneous agreements with different partners may suggest that there are interrelations between such strategies which should be taken into account. Belderbos et al. (2004), using data from the Dutch Community Innovation Survey, apply a multivariate probit model which accounts for possible systematic correlations between the different cooperation strategies (competitors, suppliers, customers and research institutions). They supported the notion of interdependence between the different cooperation decisions, which may be due to complementarities in R&D

cooperation strategies but also to omitted firm-specific factors affecting all types of cooperation.

In regard to sectoral differences in the determinants of R&D cooperation, Abramovsky et al. (2009) provides some evidence on the heterogeneity in the motivation for R&D collaboration agreements across sectors. They obtain that cooperation is less frequent in manufactures which could be related to the fact that in such sector legal protection methods are used more intensively. As a direct consequence, one could think that a greater use of protection methods has a lower impact on R&D cooperation in the service sector than in manufacturing. However, Serrano-Bedia et al. (2010), who only analyse institutional cooperation for Spanish firms, find that legal protection is not statistically significant neither in the manufacturing nor in the service sector, so that certain ambiguity of the effect of appropriability seems to be there. Another interesting difference found in Abramovsky et al. (2009) refers to the impact of internal R&D intensity on cooperation which appears to be clearer in the service sector, implying that internal and external R&D might be substitutes in such sector, at a greater extent than in manufactures. However, Serrano-Bedia et al. (2010) provided evidence of a positive relationship between absorptive capacity and the incentives to cooperate both in manufactures and services in the Spanish case.

3. Data and Descriptive Analysis

The database used in this study is the Technological Innovation Panel (PITEC)[1], a panel produced jointly by the Spanish National Statistics Institute (INE), the Spanish Foundation for Science and Technology (FECYT) and the Cotec Foundation, with information on innovative activity of Spanish companies. PITEC is a survey carried out yearly and the questions about cooperation are asked in a 3-year period. The advantage of using this database is that it allows partial control over potential endogeneity problems inherent in this kind of analysis by introducing lags in the explanatory variables. Specifically, the variables for R&D cooperation (dependent variables) are taken from the 2008 survey (wave 2006-2008), while the explanatory variables correspond to the 2006 survey (wave 2004-2006).[2]

[1] This database is available to the public at http://icono.fecyt.es/PITEC/Paginas/por_que.aspx

[2] Note that, although PITEC has a panel structure, we carried out a cross-section analysis because of the complexity of the estimation strategy, as discussed in section 4.1.

The PITEC sample in 2008 contains information on 12813 businesses, but after a cleaning of the data[3] and selecting only the firms of manufacturing and services, the figure falls to 10443. Moreover, since the aim of this paper is to study R&D cooperation, and since only firms engaged in innovation respond to the questions relevant to cooperation, the analysis is restricted to the group of innovative companies.[4] Finally, our sample comprises 7362 companies. Table A1 in the Appendix provides more information on the selection of the sample.

PITEC asks firms which kind of partner they cooperated with in their innovation processes. According to this question, we distinguish between three different types of cooperation agreements:[5]

- Horizontal cooperation: cooperation agreements with competitors or other enterprises of the same sector.
- Vertical cooperation: cooperation agreements with suppliers of equipment, materials, components or software or with customers or clients.
- Institutional cooperation: cooperation agreements with consultants, commercial labs, or private R&D institutes, universities or other higher education institutions, government or public research institutes, technological centres.

Table 1 shows the different strategies of cooperation chosen by innovative companies. Around 34% of innovative enterprises in the industrial and service sectors reported cooperating with at least one partner during the period 2006-2008. Research institutions are the main partners in innovation activities, accounting for 78% of all cooperation agreements, while only 24% of firms cooperate with their competitors. Moreover, we see that 48% of companies maintain agreements simultaneously with at least two types of partners. For example, out of the 1954 companies that cooperate with institutions, 60% also have agreements with other partners. It seems, therefore, that companies find benefits in having

[3] Firms that report confidentiality issues, mergers, closures, employment incidents and so on are eliminated, as are those observations that present anomalies such as firms with zero business levels or excessively high values of R&D intensity, measured as the ratio between R&D expenditure and turnover (the rule used was the mean plus twice the standard deviation).
[4] That is, firms that have introduced innovations in products or processes, or who were undertaking innovation activities during the analysed period or abandoned them.
[5] The survey also offers information on another type of cooperation: cooperation with firms in the same group. However, we do not consider such typology since only firms belonging to a group can cooperate within their group, while all the other types of partners can be chosen by all firms. However, in order to control for possible different behaviour of such firms, the regression analysis includes a dummy variable for firms belonging to a group. The same kinds of cooperation are used in López (2008) and Abramovsky et al. (2009).

different forms of cooperation simultaneously. Specifically, the data show that cooperation with research institutions tends to be most often complemented by vertical cooperation.

[Insert Table 1 around here]

The proportion of innovative companies with the diverse types of cooperation agreements and according to the two sectors under consideration is shown in Table 2. As it can be seen, there is a higher proportion of innovative companies in the industrial sector (80.9%) than in the service sector (61.3%). However, the propensity to cooperate is higher in the service sector: 40% of innovative companies in this sector have cooperation agreements with other partners, compared to 31% in the industrial sector. This may be related to the fact that manufacturing firms use legal protection methods more intensively and then, they do not need to cooperate to have a secure atmosphere where to carry out innovation activities. That is, cooperation may act as a substitute to legal protection through patenting. On the contrary, it seems that the formal protection methods used in the service sector, more relying in trademarks and copyright would not be working as a substitute to R&D cooperation activities.

Table 2 also shows that innovative companies in both sectors prefer to cooperate with research institutions (31% in services versus 24% in manufactures) followed by suppliers or customers (24% versus 19%). In turn, the least frequent partner is that of competitors, with the highest difference among sectors found in such a case (13% in services and 5% in manufactures). This low level of horizontal cooperation may be just because firms do not find it profitable to do so either because of anticompetitive or procompetitive reasons. According to the former, cooperation with rivals offer firms an opportunity to coordinate behaviour, which can facilitate collusions. However, in many cases collusive arrangements are not attractive because of free-riding behaviour or anti-trust concerns and hence make firms less likely to form R&D collaborations with competitors (Goeree and Helland, 2010). We might expect incentives to cheat to be stronger within cooperation agreements with competitor firms, leading to horizontal cooperation being less frequent and even less in the manufacturing sector, where competition tends to be higher (Abramovsky et al., 2009). On the other hand, procompetitive benefits from R&D collaborations, such as shared risks, alleviated financial constraints and shared costs could not be achieved large enough to compensate anticompetitive effects of collusion (Gugler and Siebert, 2007).

[Insert Table 2 around here]

Table 3 presents statistics on the characteristics of the companies engaged in cooperation and according to the types of agreement involved. It appears that innovative firms that engage in cooperation agreements are more likely to place higher importance on incoming spillovers and to receive public funding than those which do not cooperate; they also tend to have a higher mean of internal R&D intensity, and use some form of legal protection at a higher rate. A conclusion which is consistent in both sectors.

Related to size, smaller firms in both sectors show a greater propensity to cooperate than big firms. But if we focus on SMEs (i.e. the group of firms with less than 50 employees), while in the service sector the percentage of firms cooperating and not cooperating is exactly the same, in the case of manufactures there are nine percentage points of difference in favour of non-cooperative firms. This suggests that SMEs in the industrial sector are not so motivated to cooperate as in the case of services.

[Insert Table 3 around here]

Finally, Table 3 shows that the differences in the characteristics of cooperative firms are minimal according to the type of cooperation partner, except that companies involved in horizontal cooperation have higher mean of internal R&D intensity and are more likely to have received some public financial support for their innovation activities in the case of the industrial sector.

4. Estimation Procedure

4.1 Method of estimation

We define three binary dependent variables for each of our three types of cooperation: horizontal, vertical and institutional cooperation. In order to identify the determinants of the decisions to participate in the different forms of cooperation, we specify and estimate a multivariate probit model that accounts for systematic correlation among the different decisions to cooperate. As noted in the previous section, the different cooperation strategies chosen by the firms are not mutually exclusive, which may imply that the choice of diverse types of partners is not independent from each other. Additionally, such systematic correlation may account for unobserved factors affecting all equations, so that estimating separate (probit) equations would lead to inefficient estimations (Zellner and Haung, 1962).

Although we had other estimation alternatives, we considered them not to be suitable. For instance, Kaiser (2002) estimates a nested logit model which assumes a sequential process in which firms initially decide whether to cooperate or not and, in a second step, they decide the type of cooperation partner. However, this approach does not take into account that firms can simultaneously engage multiple types of cooperation agreements. Additionally, a multinomial logit approach should consider all the potential excluding alternatives of cooperation, which are the eight alternatives shown in Table 1. This type of multinomial choice modelling has several weaknesses: it has too many parameters and it is difficult to interpret, and the Independence of Irrelevant Alternatives (IIA) assumption is likely to be violated given that the decisions of cooperation between the different types of partners are interdependent (McFadden, 1974).

We have three latent variables, $y^*_{i1}, y^*_{i2}, y^*_{i3}$ which measure the difference between benefits and costs that company *i* obtains by cooperating in R&D with competitors, with suppliers and/or customers, and with research institutions, respectively. Assuming that these differences depend linearly on a set of firm and sectoral characteristics, contained in *x*, we have:

$$y^*_{ij} = x'_{ij}\beta_j + \varepsilon_{ij}, \qquad j = 1, 2, 3 \qquad (1)$$

where β_j is a vector of parameters including the constant term and ε_{ij} are error terms distributed as a normal multivariate, each with mean zero and a variance-covariance matrix *V*, where *V* has values of 1 on the leading diagonal and correlations $\rho_{jk} = \rho_{kj}$ (*k*=1, 2, 3) as off-diagonal elements.

Since the latent variables are not directly observable and only their signs can be accounted for, binary variables are defined that summarize the signs as the choice made by firms for each type of partner. Thus, the multivariate probit model specifies the binary variables as follows:[6]

$$y_{ij} = \begin{cases} 1 & if \quad y_{ij}^{*} > 0 \\ 0 & if \quad y_{ij}^{*} \leq 0 \end{cases} \qquad j = 1, 2, 3 \qquad (2)$$

In this case, with three equations, there are eight joint probabilities corresponding to the eight combinations of different types of partners for cooperation and non-cooperation (as given in Table 1). The possible probabilities are determined by (Wooldridge, 2002; Capellari and Jenkins, 2003; Cameron and Trivedi, 2005; Greene, 2008):

$$\begin{aligned} p_{hkl} &= \Pr\left[y_1 = h,\, y_2 = k,\, y_3 = l\right] \\ &= \Phi\left(q_1 x_{i1}^{'} \beta_1,\, q_2 x_{i2}^{'} \beta_2,\, q_3 x_{i3}^{'} \beta_3,\, \rho_{21},\, \rho_{31},\, \rho_{32}\right) \end{aligned} \qquad (3)$$

where $\Phi(.)$ is the normal trivariate distribution function, q_n=1 if y_{in}=1 and q_n=-1 if y_{in}=0 for n=1, 2, 3. These probabilities are the basis for the maximum likelihood estimation, which is carried out using the routine developed by Cappellari and Jenkins (2003) who use simulation methods of the maximum likelihood function, specifically the GHK (Geweke-Hajivassiliou-Keane) simulator to calculate the probabilities.

4.2 Variables

Bearing in mind the literature review presented above, among the reasons leading firms to engage in collaborative innovative activity, in this paper we focus on the roles of incoming spillovers and legal protection, cooperation as a means of overcoming constraints (i.e. risks, costs and lack of qualified personnel), the absorptive capacity of the firm and the receipt of public funding for innovation. We also control for some firm’s characteristics such as firm size, belonging to a group of enterprises and sectoral dummy variables indicating the sector to which the firm belongs to. Although all these variables are listed and defined in Table 4, we make here some clarifications.

[6] Note that firms can choose not to cooperate in all cases.

Incoming spillovers are measured by the importance that the firm attributed, on a four-point scale, to publicly available information for the innovation process of the firm. The information sources were conferences, trade fairs, exhibitions, scientific journals and trade/technical publications, professional and industry associations. To generate a firm-specific measure of incoming spillovers, we aggregated these answers by summing the scores on each of these questions and then the variable was rescaled from 0 (unimportant) to 1 (crucial). Firms that rate generally available external information sources as more important inputs to their innovation process are expected to be more likely to be actively engaged in cooperative R&D agreements. With the same survey data, we also computed the variable proxying for *legal protection*, which considers whether the firm used at least one legal method for protecting inventions or innovations (patents, registered an industrial design, trademark or copyright), taking a value of 1 if used, and 0 otherwise. There is not a consensus on the impact of such variable on cooperation, as surveyed in section 2. Although we could have considered other proxies for these spillover variables, we have followed Cassiman and Veugelers (2002) who pointed that the advantage of the ones suggested here is that they are direct and firm-specific, allowing for heterogeneity among firms.

Other motives for engaging in cooperative R&D, such as cost- and risk-sharing and access to qualified personnel, have been proxied through the rates the firm attributed to the different obstacles to innovation: the uncertain demand for innovative goods or services (*Risks*), the lack of funds within the enterprise or lack of finance from sources outside the enterprise or the consideration that innovation costs are too high (*Costs*) and the lack of qualified personnel (*Lack of HK*). In the three cases, the variables were rescaled from 0 (unimportant) to 1 (crucial). This way, when costs, risks or lack of personnel are an important obstacle to innovation, we expect to observe more cooperative R&D agreements for the purpose of cost-, risk- and personnel-sharing.

Absorptive capacity as well as the firm's internal innovative activity is captured through the ratio between the intramural R&D expenditure and turnover (*R&D intensity*). *Firm size* (<50 employees, 50-249, 250-499 and >500), *public funding* of innovation and *belonging to a group* are binary dummy variables, taking the value 1 if the firm belongs to the corresponding size range, has received any kind of public funding (local, regional or national) and belongs to a group of companies, respectively, and zero otherwise. Finally, we included dummy variables for the sector, which we assume will pick up unobserved sectoral-specific attributes that contribute to the decision of a firm to enter into an R&D cooperative agreement.[7]

[Insert Table 4 around here]

As the coefficients of multivariate probit models cannot be directly interpreted, we calculated the marginal effects on the unconditional expectations of the dependent variables. The marginal effect of an explanatory variable, x_{ij}, on the unconditional expectation of a dependent variable, y_{ij}, shows the impact of such explanatory variable on the propensity to engage in any kind of cooperation unconditional to another cooperation adopted by the firm. We present the marginal effects calculated at the mean marginal effect over all observations.[8]

4.3 Addressing the problem of endogeneity

One problem in our estimation procedure refers to the possible endogeneity of some explanatory variables mainly due to simultaneity in the decision to engage in R&D cooperation agreements. In fact, both theoretical literature on Industrial Organization and most empirical literature, have signalled that the extent to which firms benefit from incoming spillovers, the extent to which they can appropriate the returns to their innovative activity and the amount of resources devoted to R&D can themselves depend on whether or not firms engage in cooperation agreements (Cassiman and Veugelers, 2002; Belderbos et al., 2004; López, 2008). We next explain the potential endogeneity of these three variables.

Incoming spillovers may be affected by R&D cooperation activities because firms may use these agreements to manage external knowledge flows and because the ability to create incoming spillovers from the general pool of knowledge can be a function of other innovation activities of the firm such as participation in cooperative agreements. Also, cooperating firms may try to maximize incoming spillovers among partners through information sharing, which will enhance the stability of cooperation. At the same time, firms that cooperate tend to protect their proprietary knowledge. In other words, we expect that firms engaged in cooperation agreements have an incentive to become more successful at controlling

[7] We include a binary sector variable (1=manufactures and 0=services) in the model for the whole sample and industry dummies at 2-digit level according to NACE-93 in the separate models for manufactures and services.
[8] A more detailed explanation of several types of marginal effects can be found in Sodjinou and Henningsen (2012).

information sharing with their partners, as well as limiting free-riding by nonpartners. On the other hand, since cooperation R&D agreements may make internal expenditures more effective, R&D intensity can be influenced by such agreements.

Following the reasoning above and thanks to the availability of two different waves from our database, we lagged explanatory variables in order to limit the simultaneity bias inherent to this kind of studies, enabling us to overcome an important limitation in most previous studies. However, this approach only reduces the bias but does not correct for it.[9] Therefore, we attempt to deal with this potential endogeneity through a two-stage residual inclusion (2SRI) method (Terza et al., 2008). More generally this method is called a control function approach (Rivers and Vuong, 1988; Wooldridge, 2002), which has been shown to be consistent in non-linear models. In a nutshell, the first stage consists of the estimation of the residuals from the regression of the potential endogenous variables on all the assumed exogenous explanatory variables and the instruments. The second stage is the estimation of our main model including the predicted residuals obtained from the first stage as additional regressors (without excluding the potential endogenous variables). According to Rivers and Vuong (1988), the usual t-statistic on the coefficient of the residuals is a valid test of the null hypothesis of exogeneity.

As instruments, we use the following ones: basicness of R&D, export intensity and the industry averages for each of the potentially endogenous variables at the two-digit industry level. With respect to the basic idea behind these instruments, *basicness of R&D* represents the extent to which the firm's R&D activity is directed towards basic research. According to Kamien and Zang (2000) firms for which the sources of basic R&D are more important for their innovation process are more likely to benefit from incoming spillovers. Therefore, we proxy the basicness of R&D performed by the firms through the variable that picks up the importance given to sources of information from universities or research institutes for the innovation processes. We expect this variable to be positively correlated not only with the score on incoming spillovers, but also with R&D intensity, in other words, the firm's absorptive capacity.

[9] Despite lagging the explanatory variables, as pointed out by Belderbos et al. (2004), if cooperation is persistent, the factors determining this cooperation are still partly affected by those R&D agreements that were formed in the past and still in existence in the current period.

Turning to *export intensity*, this variable attempts to measure the extent of competition that firms face and we expect that it has a positive correlation with the use of protection methods. The idea is that exporting firms, which typically face a more competitive environment, protect more their innovation given their higher reliance on protection methods (Arundel and Kabla, 1998; Cassiman and Veugelers, 2002).

Finally, *industry level averages of incoming spillovers*, *legal protection* and *R&D intensity* are included in order to pick up the effect of unobserved industry-specific characteristics related to the respective potentially firm-specific endogenous variable (Pakes, 1983; López, 2008). Although it must be admitted that it is likely that some of these instruments are not completely exogenous, we must highlight the difficulty to find suitable instruments in the kind of database used in this research, namely a survey, in which the number and type of variables available are given a priori. In addition, we must signal that the instruments chosen in this piece of research have been also considered in previous papers (Cassiman and Veugelers, 2002; López, 2008; Abramovsky et al., 2009; Chun and Mun, 2012). In any case, in the next section we provide empirical evidence on the validity of our instruments.[10]

5. Results

With the aim of analysing the determinants of R&D cooperative agreements with different types of partners and seeing the differences between the industrial and service sectors, in a first stage we estimate a model for all firms in both sectors and include a sectoral dummy variable to control for unobserved determinants common to the sector. Afterwards, we perform the same estimation for the subsamples of industrial and service firms separately. In the latter, we also include industry dummies at the 2-digit level according to NACE-93.

5.1 Considering endogeneity

The endogeneity of the variables proxying for incoming spillovers, legal protection and R&D intensity is confirmed by applying the Rivers-Vuong test and calculating the Durbin-Wu-Hausman endogeneity test (see Table 5 and Table A3 in the Appendix). In this approach the

[10] In addition, following Pakes (1983)'s study and some recently literature (Arvanitis and Bolli, 2013), we also estimated our models using the industry averages for each of the potentially endogenous variables as the only instruments; that is, excluding export intensity and basicness of R&D variables of the set of instrumental variables. Overall, the main results remain. They can be provided by the authors upon request.

instruments must satisfy two conditions: relevance and exogeneity. The first condition can be tested on the basis of the first stage regressions shown in Table A4 of the Appendix, through the computation of two tests: the Angrist-Pischke test of underidentification and the F test for weak instruments (Wooldridge, 2002; Angrist and Pischke, 2009). The first checks whether the model is identified, identification requiring the excluded instruments to be correlated with the potentially endogenous variables. The second tests weak identification which arises when the instruments are correlated with the potentially endogenous variables, but only weakly. The values for both tests (Table A4 in the Appendix) show that the null hypothesis of underidentification is rejected, the same as for weak instruments, concluding in favour of the relevance of the instruments.[11]

The second condition, the exogeneity of the instruments, is more complicated to test in the context of a multivariate probit model, because tests on the exogeneity of the instruments, such as the Sargan's test of overidentifying restrictions, have not been implemented for this kind of models. Nevertheless, in order to provide some evidence about such exogeneity, we compute the Sargan's test but in the framework of separate univariate probit models (Newey, 1987; Lee, 1992). In this context, this is done by regressing the residuals from an instrumental probit model (a probit for each type of cooperation) on all instruments, where the joint null hypothesis states that the instruments are valid, that is, that they are uncorrelated with the error term, and that the exclusion of exogenous instruments is correct.

The results of the Sargan's tests of overidentifying restrictions (Table A5 in the Appendix) reveal that the joint null hypothesis that the excluded instruments are uncorrelated with the error term and, therefore, correctly excluded from the estimated equation, cannot be rejected neither for the whole sample nor for the manufacturing and service samples separately. Therefore, these results point to the validity of the instruments used.

The estimated coefficients and their corresponding marginal effects of the second-stage are presented in Tables 5 and 6, respectively.[12] Although the results without instrumenting are not reported here if compared with the results in Table 6, we must admit that there are differences in some of the marginal effects, nevertheless, the main results are maintained. For instance,

[11] Note that the partial R^2 of the first stage are very low and the value of the F-tests statistics are well above 10, which is usually considered a good threshold, and so the instruments cannot be judged as weak.
[12] In order to adjust the coefficients' standard errors for the use of generated regressors we have obtained them through bootstrapping.

the marginal effects of incoming spillovers and R&D intensity are higher in the estimations corrected by endogeneity problems, probably due to endogeneity biases or alternatively to measurement errors. As pointed out by Cassiman and Veugelers (2002) in the case of incoming spillovers, the problem may arise from the use of qualitative measures for which the estimates without correcting for endogeneity are biased towards zero. The downward bias can also reflect the impact of past cooperation on the importance to publicly available information for innovation since once the firm has engaged in cooperation agreements, it could place more importance to knowledge flows shared among partners than to other external sources of information. After instrumenting, we also find that the marginal effects of the legal protection variable are not significant any more, with the exception of the cases of vertical cooperation for the whole and the manufacturing samples, in which this variable presents a negative effect. Overall, our analysis on the endogeneity problem shows that it can affect the results on the determinants of R&D cooperation strategies and hence, our procedure, not only considering lagged explanatory variables but also performing a two-step estimation, allows us to mitigate the bias produced.

[Insert Tables 5 and 6 around here]

5.2 Determinants of cooperation strategies for innovation

The results of the estimations on the determinants of cooperation strategies for the whole sample, and by industrial and service sectors separately, reported in Table 5, show that the error terms are positively and significantly correlated (ρ) across the different types of cooperation partners indicating the superiority of the multivariate probit model to the estimation of separated univariate probit models. In order to ease the analysis of the determinants of the different R&D cooperation strategies as well as the differences between the industrial and service sectors, we computed the marginal effects of each one of the explanatory variables (Table 6).

In general terms, we can observe that the determinants of R&D cooperation differ among the different types of cooperation partners. This finding shows the heterogeneity in the motivations for carrying out the different types of cooperation, and points to the need of studying them separately. We also note a significant effect of the sector on the probability of cooperating with any partner. The statistical significance of the marginal effects associated with the variable sector in the model for the whole sample and the different effects observed in the separated estimates for industrial and service firms, highlight these sectoral differences. We calculated a likelihood ratio test (LR) comparing the coefficients obtained for the full sample of firms with the ones obtained in the two separate subsamples (manufacturing and service firms). We obtained a test statistic of 67.42 which is above the critical value of the chi-squared with 89 degrees of freedom. So, we can conclude that there are significant differences between sectors in the sets of marginal effects. The negative sign of the sector variable in Table 6 shows that the probability of cooperating is lower for manufactures than for services, with much more pronounced differences in the case of horizontal cooperation (with competitors), while no significant differences are found between the two sectors in the case of vertical cooperation. These results are consistent with the descriptive statistics shown in Section 3. All in all, cooperation is less frequent in manufactures which can be related to the fact that in such sector legal protection methods are used more intensively. That is, cooperative innovation may be used as a substitute to patenting in the manufactures but not in services.

With respect to the main drivers of R&D cooperation, results show a positive and significant relationship between incoming spillovers and the likelihood of the three types of cooperation. The higher the importance attributed by the firm to external sources of information, the more likely it is to obtain benefits through cooperation agreements (Cassiman and Veugelers, 2002; López, 2008). This impact is significantly higher in the case of partnerships with research institutions, particularly in industrial firms: a higher importance given to publicly available information increases the probability of institutional cooperation by approximately 92 and 72 percentage points in the industrial and service sector, respectively. This result is in line with the theoretical argument given by Abramovsky et al. (2009) that firms which are able to get more benefits from external knowledge might be more likely to engage in cooperation agreements with the research base or, at least, with firms outside their own industry. So, it seems fair to conclude that industrial firms benefit the most from the information coming from external sources, especially with regard to cooperating with research institutions. This probably has to do with the basicness of the research carried out by research institutions and universities, which is more likely to be of direct relevance to manufacturing firms.

The results for the legal protection variable, proxying for appropriability, show that it has a negative and significant effect on cooperation with suppliers or customers at the level of the whole sample and for industrial firms, but not in the rest of partnerships. This suggests that a higher use of legal protection methods may hamper the internalization of knowledge flows shared between manufacturing firms, in particular with suppliers or customers, and may thus decrease the probability of this kind of R&D cooperation agreements. In the case of the service sector we do not observe any significant effect. As mentioned by Abramovsky et al. (2009), cooperation might be perceived as a substitute to protection methods such as patenting innovations in the industrial sector, whereas it may not be used as a substitute to formal protection methods such as trademarks and copyright in service firms. That is, a higher use of protection methods has a lower impact on R&D cooperation in the service sector than in manufacturing. In any case, we may highlight that this result is only valid for vertical cooperation, since in all other cases, there is not a significant effect, probably due to the ambiguity of the impact of appropriability.

Regarding R&D intensity, the results show that the higher internal R&D intensity, the higher likelihood of cooperation with suppliers or customers and research institutions, but only in the service sector. This positive result is consistent with the literature highlighting the fact that a higher absorptive capacity of a firm may allow it to derive greater benefits from cooperation with other partners (Cohen and Levinthal, 1989). However, we do not find internal R&D intensity to affect significantly such decisions in the industrial sector. A possible explanation for this might be that the magnitude of internal R&D expenditure over turnover (as shown in Table 3) is much lower in manufactures than in services.

As far as factors hampering innovation activities are concerned, the results show that cost-sharing is not a significant motivation for cooperation in the Spanish case. Additionally, when a higher importance is attributed to risk, we obtain a lower probability of institutional cooperation, with no significant impact in the case of the other two types of partners (vertical and horizontal cooperation) for manufactures. This negative effect is also found in Veugelers and Cassiman (2005) for Belgian industrial firms. These authors claim that given the specific characteristics of scientific knowledge, the relation between research institutions and industrial firms is characterized by a large amount of uncertainty and therefore a higher risk makes it more difficult to enforce partner compliance in cooperation agreements.

Another difference between the industrial and service sectors lies in the importance of the limitations related to the lack of qualified personnel (lack of HK). No significant effects are found for the whole sample, but when it is split into industrial and services the impacts are notable in the latter. A higher importance attributed by service firms to the lack of human capital increases the probability of any kind of cooperation by approximately 5 percentage points. This positive effect implies that firms see the possibility of accessing additional human resources through partnerships with other companies or institutions. In contrast, decisions on R&D cooperation in the industrial sector do not seem to be driven by a shortage of human resources. This result is probably related to the fact that innovation is more closely involved with worker skills in the service sector than in manufactures, where machine and equipment play a more important role in the innovation process (Baldwin, 1999).

Public financial support from local, regional and national administrations is one of the main determinants of cooperation in the Spanish case in all its forms. The highest positive effect is found in the case of cooperation with research institutions, especially in the service sector. As shown in Table 6, the probability of engaging in institutional cooperation in the service sector is around 21 percentage points higher among firms that receive public funding for innovation compared to non-receivers of such funding. This effect is notably greater than for the other types of partnership (the marginal effects are approximately 10 percentage points lower in the horizontal and vertical cooperation). This positive effect of public funding may be due to the fact that subsidies are often designed to encourage the interaction between businesses and research institutions. Moreover, companies that can alleviate financial problems by means of public funding are keener to cooperate with their competitors, perhaps because public funding is a factor that is outside the realm of competition (Tether, 2002). In other words, there are reasons to believe that public support programs for R&D activities may ease cooperative innovation agreements by firms that would otherwise do not engage in such activity.

Finally, the results show that, in general, large companies are more likely to establish agreements for innovation without striking differences neither among types of partnerships nor between sectors. In both sectors, companies with more than 500 employees are most likely to cooperate with suppliers or customers (14 and 18 percentage points higher than SMEs in the industrial and the service sector, respectively), followed by cooperation with research institutions (10 and 9 percentage points higher in the industrial and the service sector, respectively). The ability of large firms to better reap the returns of cooperation agreements, thanks to the availability of a greater structure and resources to be able to face the commitment required in partnerships, would explain this higher probability of cooperating. And therefore, the argument that small firms may cooperate more intensively because they may need such cooperation in order to manage innovation activities which otherwise could not carry out because of their limited resources seems not to be applicable for the Spanish case.

5.3 Interrelations between cooperation strategies

As mentioned in the previous section, the perturbation terms of the different equations, each one for one type of cooperation partner, were positively and significantly correlated, indicating that analysing all cooperation decisions simultaneously is much more efficient that analysing each one separately, in other words, the results of our multivariate probit model are more precise than the results from separate traditional probit models. The positive sign of such correlations may be due to the existence of certain unobserved factors influencing the choice of several types of cooperation in the same direction (e.g. managerial ability or the stock of tacit knowledge) and/or that the cooperation with one partner may drive the cooperation with another type.[13]

In this sense, in Table 7 we present the correlations between the R&D cooperation decisions in the data, between the disturbances terms of the different partnerships and between the unconditional probabilities predicted by our multivariate probit model. While the correlation coefficients of the perturbation terms provide evidence about the existence of interrelations between cooperation decisions due to common unobserved factors or complementarities, the correlations between the unconditional probabilities indicate that such interrelations are due to common observed factors.[14] As seen from Table 7, all these coefficients of correlation are statistically significant and positive, with higher values in the case of the correlations between the unconditional probabilities, which indicate that the interrelations between the cooperation strategies decisions are mainly driven by common observed factors.

[13] As pointed out by Belderbos et al. (2004), the multivariate probit model takes these correlations into account, without being able to distinguish between the two sources of correlation. In this regard, a formal test of complementarity as in Mohnen and Röller (2005) would be necessary but it is beyond the scope of this paper.
[14] See Sodjinou and Henningsen (2012) for an application in the case of the interrelations between different technology adoption decisions.

Finally, our model allows us to obtain the predicted conditional probabilities of engaging in a certain type of cooperation partnership given that another cooperation decision is made. The values of such probabilities are reported in Table 8. The most striking conclusion from these results is that, on average, the probability of engaging in one type of cooperation is higher when another cooperation partnership has already been carried out simultaneously. For example, for industrial firms, the predicted probability of engaging in vertical cooperation, column P(V=1), if the firm also participates in institutional and horizontal cooperation projects is 79%, while this probability is only 13% when the firm does not participate in any other kind of cooperation agreement. Additionally, it is also important to point out that the predicted probability of carrying out cooperation with competitors (horizontal cooperation) when at least one other type of cooperation has been chosen is notably higher for service than industrial firms. That is, carrying out at least one type of cooperation facilitates the existence of cooperation with competitors in the service sector, whereas this relationship is less likely to occur among manufactures. This can be related to the lower competition present in services, leading them to cooperate more with competitors, and with a higher rate in the case of having the experience and the expertise provided by the fact of being already working cooperately in R&D projects with other types of partners.

6. Conclusions

This paper analysed the determinants in the choice of the different strategies of R&D cooperation (horizontal, vertical and institutional cooperation), with particular emphasis on the heterogeneities of their impact across the different strategies while explicitly considering the interrelations between them. Additionally, we tried to disentangle the differences between firms in the service and manufacturing sectors when choosing partners for R&D cooperation. The analysis was performed with data from the Technological Innovation Panel (PITEC) using the waves 2006 and 2008 for Spanish innovative firms. The availability of two waves as well as the use of a control function approach allowed us to address the problem of endogeneity.

Spanish firms tended to choose simultaneously several types of partners to carry out their innovation activities. Around 48% of the enterprises that decided to cooperate did so with at least two types of partners, and almost 14% cooperated with the three types of partners at a time. The most common partner was research institutions, and it was most frequently matched with partnerships with suppliers and/or customers. Statistical tests suggested that the choice of the type of partner is not independent one from another, pointing to the need for a multi-equation estimation that considers the interdependences between the three cooperation strategies. In fact, the econometric estimates obtained using a multivariate probit model corroborated the validity of this method compared with univariate estimations.

Related to the drives of R&D cooperation we confirmed that, in the case of Spanish firms, incoming spillovers were an important determinant of the choice of cooperating with any type of partner, regardless of the sector, but this impact was significantly higher in the case of partnerships with research institutions and universities. This result is consistent with the notion that firms which are able to get more benefits from external knowledge might be more likely to engage in cooperation agreements with the research base or, at least, with firms outside their own industry. Similarly, public funding also played a key role in the firms' decisions to cooperate, especially when the partners are research institutions. This may be related to the fact that much of the public funding for innovation aims to encourage and promote knowledge transfer from research institutions to companies. Results also show that large firms are more likely to cooperate with all types of partner than small firms, highlighting the fact that large firms are more likely to face the commitment required in partnerships and better reap the returns of cooperation agreements.

The differences found among the main determinants of R&D cooperation across sectors are also of great interest. In the case of Spanish firms, there was a greater propensity to cooperate in the service sector (40%) than in manufactures (31%). Additionally, this lower probability of R&D cooperation for manufactures was more pronounced in the case of horizontal cooperation (with competitors). This can be related with previous findings suggesting that in the manufacturing sector, for which legal protection methods are in general more important than for the service sector, cooperation may act as a substitute to legal protection through patenting. With respect to the effects of factors hampering innovations activities, a higher importance attributed to risk makes manufactures less likely to enter cooperation agreements with research institutions while in the service sector this factor is less important in influencing this type of cooperation. On the other hand, the need to address shortfalls of human resources to carry out innovations activities via cooperation agreements with different kinds of partners is an important factor for service firms but not for manufactures. Firms in the service sector see cooperation agreements as an effective way to enhance and complement their human resources for carrying out R&D activities. These differences are presumably due to sectoral differences in the orientation of innovations in industrial and services firms, since, for instance, innovation is more closely involved with worker skills in the services sector than in manufactures, where machine and equipment play a more important role in the innovation process (Baldwin, 1999). Finally, using legal protection methods reduces the probability of cooperating with suppliers and customers in the case of manufactures. This can be due to the fact that legal protection methods may hamper the internalization of knowledge flows shared between firms.

All in all, this paper has given evidence on the differences observed in the determinants of R&D cooperation agreements among the different types of partnership and also across different sectors, which should be taken into account when designing policies that aim to encourage R&D cooperation as a means of increasing innovation in firms. In other words, the extent to which the motives for cooperation vary with different partners, which has been observed to be especially different in the case of R&D cooperation agreements with research institutes or universities, should be considered when policy makers decide the targets of their R&D policies, if they aim to maximise the impact of public funding. In this sense, it seems sensitive for public administrations to seek ways of directing a higher proportion of their funding towards firms that have the potential to gain significant benefits from working cooperatively in R&D projects with universities.

References

Abramovsky, L., Kremp, E., López, A., Schmidt, T. and Simpson, H. (2009) Understanding co-operative innovative activity: Evidence from four European countries, *Economics of Innovation and New Technology*, 18(3), pp. 243-265.

Angrist, J.D. and Pischke, J.-S. (2009) *Mostly Harmless Econometrics: An Empiricist's Companion*. Princeton: Princeton University Press.

Arranz, N. and Arroyabe, J.C.F. (2008) The choice of partners in R&D cooperation: An empirical analysis of Spanish firms, *Technovation*, 28(1/2), pp. 88-100.

Arundel, A. and Kabla, I. (1998) What percentage of innovations are patented? Empirical estimates for European firms, *Research Policy*, 27(2), pp. 127-141.

Arvanitis, S. and Bolli, T. (2013) A comparison of national and international innovation cooperation in five European countries, *Review of Industrial Organization*, 43, pp. 163–191.

Baldwin, J.R. (1999) Innovation, training and success, *Research paper* No. 137, Analytical Studies Branch, Statistics Canada, Ottawa.

Bayona, C., Gracia-Marco, T. and Huerta, E. (2001) Firms' motivation for cooperative R&D: An empirical analysis of Spanish firms, *Research Policy*, 30(8), pp. 1289–307.

Belderbos, R., Carree, M.A., Diederen, B., Lokshin, B. and Veugelers, R. (2004) Heterogeneity in R&D co-operation strategies, *International Journal of Industrial Organization*, 22(8/9), pp. 1237–63.

Belderbos, R., Carree, M.A. and Lokshin, B. (2006) Complementarity in R&D cooperation strategies, *Review of Industrial Organization*, 28(4), pp. 401–426.

Busom, I. and Fernández-Ribas, A. (2008) The impact of firm participation in R&D programmes on R&D partnerships, *Research Policy*, 37(2), pp. 240-257.

Cameron, C. and Trivedi, P. (2005) *Microeconometrics: Methods and Applications*. New York: Cambridge University Press.

Cappellari, L. and Jenkins, S.P. (2003) Multivariate Probit Regression using simulated maximum likelihood, *Stata Journal*, 3(3), pp. 221– 235.

Cassiman, B. and Veugelers, R. (2002) R&D cooperation and spillovers: Some empirical evidence from Belgium, *The American Economic Review*, 92(4), pp. 1169-1184.

Chun, H. and Mun, S.-B. (2012) Determinants of R&D cooperation in small and medium-sized enterprises, *Small Business Economics*, 39(2), pp. 419-436.

Cohen, W. and Levinthal, D. (1989) Innovation and learning: The two faces of R&D, *Economic Journal*, 99, pp. 569–596.

D'Aspremont, C. and Jacquemin, A. (1988) Cooperative and noncooperative R&D in duopoly with spillovers, *The American Economic Review*, 78(5), pp. 1133-7.

European Commission (2012) Guide to Research and Innovation Strategies for Smart Specialisations (RIS 3). *Smart Specialisation Platform*.

Fritsch, M. and Lukas, R. (2001) Who cooperates on R&D? *Research Policy*, 30(2), pp. 297-312.

Goeree, M.S. and Helland, E. (2010) Do Research Joint Ventures serve a collusive function? *Working Paper* No 448, University of Zurich.

Greene, W. (2008) *Econometric Analysis*. Prentice Hall, 7th Edition.

Gugler, K. and Siebert, R. (2007) Market power versus efficiency effects of mergers and Research Joint Ventures: Evidence from the semiconductor industry, *Review of Economics and Statistics*, 89(4), pp. 645-659.

Hagedoorn, J. (1993) Understanding the rationale of strategic technology partnering: Interorganizational modes of co-operation and sectoral differences, *Strategic Management Journal*, 14(5), pp. 371–85.
Hernán, R., Marin, P. and Siotis, G. (2003) An empirical analysis of the determinants of Research Joint Venture Formation, *Journal of Industrial Economics*, 51, pp. 75-89.
Hoffman, K., Milady, P., Bessant, J. and Perren, L. (1998) Small firms, R&D, technology and innovation in the UK: A literature review, *Technovation*, 18, pp. 39–55.
Kaiser, U. (2002) An empirical test of models explaining research expenditures and research co-operating: Evidence from the German service sector, *International Journal of Industrial Organization*, 20(6), pp. 747-774.
Kamien, M. and Zang, I. (2000) Meet me halfway: Research joint ventures and absorptive capacity, *International Journal of Industrial Organization*, 18(7), pp. 995–1012.
Kamien, M., Muller, E. and Zang, I. (1992) Research Joint Ventures and R&D cartels, *The American Economic Review*, 82(5), pp. 1293-1306.
Katz, M. (1986) An analysis of cooperative research and development, *The RAND Journal of Economics*, 17(4), pp. 527–543.
Lee, L. (1992) Amemiya's Generalized Least Squares and tests of overidentification in simultaneous equation models with qualitative or limited dependent variables, *Econometric Reviews*, 11(3), pp. 319-328.
López, A. (2008) Determinants of R&D cooperation: Evidence from Spanish manufacturing firms, *International Journal of Industrial Organization*, 26(1), pp. 113-136.
Lundvall, B.-Å. (1988) Innovation as an interactive process: From user–producer interaction to the national system of innovation. In: Dosi, G. Freeman, C., Nelson, R., Silverberg, G., Soete, L. (Eds.), *Technical Change and Economic Theory*. Pinter, London, pp. 349–369.
Lundvall, B.-Å. (2007) National innovation system: Analytical focusing device and policy learning tool, *Working Paper R2007:004*, ITPS – Swedish Institute for Growth Policy Studies.
McFadden, D. (1974) Conditional logit analysis of qualitative choice behaviour, in: P. Zarembka (Ed), *Frontiers in Econometrics*. Academic Press, New York, pp. 105-142.
Miotti, L. and Sachwald, F. (2003) Cooperative R&D: Why and with whom? An integrated framework of analysis, *Research Policy*, 32(8), pp. 1481–1499.
Mohnen, P. and Röller, L. (2005) Complementarities in innovation policy, *European Economic Review*, 49(6), pp. 1431–1450.
Newey, W.K. (1987) Efficient estimation of limited dependent variable models with endogenous explanatory variables, *Journal of Econometrics*, 36, pp. 231-250.
Pakes, A. (1983) On group effects and errors in variables aggregation, *Review of Economics and Statistics*, 65(1), pp. 168–173.
Powell, W.W. and Grodal, S. (2005) Networks of innovators. In: Fagerberg, J., Mowery, D.C., Nelson, R.R. (Eds.), *The Oxford Handbook of Innovation*. Oxford University Press, Oxford, pp. 56–85.
Rivers, D. and Vuong, Q.H. (1988) Limited information estimators and exogeneity tests for simultaneous probit models, *Journal of Econometrics*, 39, pp. 347–366.
Röller, L., Siebert, R. and Tombak, M. (2007) Why firms form (or do not form) RJVS, *The Economic Journal*, 117(522), pp. 1122-1144.
Sakakibara, M. (1997) Heterogeneity of firm capabilities and cooperative research and development: An empirical examination of motives, *Strategic Management Journal*, 18(S1), pp. 143-164.
Schilling, M.A. (2008) Understanding the alliance data, *Strategic Management Journal*, 30(3), pp. 233-260.

Segarra-Blasco, A. and Arauzo-Carod, J.M. (2008) Sources of innovation and industry-university interaction: Evidence from Spanish firms, *Research Policy*, 37(8), pp. 1283-1295.

Serrano-Bedia, A.M., López-Fernández, M.C. and García-Piqueres, G. (2010) Decision of institutional cooperation on R&D: Determinants and sectoral differences, *European Journal of Innovation Management*, 13(4), pp. 439-465.

Sodjinou, E. and Henningsen, A. (2012) Community-Based management and interrelations between different technology adoption decisions: Innovations in Village Poultry Farming in Western Africa. *FOI Working Paper* 2012/11, University of Copenhagen, Institute of Food and Resource Economics.

Terza, J.V., Basu, A. and Rathouz, P.J. (2008) Two-Stage Residual Inclusion Estimation: Addressing Endogeneity in Health Econometric Modelling, *Journal of Health Economics,* 27, pp. 531–543.

Tether, B.S. (2002) Who co-operates for innovation, and why: An empirical analysis, *Research Policy*, 31(6), pp. 947-967.

Trigo, A. and Vence, X. (2011) Scope and patterns of innovation cooperation in Spanish service enterprises, *Research Policy*, 41(3), pp. 602-613.

Vega-Jurado, J., Gutiérrez-Gracia, A. and Fernández-de-Lucio, I. (2009) Does external knowledge sourcing matter for innovation? Evidence from the Spanish manufacturing industry, *Industrial and Corporate Change*, 18(4), pp. 637–670.

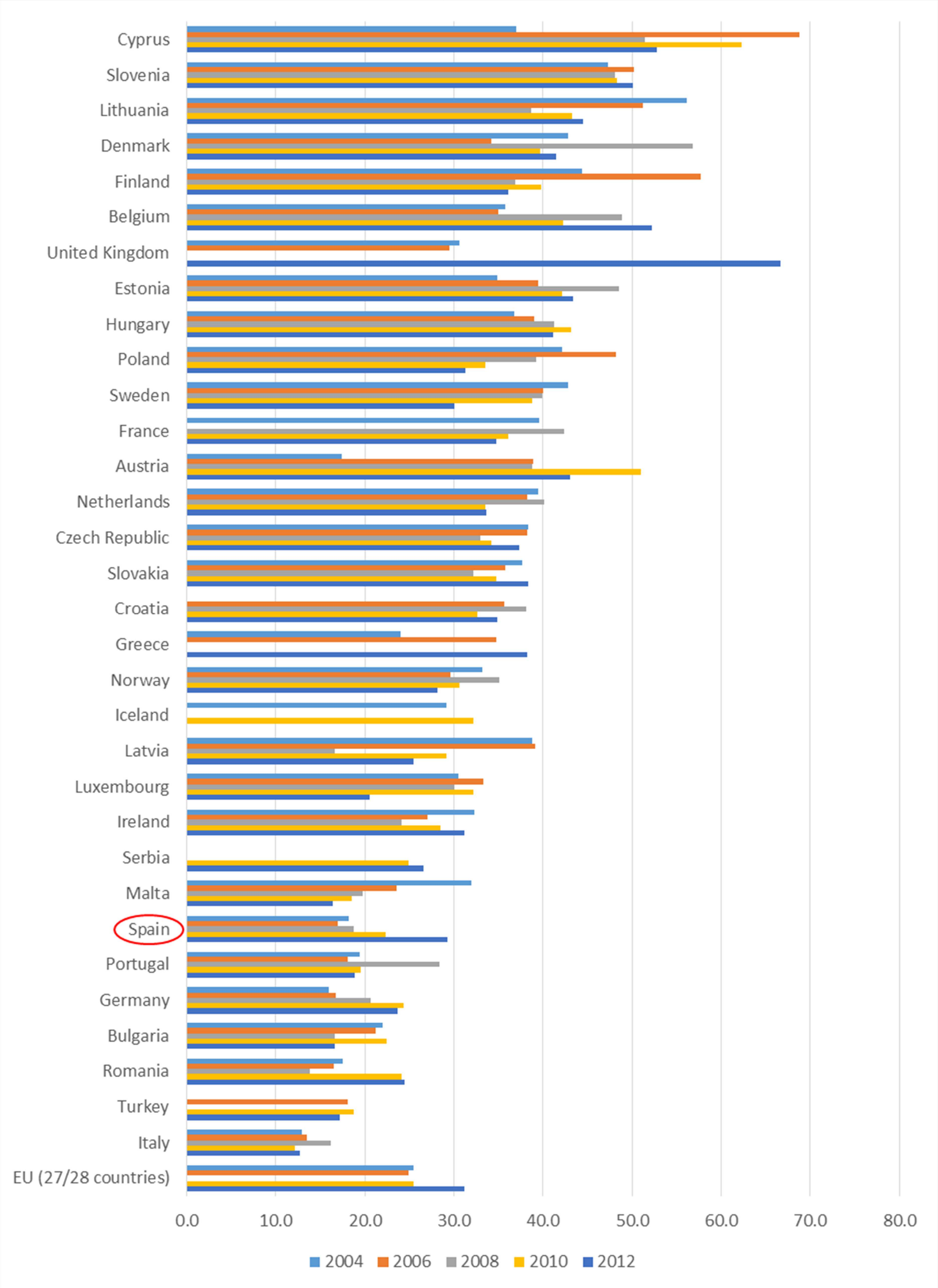
Veugelers, R. and Cassiman, B. (2005) R&D cooperation between firms and universities, some empirical evidence from Belgian manufacturing, *International Journal of Industrial Organization*, 23(5/6), pp. 355–379.

Wooldridge, J. (2002) *Econometric Analysis of Cross-Section and Panel Data*. Cambridge: MIT Press.

Zellner, A. and Haung, D. (1962) Further properties of efficient estimators for seemingly unrelated regression equations, *International Economic Review*, 3, pp. 300-313.

Tables and Figures

Figure 1. Share of innovative firms with any type of cooperation



Source: EUROSTAT, Community Innovation Survey

Table 1. R&D cooperation strategies among Spanish innovative firms

I	V	H	Strategies	Firms	%
0	0	0	Non-cooperation	4842	**65.8**
0	0	1	Only Horizontal	80	3.2
0	1	0	Only Vertical	436	17.3
0	1	1	Vertical + Horizontal	50	2.0
1	0	0	Only Institutional	788	31.3
1	0	1	Institutional + Horizontal	132	5.2
1	1	0	Institutional + Vertical	683	27.1
1	1	1	All strategies	351	13.9
Total innovative firms with at least a cooperative agreement				2520	**34.2**
Horizontal R&D cooperation (H)*				613	24.3
Vertical R&D cooperation (V)*				1520	60.3
Institutional R&D cooperation (I)*				1954	77.5

* H: Competitors; V: Suppliers and/or Customers; I: Consultants, commercial labs or private R&D institutes; universities; government or public research institutes; technological centres.
Note: Except for the 2 values in bold, the rest of % are computed over the total number of firms cooperating.

Table 2. Percentage of innovative firms by type of cooperation and sector

Sector	Innovative Firms	Cooperation	Horizontal	Vertical	Institutional
Industrial	80.93	31.07	5.38	18.92	23.81
Service	61.30	39.57	13.30	23.57	31.17
Total	72.32	34.23	8.33	20.65	26.54

Table 3. Characteristics of innovative firms and their strategies of cooperation[a]

Sector	Variables	Innovative Firms	Cooperative	Non-cooperative	Type of cooperation		
					Horizontal	Vertical	Institutional
Industrial	N	4625	1437	3188	249	875	1101
	Incoming Spillovers	0.356	0.420	0.327	0.489	0.436	0.430
	Legal Protection	36%	43%	33%	46%	44%	45%
	R&D Intensity	0.053	0.072	0.044	0.109	0.071	0.083
	Risks	0.533	0.554	0.524	0.553	0.555	0.556
	Costs	0.588	0.602	0.582	0.616	0.596	0.608
	Lack of HK	0.471	0.481	0.466	0.477	0.473	0.476
	Public funding	42%	62%	34%	70%	61%	67%
	Belonging to a Group	37%	47%	33%	55%	51%	48%
	Less than 50 emp	48%	42%	51%	35%	37%	42%
	50 - 249 emp	37%	37%	37%	38%	38%	36%
	250 - 499 emp	9%	12%	8%	15%	14%	12%
	500 or more emp	6%	9%	5%	12%	11%	10%
Service	N	2737	1083	1654	364	645	853
	Incoming Spillovers	0.365	0.439	0.316	0.485	0.454	0.460
	Legal Protection	33%	41%	28%	45%	42%	43%
	R&D Intensity	0.274	0.420	0.178	0.468	0.451	0.476
	Risks	0.497	0.528	0.477	0.565	0.514	0.543
	Costs	0.589	0.629	0.562	0.639	0.613	0.643
	Lack of HK	0.442	0.472	0.422	0.497	0.476	0.481
	Public funding	45%	65%	33%	72%	64%	72%
	Belonging to a Group	36%	36%	35%	37%	42%	34%
	Less than 50 emp	59%	59%	59%	52%	51%	61%
	50 - 249 emp	21%	21%	21%	28%	25%	22%
	250 - 499 emp	8%	6%	9%	6%	7%	5%
	500 or more emp	12%	13%	11%	14%	17%	11%

Note: Mean values are presented as absolute values and % indicates the share of firms with the described characteristic.
[a] The definition of the variables is presented in Table 4.

Table 4. Definition of the variables included in the empirical analysis

Variables	Definitions
Dependent	
Cooperation with competitors (Horizontal)	= 1 if the firm cooperated in some of its innovation activities with competitors or other enterprises of the same sector in the period 2006-2008 = 0 otherwise
Cooperation with suppliers or customers (Vertical)	= 1 if the firm cooperated in some of its innovation activities with clients or customers; suppliers of equipment, materials, components or software in the period 2006-2008 = 0 otherwise
Cooperation with research institutions (Institutional)	= 1 if the firm cooperated in some of its innovation activities with consultants, commercial labs or private R&D institutes; universities or other higher education institutions; government or public research institutes; technological centres in the period 2006-2008 = 0 otherwise
Independent	
Incoming Spillovers	= 1 minus sum of the scores of importance that the firm attributed [number between 1 (high) and 4 (not used)] to the following information sources for undertaking its innovation activities: conferences, trade fairs, exhibitions; scientific journals and trade/technical publications; professional and industry associations. Rescaled from 0 (unimportant) to 1 (crucial)
Legal Protection	= 1 if the firm used at least one of the following legal methods for protecting inventions or innovations: applied for a patent; registered an industrial design; registered a trademark; claimed copyright = 0 otherwise
R&D Intensity	Ratio between intramural R&D expenditure and turnover
Firm Size	<50 employees =1 if the firm has less than 50 employees; =0 otherwise 50 – 249 employees =1 if the firm has between 50 and 249 employees; =0 otherwise 250 – 499 employees =1 if the firm has between 250 and 499 employees; =0 otherwise 500 or more employees =1 if the firm has 500 or more employees; =0 otherwise
Risks	= 1 minus the score of importance that the firm attributed [number between 1 (high) and 4 (not used)] to the uncertain demand for innovative goods or services as a factor that hampered its innovation activities. Rescaled from 0 (unimportant) to 1 (crucial)
Costs	= 1 minus sum of the scores of importance that the firm attributed [number between 1 (high) and 4 (not used)] to the following factors that hampered its innovation activities: lack of funds within the enterprise or enterprise group; lack of finance from sources outside the enterprise; innovation costs too high. Rescaled from 0 (unimportant) to 1 (crucial)
Lack of qualified personnel (Lack of HK)	= 1 minus the score of importance that the firm attributed [number between 1 (high) and 4 (not used)] to the lack of qualified personnel as a factor that hampered its innovation activities. Rescaled from 0 (unimportant) to 1 (crucial)
Public funding of innovation	= 1 if the firm received funding from local or regional authorities; or from central government to carry out its innovation activities = 0 otherwise
Belonging to a Group	= 1 if the firm belongs to a group of companies = 0 otherwise
Dummy of sector (Sector)	= 1 if the firm belongs to industrial sector = 0 if the firm belongs to service sector
Instrumental	
Basicness of R&D	= 1 minus sum of the scores of importance that the firm attributed [number between 1 (high) and 4 (not used)] to the following information sources to carry out its innovation activities: universities or other higher education institutions, government or public research institutions and technological centres. Rescaled from 0 (unimportant) to 1 (crucial)
Export Intensity (Export)	Ratio between amount of export and turnover
Industry level of Incoming Spillovers (SpillSECT)	Mean of incoming spillovers at the industry level according to 2-digit NACE-93
Industry level of Legal Protection (LegalProtSECT)	Mean of legal protection at the industry level according to 2-digit NACE-93
Industry level of R&D Intensity (IntensSECT)	Mean of R&D intensity at the industry level according to 2-digit NACE-93

Note: Independent variables come from PITEC 2006. In table A2 of Appendix we show the matrix of correlation between explanatory variables

Table 5. Estimates of multivariate probit model for R&D cooperation corrected by endogeneity

	Total Firms			**Industrial Firms**			**Service Firms**		
	Horizontal Cooperation	**Vertical Cooperation**	**Institutional Cooperation**	**Horizontal Cooperation**	**Vertical Cooperation**	**Institutional Cooperation**	**Horizontal Cooperation**	**Vertical Cooperation**	**Institutional Cooperation**
Incoming Spillovers/	1.980***	1.573***	3.276***	2.385***	1.768***	3.729***	1.685***	1.312***	2.591***
	(0.180)	(0.165)	(0.178)	(0.331)	(0.253)	(0.283)	(0.276)	(0.216)	(0.230)
Legal Protection/	-0.172	-0.515**	-0.383	-0.717	-0.670**	-0.449	0.055	-0.204	-0.439
	(0.290)	(0.220)	(0.233)	(0.468)	(0.294)	(0.336)	(0.439)	(0.389)	(0.401)
R&D Intensity/	0.307***	0.397***	0.370***	0.800	0.538	0.178	0.173	0.337***	0.422***
	(0.099)	(0.094)	(0.088)	(0.646)	(0.389)	(0.374)	(0.117)	(0.110)	(0.099)
Risks	-0.049	-0.056	-0.191***	-0.130	0.034	-0.192**	0.029	-0.186*	-0.174*
	(0.080)	(0.060)	(0.063)	(0.115)	(0.085)	(0.075)	(0.123)	(0.102)	(0.097)
Costs	-0.036	-0.038	-0.099	-0.004	-0.045	-0.093	-0.141	-0.049	-0.099
	(0.084)	(0.082)	(0.073)	(0.134)	(0.080)	(0.086)	(0.134)	(0.132)	(0.100)
Lack of HK	0.080	0.080	-0.003	0.032	-0.012	-0.117	0.202*	0.226**	0.188**
	(0.077)	(0.063)	(0.064)	(0.113)	(0.075)	(0.074)	(0.117)	(0.108)	(0.092)
Public funding	0.444***	0.444***	0.674***	0.454***	0.440***	0.667***	0.440***	0.452***	0.699***
	(0.048)	(0.041)	(0.039)	(0.067)	(0.050)	(0.043)	(0.089)	(0.073)	(0.083)
Belonging to a Group	0.141***	0.211***	0.134***	0.228***	0.227***	0.168***	0.018	0.159**	0.025
	(0.049)	(0.041)	(0.043)	(0.080)	(0.048)	(0.053)	(0.073)	(0.066)	(0.068)
Firm Size (base <50 employees)									
50 - 249 emp	0.145**	0.162***	0.003	0.137	0.134**	-0.018	0.207***	0.233***	0.048
	(0.060)	(0.042)	(0.045)	(0.085)	(0.055)	(0.055)	(0.078)	(0.070)	(0.071)
250 - 499 emp	0.144	0.277***	0.012	0.170	0.306***	0.007	0.078	0.235**	-0.027
	(0.097)	(0.068)	(0.073)	(0.121)	(0.087)	(0.099)	(0.143)	(0.110)	(0.113)
500 or more emp	0.356***	0.532***	0.317***	0.293**	0.510***	0.359***	0.421***	0.587***	0.322***
	(0.091)	(0.068)	(0.073)	(0.146)	(0.113)	(0.114)	(0.115)	(0.091)	(0.091)
Sector (=1 industrial)	-0.419***	-0.034	-0.083**						
	(0.053)	(0.043)	(0.040)						
$\hat{u}_1$	-1.703***	-1.210***	-3.296***	-2.017***	-1.360***	-3.789***	-1.493***	-0.987***	-2.524***
	(0.182)	(0.187)	(0.188)	(0.348)	(0.267)	(0.306)	(0.322)	(0.257)	(0.251)
$\hat{u}_2$	0.275	0.658***	0.573**	0.781	0.784**	0.598*	0.088	0.398	0.694*
	(0.287)	(0.221)	(0.241)	(0.478)	(0.296)	(0.333)	(0.434)	(0.404)	(0.402)
$\hat{u}_3$	-0.298***	-0.352***	-0.345***	-0.757	-0.506	-0.122	-0.177	-0.287**	-0.406***
	(0.106)	(0.098)	(0.096)	(0.660)	(0.398)	(0.388)	(0.117)	(0.113)	(0.103)
Constant	-2.315***	-1.679***	-1.987***	-2.797***	-1.809***	-2.247***	-2.358***	-1.676***	-1.787***
	(0.107)	(0.072)	(0.076)	(0.168)	(0.090)	(0.099)	(0.142)	(0.109)	(0.090)
ρ21		0.537***			0.515***			0.558***	
		(0.023)			(0.033)			(0.033)	
ρ31		0.566***			0.528***			0.605***	
		(0.023)			(0.034)			(0.031)	
ρ32		0.668***			0.664***			0.679***	
		(0.015)			(0.020)			(0.024)	
N		7362			4625			2737	
LogL		-7928.36			-4590.45			-3304.20	
Wald Test		Chi-sq(45) = 3204.54			Chi-sq(129) = 1617.80			Chi-sq(102) = 2205.63	
Ho: The coefficients are jointly = 0		Pval = 0.000			Pval = 0.000			Pval = 0.000	
Likelihood Test		Chi-sq(3) = 1593.5			Chi-sq(3) = 853.5			Chi-sq(3) = 740.2	
Ho: ρ21=ρ31=ρ32=0		Pval = 0.000			Pval = 0.000			Pval = 0.000	

( ) Bootstrapped standard errors. / indicates instrumented. *** p<0.01, ** p<0.05, * p<0.1
Estimations of the industrial and service samples include industry dummies at 2-digit level according to NACE-93. $\hat{u}_1$, $\hat{u}_2$ and $\hat{u}_3$ are respectively the predicted residuals of the incoming spillovers, legal protection and R&D intensity.

Table 6. Marginal effects on R&D cooperation corrected by endogeneity

	Total Firms			Industrial Firms			Service Firms		
	Horizontal Cooperation	Vertical Cooperation	Institutional Cooperation	Horizontal Cooperation	Vertical Cooperation	Institutional Cooperation	Horizontal Cooperation	Vertical Cooperation	Institutional Cooperation
Incoming Spillovers/	0.265***	0.396***	0.844***	0.231***	0.422***	0.920***	0.322***	0.360***	0.716***
Legal Protection/	-0.022	-0.118**	-0.094	-0.065	-0.140**	-0.098	0.012	-0.049	-0.107
R&D Intensity/	0.040***	0.100***	0.095***	0.078	0.125	0.036	0.032	0.088***	0.114***
Risks	-0.007	-0.013	-0.049***	-0.013	0.006	-0.048**	0.005	-0.045*	-0.043*
Costs	-0.005	-0.009	-0.025	0.001	-0.010	-0.022	-0.026	-0.015	-0.028
Lack of HK	0.010	0.020	-0.001	0.003	-0.004	-0.030	0.038*	0.061**	0.050**
Public funding	0.060***	0.115***	0.187***	0.044***	0.109***	0.176***	0.085***	0.126***	0.209***
Belonging to a Group	0.019***	0.053***	0.034***	0.023***	0.055***	0.042***	0.003	0.043**	0.007
Firm Size (base <50 employees)									
50 - 249 emp	0.019**	0.041***	0.001	0.013	0.032**	-0.005	0.041**	0.066***	0.015
250 - 499 emp	0.020	0.074***	0.003	0.017	0.077***	-0.002	0.013	0.065*	-0.007
500 or more emp	0.055***	0.154***	0.088***	0.032**	0.140***	0.095***	0.091***	0.175***	0.091***
Sector (=1 industrial)	-0.059***	-0.011	-0.024**						
	(0.008)	(0.010)	(0.011)						

/ indicates instrumented. *** p<0.01, ** p<0.05, * p<0.1

Table 7. Correlation between the R&D cooperation decisions in the data (a), between the perturbation terms in the R&D cooperation model (b) and between the unconditional probabilities by the Multivariate Probit Model (c)

		Total Firms		Industrial Firms		Service Firms	
		Horizontal Cooperation	Vertical Cooperation	Horizontal Cooperation	Vertical Cooperation	Horizontal Cooperation	Vertical Cooperation
Vertical Cooperation	(a)	0.333		0.286		0.383	
	(b)	0.537		0.515		0.558	
	(c)	0.873		0.862		0.909	
Institutional Cooperation	(a)	0.357	0.479	0.301	0.466	0.410	0.493
	(b)	0.566	0.668	0.528	0.664	0.605	0.679
	(c)	0.880	0.891	0.914	0.864	0.900	0.884

All coefficients of correlation are statistically significant at 5 percent level.

Table 8. Conditional probabilities predicted by the Multivariate Probit Model

	Total Firms			Industrial Firms			Service Firms		
Strategies	**P(H=1)**	**P(V=1)**	**P(I=1)**	**P(H=1)**	**P(V=1)**	**P(I=1)**	**P(H=1)**	**P(V=1)**	**P(I=1)**
Only Horizontal	0.026	0.422	0.386	0.015	0.428	0.364	0.048	0.401	0.392
Only Vertical	0.100	0.137	0.443	0.064	0.133	0.441	0.161	0.141	0.442
Only Institutional	0.120	0.533	0.116	0.071	0.536	0.114	0.208	0.530	0.114
Vertical + Horizontal			0.740			0.723			0.749
Institutional + Horizontal		0.783			0.792			0.768	
Institutional + Vertical	0.278			0.189			0.412		

P(H=1), P(V=1) and P(I=1) indicate the probability of engaging in horizontal, vertical and institutional cooperation, respectively.

Appendix

Table A1. Selection of sample

Total firms 2008	12813
Firms with some incident and primary and construction sector	2370
Non-innovative firms	2532
Firms with some incident or anomaly in 2006	549
Final sample	7362

Table A2. Correlation between explanatory variables

	Incoming Spillovers	Legal Protection	R&D Intensity	Risks	Costs	Lack of HK	Public funding	Belonging to a Group
Incoming Spillovers	1							
Legal Protection	0.1483	1						
R&D Intensity	0.0628	0.0455	1					
Risks	0.1626	0.0726	0.0118	1				
Costs	0.1512	0.0646	0.0528	0.3968	1			
Lack of HK	0.1059	0.0446	-0.0027	0.3420	0.4052	1		
Public funding	0.1387	0.1089	0.1472	0.0910	0.1256	0.0485	1	
Belonging to a Group	0.0277	0.0102	-0.0621	-0.0699	-0.1566	-0.083	-0.0222	1
Firm Size	0.0047	0.0202	-0.0341	-0.0626	-0.0858	-0.0403	-0.0289	0.1681

Table A3. Durbin-Wu-Hausman Test for endogeneity

	Total Firms	Industrial Firms	Service Firms
Ho: coefficients on the residuals = 0	Chi-sq(9) = 493.67 Pval = 0.000	Chi-sq(9) = 311.45 Pval = 0.000	Chi-sq(9) = 161.05 Pval = 0.000

Table A4. OLS first-stage regressions to control for endogeneity

	Total Firms			**Industrial Firms**			**Service Firms**		
	Incoming Spillovers	**Legal Protection**	**R&D Intensity**	**Incoming Spillovers**	**Legal Protection**	**R&D Intensity**	**Incoming Spillovers**	**Legal Protection**	**R&D Intensity**
Basicness of R&D	0.456***	0.131***	0.124***	0.438***	0.165***	0.063**	0.492***	0.067*	0.199***
	(0.012)	(0.022)	(0.031)	(0.015)	(0.029)	(0.025)	(0.02)	(0.035)	(0.069)
Export	0.001	0.001***	0.001	0.001	0.001***	0.001	0.001	0.001	0.003
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.003)
SpillSECT	0.602***	-0.168	-0.141	0.686***	-0.216	-0.100	0.387***	-0.478*	-0.582
	(0.077)	(0.148)	(0.187)	(0.111)	(0.223)	(0.212)	(0.135)	(0.252)	(0.48)
LegalProtSECT	-0.004	1.001***	0.004	-0.011	1.068***	-0.001	-0.024	0.883***	-0.108
	(0.044)	(0.077)	(0.092)	(0.065)	(0.118)	(0.136)	(0.063)	(0.11)	(0.154)
IntensSECT	-0.048***	-0.031	0.918***	0.067	0.048	0.864***	-0.034	0.013	0.919***
	(0.016)	(0.033)	(0.094)	(0.048)	(0.124)	(0.255)	(0.024)	(0.047)	(0.125)
Risks	0.069***	0.048***	-0.011	0.069***	0.052**	-0.007	0.068***	0.035	-0.031
	(0.010)	(0.018)	(0.024)	(0.012)	(0.023)	(0.023)	(0.016)	(0.029)	(0.049)
Costs	0.042***	0.048**	0.009	0.029**	0.011	0.015	0.063***	0.105***	-0.012
	(0.011)	(0.021)	(0.028)	(0.013)	(0.026)	(0.023)	(0.018)	(0.033)	(0.066)
Lack of HK	0.033***	0.018	-0.023	0.045***	0.028	-0.032	0.011	0.014	0.001
	(0.01)	(0.02)	(0.024)	(0.013)	(0.025)	(0.021)	(0.017)	(0.032)	(0.053)
Public funding	-0.015**	0.069***	0.081***	-0.018**	0.050***	0.027**	-0.006	0.100***	0.178***
	(0.006)	(0.012)	(0.014)	(0.007)	(0.015)	(0.011)	(0.011)	(0.02)	(0.036)
Belonging to a Group	-0.002	-0.009	-0.010	0.001	-0.007	-0.007	0.001	-0.016	-0.010
	(0.007)	(0.013)	(0.016)	(0.009)	(0.017)	(0.017)	(0.011)	(0.02)	(0.034)
Firm Size (base <50 employees)									
50 - 249 emp	0.016**	0.022	-0.089***	0.007	0.021	-0.058***	0.033**	0.029	-0.149***
	(0.007)	(0.013)	(0.015)	(0.008)	(0.016)	(0.014)	(0.013)	(0.023)	(0.035)
250 - 499 emp	0.027**	0.043**	-0.112***	0.018	0.057**	-0.066***	0.043**	0.009	-0.156***
	(0.011)	(0.021)	(0.017)	(0.014)	(0.028)	(0.021)	(0.019)	(0.033)	(0.027)
500 or more emp	0.022**	0.076***	-0.102***	-0.005	0.112***	-0.044	0.048***	0.045	-0.135***
	(0.011)	(0.022)	(0.024)	(0.015)	(0.033)	(0.041)	(0.016)	(0.031)	(0.029)
Constant	-0.033	-0.075	0.060	-0.058	-0.083	0.061	0.016	0.047	0.196
	(0.024)	(0.047)	(0.057)	(0.036)	(0.073)	(0.061)	(0.047)	(0.088)	(0.177)
N		7362			4625			2737	
R^2	0.251	0.051	0.162	0.229	0.048	0.037	0.290	0.061	0.178
Underidentification Test (Angrist and Pischke, 2009)									
		Chi-sq(3)			Chi-sq(3)			Chi-sq(3)	
	1313.32	168.38	741.55	601.66	87.03	81.71	649.32	62.53	260.68
	Pval = 0.000	Pval = 0.000	Pval = 0.000	Pval = 0.000	Pval = 0.000	Pval = 0.000	Pval = 0.000	Pval = 0.000	Pval = 0.000
Weak Instrument Test (Wooldridge, 2002, pp. 90 - 92; Angrist and Pischke, 2009)									
		F(3,7347)			F(3,4582)			F(5,2703)	
	F = 436.88	F = 56.01	F = 246.68	F = 199.82	F = 28.90	F = 27.14	F = 215.25	F = 20.73	F = 86.42

( ) Heteroskedasticity-Robust Standard Errors. *** p<0.01, ** p<0.05, * p<0.1

Estimations for total sample include a binary sector variable (1=industrial and 0=service), and for the industrial and services samples include sector dummies at 2-digit level according to NACE-93.

Table A5. Sargan's test of overidentifying restrictions (a framework of univariate probit models)

Total Firms			Industrial Firms			Service Firms		
Horizontal Cooperation	**Vertical Cooperation**	**Institutional Cooperation**	**Horizontal Cooperation**	**Vertical Cooperation**	**Institutional Cooperation**	**Horizontal Cooperation**	**Vertical Cooperation**	**Institutional Cooperation**
	Chi-sq(2)			Chi-sq(2)			Chi-sq(2)	
Chi2 =0.001	Chi2 =2.080	Chi2 =1.137	Chi2 = 0.663	Chi2 = 3.345	Chi2 = 3.314	Chi2 =0.698	Chi2 = 1.038	Chi2 = 4.875
Pval = 0.999	Pval = 0.353	Pval = 0.567	Pval = 0.718	Pval = 0.188	Pval = 0.191	Pval = 0.705	Pval = 0.595	Pval = 0.087