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"What Drives the Choice of Partners in R&D Cooperation? Heterogeneity across Sectors"

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Abstract

In this paper we analyse the heterogeneity in firms' decisions to engage in R&D cooperation, taking into account the type of partner (other companies from the same group, suppliers or customers, competitors, and research institutions) and the sector to which the firm belongs (industrial or services). We use information from the Technological Innovation Panel (PITEC) for the years 2006-2008 and estimate multivariate probit models corrected for endogeneity. We find that the determinants of R&D cooperation differ between sectors. In the industrial sector, the perception of risk as an obstacle to innovation reduces the likelihood of cooperating with companies in the same group and competitors, while in the service sector it reduces cooperation with suppliers or customers. For its part, the possibility of accessing additional human resources has a significantly positive effect on cooperation with all types of partner in the service sector, but not for manufactures.

JEL classification: O30; O32; L24; L60; L80.
Keywords: R&D cooperation; Choice of partners; Industrial sector; Service sector; Innovative Spanish firms.

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1. Introduction

Innovation is a process of generating new ideas, products and services aimed at increasing productivity. Today, with the globalization of markets, innovation has become a key element in maintaining the competitiveness of firms, regions and countries and their positions in a given market. In addition, the ease with which information circulates means that the processes of adopting new knowledge are inevitable and bring wide-ranging economic and social benefits (Schumpeter, 1939; Stoneman, 1990).

However, the innovation processes of companies are becoming more and more complex, and the cost of innovation has increased in proportion. Firms have to devote more time and resources to innovation processes in order to remain competitive in the market. One strategy for engaging in innovation activities is via cooperation with other firms or with public or private institutions.

Studies examining the effects of R&D cooperation highlight its importance as an input for firms' economic performance. As Faems et al. (2005) argues, the economic success is determined by the combination of the strategies of cooperation in R&D and the complementary mechanisms that are generated between these strategies. The theoretical work of D'Aspremont and Jacquemin (1988) shows that cooperation has a positive impact on competitiveness and even on economic welfare. Miotti and Sachwald (2003), Belderbos et al. (2004a), Lööf and Broström (2008), and Aschoff and Schmidt (2008) provide empirical evidence showing that firms' economic performance is influenced positively by R&D cooperation agreements.

This paper examines the determinants of cooperation strategies in R&D chosen by Spanish companies to carry out their innovation activities. Although many aspects of cooperation in R&D have been examined in previous work, few studies have focused on the heterogeneity of the determinants of cooperation according to its various forms (with firms from the same group, with competitors, with suppliers and/or customers or with research institutions) and according to economic sector to which a particular firm belongs (typically, the analyses have focused on the industrial sector). To try to understand firms' strategies, we examine how the effect of the determinants of cooperation with a certain type of partner differs according to the sector to which the firm belongs.

In this study we use the Technological Innovation Panel (PITEC), a comprehensive database of Spanish companies compiled over the period between 2003 and 2009. Most previous studies have been limited by their use of cross-sectional databases, and the panel structure of the PITEC database avoids many of the problems that these previous studies encountered. The longitudinal database allows us to take into account the simultaneity bias inherent to cross section analysis via the inclusion of lagged variables. In addition, corrections for endogeneity are made by instrumental variable techniques.

We estimate a multivariate probit model with four equations, each one representing the type of cooperation chosen by firms: cooperation with firms in the same group, with competitors, with suppliers and/or customers, and with research institutions. The model allows us to analyse the heterogeneities between the cooperation strategies and to take into account the possible correlation between them.

Therefore, the value added of this paper is threefold. First of all, it tries to disentangle the differences between service and industrial sectors when choosing partners in R&D cooperation. Most empirical studies are based on the manufacturing sector and do not include analyses on service sector, which has its own innovation dynamics. Second, our study considers that firms seek to make simultaneous agreements with different partners and consequently the decisions regarding the type of cooperation partner are not independent from each other and may lead to complementarities. Thirdly, thanks to the availability of a longitudinal database, the time dimension is taken into account by the use of lagged variables and instrumental variables in order to minimized endogeneity problems in this kind of analysis.

The results show that there is significant heterogeneity between the strategies of cooperation in R&D, and hence stress the need to analyse the different types of partner involved. In this regard, there is interdependence in decisions to participate in cooperative arrangements with a particular partner, because in most cases a single company is simultaneously involved in cooperation agreements of different types. We also find that there are significant sector-related differences in the cooperation decisions taken by firms, particularly with regard to the risks involved in innovation processes and the need to address shortfalls of human resources to carry out the innovation activities via cooperation agreements. On the one hand, in industrial firms an increase in the perception of risk reduces the probability of entering into agreements with other companies in the same group, with competitors and with institutions, but does not affect cooperation with suppliers or customers, while the firms in the service sector facing a greater risk prefer not to cooperate with suppliers or customers, and institutions. On the other hand, a positive relationship is found in firms in the service sector between the lack of human capital and the probability of cooperating with all kinds of partner, which is not found in firms in the industrial sector.

Differences were also found in the effect of firm size on cooperation strategies inside the industrial sector, where large firms are more likely to cooperate with institutions, suppliers or customers, and companies in the same group; in horizontal cooperation, however, size does not appear to be determinant. Meanwhile, in the service sector firm size has a positive effect on the probability of cooperating with partners of all kinds. In this sector as well, large firms are the ones that are most likely to cooperate.

After this introduction, Section 2 proceeds with a literature review. Section 3 describes the database used 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

Two main approaches have been used to study the factors influencing the decisions of companies to participate in R&D cooperation projects. The literature of industrial organization emphasizes knowledge spillovers due to the inclusion of new technology, especially the work by Katz (1986), D'Aspremont and Jacquemin (1988), and Kamien et al. (1992). The other approach is presented in the literature on strategic management, and focuses on the importance of costs, risks and complementarities in the processes of innovation. In this approach the work of Pisano (1990), Das and Teng (2000), and Hagedoorn et al. (2000) are among the most significant.

With regard to knowledge spillovers, it is argued that both incoming and outgoing spillovers operate as determinants of cooperative strategies in R&D. 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.

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), Serrano-Bedia et al. (2010), and Chun and Mun (2011). Meanwhile, with regard to outgoing spillovers it is concluded that a greater ability to appropriate the innovation process increases the likelihood of vertical cooperation and has no effect on agreements with research institutions.

Analysing the determinants of cooperation between German industrial firms, Schmidt (2005) find a positive effect of the flows of information on R&D cooperation activities. However, the evidence of the impact of incoming spillovers on the probability of cooperation is not as strong as for outgoing spillovers. In the same vein, Abramovsky et al. (2009) compare the determinants of R&D cooperation data from industrial and service sector firms in France, Germany, Spain and the UK. This paper shows that incoming spillovers play a more important role in partnerships with research institutions than with other partners; in turn, the ability to benefit from the returns on innovation activities influences the decisions regarding cooperation with research institutions and suppliers and customers but not regarding cooperation with competitors. One result that this study finds for Spain, but not elsewhere, was that the primary motivation for cooperation agreements (in the manufacturing sector, though not in the service sector) is the need to overcome financial constraints.

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, approximated as the proportion of intramural R&D expenditure, the number of employees in R&D, or the presence of a permanent R&D structure, has been identified by many studies as an important feature of the firms that are more likely to cooperate (Bayona et al., 2001; Miotti and Sachwald, 2003; Lopez, 2008; 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) found a significant positive impact on the likelihood of agreements with research institutions and with suppliers and customers, but López (2008)'s conclusion was the opposite.

According to the strategic management literature, companies use research alliances with the idea of accessing complementary knowledge, or in order to share risks or costs (Hagedoorn, 1993). However, empirical studies show mixed results regarding the effects of these factors on R&D cooperation (Chun and Mun, 2011). 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. (2004b) 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.

For Spain, Bayona et al. (2001) analyse the determinants of participation in cooperative agreements in R&D without distinguishing between types of partner. Based on data from the 1996 Spanish Technological Innovation Survey, they examine the motives for cooperating in R&D in a sample of 1652 industrial firms. The authors find that the cost and uncertainty of innovation is one of the main motivations for cooperation, while market access or the search for opportunities seems to be less important reasons. Breaking down the analysis into subsamples according to company size, they find that the reasons for cooperation in R&D differ between large and small businesses, with large businesses being more likely to seek cooperation in order to innovate.

Also for the case of Spain, but distinguishing between different types of cooperation, Arranz and Arroyabe (2008) 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. These authors find that the choice of partners is driven by a variety of determinants: companies that choose to cooperate with suppliers and customers are larger, tend to be part of a group of companies and have high R&D expenditure, while companies that cooperate with research institutions do so in order to offset the high costs.

López (2008) uses a similar approach to the one developed by Cassiman and Veugelers (2002) highlighting the impact of spillovers on the cooperation agreements in R&D signed by Spanish industrial companies. Like Cassiman and Veugelers, López analyses the possible endogeneity of the spillovers and R&D intensity variables, finding that the conclusions may vary according to the estimation technique used and the way in which endogeneity is addressed. Regarding vertical cooperation and cooperation with research institutions, the main determinant is the sharing of costs and risks, while for cooperation with competitors the main determinant is the effectiveness of protection methods.

Only very few papers have considered the service sector. Kaiser (2002), for example, performed an empirical analysis via a nested logit model using data from the Survey of Innovation for the service sector in Germany. This paper investigates the decision to cooperate as a two-step process: first, the decision of the firm to cooperate or not, and second, the choice of the kind of cooperation. The author distinguishes between vertical cooperation and mixed cooperation with universities and competitors. Among the main results, the study finds that there are different motivations for cooperating with different partners, and that neither R&D expenditure nor spillovers have an effect on research cooperation.

Belderbos et al. (2004b) explore the heterogeneities in the determinants of the decision to participate in R&D cooperation, differentiating between competitors, suppliers, customers and research institutions and universities. The authors apply a multivariate probit model with data for the Netherlands from the Community Innovation Survey of 1996 and 1998, including businesses from both service and industrial sectors. The method of estimation assesses the complementary or substitutive nature of cooperation strategies in innovation on the basis of the correlations between them. Thus, the authors show that there are complementarities (i.e. the company can reap greater benefits from cooperation if it makes arrangements with different types of partner) between the various types of cooperation in innovation, and find that the determinants of cooperation differ significantly between the partners. Regarding R&D intensity, the results suggest a robust concave effect in the case of cooperation with customers, suppliers and institutions, but not in cooperation with competitors. The effect of firm size is stronger in the case of cooperation with institutions, while market uncertainty is less important; however, market uncertainty is important for agreements with competitors and suppliers. Information spillovers are important in the four types of cooperation, provided that the information comes from research institutions. The authors include a binary sector variable to control for sectoral characteristics, but find no substantial differences between manufactures and services.

This literature review suggests that there is little evidence of sectoral differences in the determinants of R&D cooperation, particularly in the service sector, which has presented significant growth in recent decades and has an innovation dynamics of its own. Similarly, most empirical analyses have assumed that the strategies of cooperation in R&D are independent; however, the existence of simultaneous agreements with different partners may lead to complementarities between the cooperation strategies, which implies that decisions regarding the type of cooperation are not independent. In addition, in the most studies the temporal character of the effects of cooperation on some of the explanatory variables has not been taken into account. This paper provides additional evidence on these issues and contributes to the analysis of sectoral differences in the processes of cooperation in innovation. In this regard, access to a longitudinal database will make it possible to correct the endogeneity that may arise in an analysis of this kind.

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. The PITEC provides information on innovative activity of Spanish companies for the period between 2003 and 2009[2]. In this study we analyse the determinants of the R&D cooperation strategies chosen by Spanish companies for the years 2006-2008. The advantage of using this database is that it allows partial control over potential endogeneity problems by introducing lagged variables as explanatory variables. Specifically, the variables for R&D cooperation (dependent variables) are taken from the 2008 survey, while the explanatory variables correspond to the 2006 survey.

The PITEC sample of 2008 contains information on 12,813 businesses, but after a cleaning of the data[3] and selection of only the firms of manufacturing and services, the figure falls to 10,443. 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, we have 7,362 companies for the years 2006 and 2008. Table A1 in the Appendix provides more information on the selection of the sample.

[1] This database is available to the public at http://sise.fecyt.es/

[2] Information on 2009 has recently been published, hence we did not use this year.

[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 period 2006-2008 or had abandoned them.

Table 1 shows the different strategies of cooperation chosen by innovative companies. Around 36% 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 74% of all cooperation agreements, while only 23% of firms cooperate with their competitors. However, most companies maintain agreements simultaneously with different types of partner: 54% cooperate with at least two types. For example, of the 1,954 companies that cooperate with institutions, 65% also have agreements with other partners. So it appears that companies find benefits in the complementarity between different forms of cooperation. Specifically, the data show that cooperation with institutions is most often complemented by vertical cooperation.

[Insert Table 1 around here]

The proportion of innovative companies with cooperation agreements and type of partner according to sector is shown in Table 2. As we see, there is a higher proportion of innovative companies in the industrial sector (80.9%) than in the service sector (61.3%). However, there is a greater propensity to cooperate in the service sector: 41.3% of innovative companies in this sector have cooperation agreements with other partners, compared with 32.7% in the industrial sector.

Table 2 also shows that innovative companies in both sectors prefer to cooperate with research institutions followed by suppliers and customers. However, the proportion of firms that cooperate with these partners is higher in the service sector (31% versus 23% and 23% versus 18%). However, the highest difference among sectors is found in the proportion of innovative companies that cooperate with competitors (13.3% in services and 5.4% in manufactures). In fact, firms in the industrial sector engage less in horizontal cooperation than in any other kind, whereas in the service sector the least frequent partner are companies from the same group and competitors. This low level of horizontal cooperation may be associated with a fear of anticompetitive practices, which firms in the industrial sector appear keener to avoid.

[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. Overall, it appears that innovative firms in both sectors that engage in cooperation agreements are more likely to receive financial support than those who do not cooperate; they are also likely to have a higher mean internal R&D intensity, and to use some form of legal protection.

In relation to size, smaller firms in both sectors show a greater propensity to cooperate. But if we focus on SMEs, while in services the percentage of firms that cooperate and those that do not is the same, the firms in the industrial sector that do not cooperate have 10 percentage points higher than those that do. This suggests that it is more difficult for SMEs in industrial to cooperate.

[Insert Table 3 around here]

Finally, Table 3 shows that the differences are minimal according to the type of cooperation partner, except that companies involved in horizontal cooperation have higher mean internal R&D intensity and are more likely to have received some public financial support for their innovation activities. Companies belonging to a group engage in internal cooperation agreements, but this is also a feature of other types of cooperation.

4. Estimation Procedure

It is important to note that the empirical analysis carried in this paper has two objectives: first, to analyse the determinants of the decision to cooperate with each type of partner, and second, to determine whether there are differences between the industrial and service sectors and therefore to identify the key determinants in each one. To do so, in the first part we estimate a model that includes both sectors and discuss the effect of the sector variable included in the model on the probability of cooperation with each type of partner. After confirming the relevance of the sector variable, we perform the same estimation for subsamples of industrial and service firms separately. In this latter model we also include a variable that captures differences within the same sector at two-digit level.

In the previous section we noted that cooperation strategies chosen by firms are not mutually exclusive, which may imply that the choice of a partner is not independent of the choice of another; there may be therefore complementarities between the decisions to cooperate with different partner types. For example, Belderbos et al. (2004b) for the Netherlands and Carboni (2010) for Italy find that the decisions of cooperation between the different partners are interdependent.

To account for possible systematic correlations between the decisions to engage in the various forms of cooperation, we propose a multivariate probit model with binary equations for each of our four types of partner: companies in the same group, competitors, suppliers and/or customers, and research institutions. If there are correlations between the equations, the separate estimates of the decisions to cooperate will be inefficient (Zellner and Haung, 1962). According to Belderbos et al. (2004b), the correlations may be due to complementarities (positive correlation) or substitutability (negative correlation) between different forms of cooperation: for example, the benefits of vertical cooperation may be higher if the company also cooperates with research institutions.

In addition to verifying the complementarity between the four forms of cooperation through the correlations, this model allows to establish whether there are differences between firms' reasons for establishing cooperation agreements with different kinds of partner in their innovation activities.

So we have four latent variables y_{i1}^*, y_{i2}^*, y_{i3}^*, y_{i4}^* which measure the difference between benefits and costs that company *i* obtains by cooperating in R&D with companies from the same group, with competitors, with suppliers and/or customers, and with research institutions respectively. Assuming that these differences depend linearly on a set of characteristics of companies and sectors, contained in x, we have:

$$y_{ij}^* = x_{ij}^{'}\beta_j + \varepsilon_{ij}\,, \qquad j = 1,\ldots,4 \qquad (1)$$

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,…,4) 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 a certain type of partner. Thus, the multivariate probit model specifies the binary variables as follows[5]:

$$y_{ij} = \begin{cases} 1 & \text{si } y_{ij}^* > 0 \\ 0 & \text{si } y_{ij}^* \leq 0 \end{cases} \qquad j = 1,\ldots,4 \qquad (2)$$

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

In this case, from four equations there are 16 joint probabilities corresponding to the 16 combinations of different types of partners for cooperation ($y_{ij}=1$) and non-cooperation ($y_{ij}=0$). The possible probabilities are determined by (Wooldridge, 2002; Greene, 2008; Capellari and Jenkins, 2003; Cameron and Trivedi, 2005):

$$\begin{aligned} p_{hklm} &= \Pr\left[y_1=h, y_2=k, y_3=l, y_4=m\right] \\ &= \Phi(\mathrm{q}_1 x_{i1}^{'}\beta_1, \mathrm{q}_2 x_{i2}^{'}\beta_2, \mathrm{q}_3 x_{i3}^{'}\beta_3, \mathrm{q}_4 x_{i4}^{'}\beta_4, \rho_{21}, \rho_{31}, \rho_{41}, \rho_{32}, \rho_{42}, \rho_{43}), \end{aligned} \quad (3)$$

where $\Phi(.)$ is the normal quatrivariate distribution function, q_n=1 if y_{in} = 1 and q_n=-1 if y_{in} = 0 for n=1,…,4. These probabilities are the basis for the maximum likelihood estimation. This estimation is carried out using the routine developed by Cappellari and Jenkins (2003) which use simulation methods of the maximum likelihood function, specifically the GHK (Geweke-Hajivassiliou-Keane) simulator to calculate the probabilities.

One issue to consider in the estimation is the possible simultaneous relationship between cooperation strategies and some of the explanatory variables. The literature has mainly emphasized the endogeneity of the variables of knowledge spillovers (incoming spillovers and legal protection) and R&D intensity. Investments in internal R&D may increase if cooperation makes internal R&D activities more effective and spillovers may be affected by the information shared between partners (Cassiman and Veugelers, 2002; López, 2008).

Although the explanatory variables are taken in a lagged manner as Belderbos et al. (2004b) propose, this only reduces the bias produced, but it does not correct it. Following Cassiman and Veugelers (2002) and Abramovsky et al. (2009), to correct this potential problem of endogeneity we perform estimation in two stages using instrumental variables. As instruments we use the degree to which the firm's innovative activity is oriented towards basic research (basic R&D), which is positively related to its absorptive capacity (internal R&D intensity) and the degree to which the firm can benefit from incoming spillovers. Also, firms with higher export intensity (export) face a more competitive environment which may improve their absorption of spillovers and increase the likelihood of investment in internal R&D. Measures at the 2-digit industry level of the potentially endogenous variables are also included to control for unobserved industry-specific characteristics (López, 2008; Chun and Mun, 2011).

5. Determinants of Cooperation Strategies for Innovation: A Multivariate Analysis

The results of the multivariate probit model corrected for endogeneity for the whole sample, and separate by industrial and service sectors are shown in Tables 5 and 6, respectively. Table 4 defines the variables used in the regression analysis. Prior to these results, we performed the Durbin-Wu-Hausman endogeneity test and the F test for weak instruments (Wooldridge, 2002; Stock and Yogo, 2005; Greene, 2008). The results of these tests (see Tables A3 and A4 in the Appendix) confirm the endogeneity of the incoming spillovers, legal protection and R&D intensity variables, and the F statistic in the first stage indicates that the instruments are highly correlated with the potentially endogenous variables[6].

[Insert Table 4 around here]

As shown in Tables 5 and 6, the statistical significance of the correlation coefficients (ρ) between the perturbation terms shows the need for multi-equation estimation. This indicates that there are processes of interdependence between the four cooperation strategies, both for the whole sample and for individual sectors. The positive sign of these coefficients confirms the possible existence of complementarities between the four cooperation strategies. These results are consistent with those reported by Belderbos et al. (2004b) and Carboni (2010) for the case of the Netherlands and Italy respectively.

[Insert Table 5 around here]

The explanatory variables introduced into the model have different effects according to the R&D cooperation strategies. This finding shows the heterogeneity between the different types of cooperation, and hence the need to separate them. We also note a significant effect of the sector on the probability of cooperating with any partner. The statistical significance of the coefficient associated with the variable sector in the model for the whole sample (Table 5) and the different effects observed in the separate estimates for industrial and service firms (Table 6), highlight these sectoral differences. Specifically, the negative sign of the sector variable in Table 5 shows that the probability of cooperating is lower for industrial firms than for service firms, with much more pronounced differences in the case of horizontal cooperation (with competitors), while no

[6] The F-statistics are above the threshold of 10 for weak instruments suggested by Stock and Yogo (2005), with the exception of R&D intensity in the sample of industrial firms.

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.

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 four types of cooperation. The greater the importance attributed by the company to external sources of information, the more likely it is to be able to exploit these spillovers in order to increase the productivity of its innovation activities, and the more likely it is to obtain benefits through cooperation agreements (Cassiman and Veugelers, 2002; López, 2008); therefore, it is more likely to cooperate. The impact is significantly greater in the case of partnerships with institutions, particularly in industrial firms. So it seems fair to conclude that it is mainly industrial firms that benefit the most from the information coming from external sources, especially with regard to cooperating with public institutions.

In contrast, the results show that the effect of the variable legal protection on cooperation is not conclusive. In fact, in the literature, the effect of this variable is ambiguous (López, 2008). On the one hand, the fact that it is easier to appropriate the results of innovation through protection may have a positive effect on cooperation in R&D, as firms can control outgoing information flows. On the other hand, excessive legal protection may hinder the internalization of the flows shared by the partners and may thus have a negative effect. In our case, there is a positive and significant effect of this variable only for cooperation with other companies in the same group, and a negative (though marginally significant) effect on cooperation with suppliers or customers at the level of the whole sample, probably related to the arguments given above. However, for the remaining of the types of cooperation (competitors and research institutions) and at the level of the individual sectors no significant effects were observed.

[Insert Table 6 around here]

The effect of internal R&D intensity is significant and positive for the whole sample. This finding is consistent with most studies that argue that firms with higher internal R&D expenditures are more likely to cooperate (Fritsch and Lucas, 2001; Laurensen and Salter, 2004). The absorptive capacity of a firm may increase with higher levels of internal R&D (Cohen and Levinthal, 1989) and this ability may allow it to derive greater benefit from cooperation with other partners, especially in relation to its competitors. However, no significant parameters are obtained for internal R&D intensity for the individual sectors.

An important difference between the industrial and service sector lies in the impact of the importance of risk as a hampering factor for the innovation processes. In industrial firms, increased risk reduces the probability of making agreements with other companies in the same group, with competitors and with institutions, but does not affect cooperation with suppliers or customers, while service firms facing greater risk prefer not to cooperate with suppliers or customers, or with institutions. This negative effect may be due to the fact that companies for which risk is a major barrier to innovation are less likely to cooperate. In this regard, in high-risk conditions it is more difficult to minimize opportunistic behaviour and to achieve success in R&D cooperation agreements. This effect of greater risk, increased opportunism and therefore a lower propensity to cooperate is more important in the case of cooperation with research institutions especially for the firms belonging to the industrial sector. A similar effect is found in Cassiman and Veugelers (2002).

Regarding the limitations related to the lack of qualified personnel (lack of HC) no significant effects are found for the whole sample, but when the sample is separated into industrial and services the impacts are notable. In the service sector the lack of qualified personnel increases the likelihood of cooperation agreements of all kinds. This positive effect implies the possibility of accessing additional resources through partnerships with other companies or institutions. The effect is relevant in service firms, since this is a knowledge-intensive sector; in contrast, decisions on cooperation in the industrial sector firms do not seem to be driven by a shortage of human resources. These results are maintained for all kind of partners.

Public financial support from local and national administrations (subsidies) is one of the main determinants of cooperation in the Spanish case in all its forms. The highest positive effect is found on cooperation with research institutions, especially in the service sector. This may well be because subsidies are often designed to encourage the interaction of business and university. This relationship is much stronger when the firm involved is knowledge-intensive, more abundant in the service sector. The finding also highlights the impact of subsidies on horizontal cooperation strategies. Companies that can address financial problems by means of the subsidies are keener to cooperate with their competitors, perhaps because public funding is a factor that is outside the realm of competition (Tether, 2002).

Finally, we note that companies that are part of a group and large companies are more likely to establish agreements for innovation. In the industrial sector, companies with more than 500 employees are most likely to cooperate with other firms in the same group, followed by cooperation with research institutions. In the service sector firms of this size are most likely to cooperate with suppliers or customers, followed by cooperation with competitors. The ability of large firms to reap the returns of cooperation agreements entails that they have a higher probability of cooperating.

6. Conclusions

In this paper we have analysed the determinants of the different strategies of R&D cooperation (cooperation with the same group of companies, horizontal cooperation, vertical cooperation, and cooperation with research institutions), with particular emphasis on the heterogeneities of their impact across the different strategies, as well as the differences between the strategies used in the industrial and service sectors. This analysis was performed with data from Technological Innovation Panel (PITEC) for the years 2006 and 2008, for Spanish innovative firms.

The descriptive analysis shows that firms choose simultaneously several types of partners to carry out their innovation activities. Fifty-four per cent of cooperative enterprises reported cooperating with at least two types of partners and almost 6% had cooperated with the four types of partners at a time. The most common relationship was with research institutions, and the strategies that complement each other most are simultaneous partnerships with institutions and with suppliers or customers. The statistical tests suggest that the choices of the type of partner are not independent of each other, indicating the need for a multi-equation estimation that considers the processes of interdependence between the four cooperation strategies. In fact, the econometric estimates obtained using a multivariate probit model corroborate the validity of this method compared with univariate estimation, and indicate the existence of heterogeneity among the four strategies of cooperation, due perhaps to complementarities between them.

In the Spanish case, according to our descriptive analysis, there is a greater propensity to cooperate in the service sector (41%) than in the industrial sector (33%). Additionally, we have obtained through the regression analysis, that this lower probability of cooperating for manufactures is more pronounced in the case of horizontal cooperation (with competitors).

Overall, the results indicate the importance of incoming spillovers in the choice of cooperating in R&D with all types of partner, regardless of the sector, but more especially in the case of partnerships with research institutions for industrial firms. Similarly, public financial support also plays a key role in the decisions to cooperate, regardless of the partner, but is particularly important in the choice of cooperation with institutions and more importantly for the service sector.

This may be because much of the public funding for innovation aims to encourage and promote knowledge transfer from universities to companies and because there are more firms considered knowledge intensive in the service sector.

The presence of high risk encourages the emergence of opportunistic behaviour in cooperative agreements and therefore, reduces the likelihood to engage in cooperation both for manufacturing and service firms. However, one of the main differences between firms in the two sectors is their unequal response to risk regarding the types of partner. For industrial companies the existence of greater risks makes them less likely to enter cooperation agreements with companies in the same group, with competitors and with institutions. In the service sector, increased risk also has a negative effect but in particular reduces their cooperation with suppliers or customers.

Another important difference between sectors is found in their ability to access human resources by entering partnerships with other companies or institutions. This effect is particularly important in the service sector, but not for manufactures. Firms in the service sector, 80% of which are classified as knowledge-intensive, see cooperation agreements as an effective way to enhance and complement their human resources for carrying out R&D activities.

The differences observed between the industrial and service sectors in relation to the cooperative agreements and the kind of partner chosen show that firms follow different paths in their innovation processes and therefore have different needs. These differences should be borne in mind in the design of policies to encourage cooperation, to increase innovation in enterprises, as a way to achieve greater competitiveness and productivity.

Tables

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

I	V	H	G	Strategies	Firms	%
0	0	0	0	Non-cooperation	4,718	**64.1**
			1	Only Group	124	4.7
		1	0	Only Horizontal	75	2.8
			1	Horizontal + Group	5	0.2
	1	0	0	Only Vertical	346	13.1
			1	Vertical + Group	90	3.4
		1	0	Vertical + Horizontal	31	1.2
			1	Vertical + Horizontal + Group	19	0.7
1	0	0	0	Only Institutional	680	25.7
			1	Institutional + Group	108	4.1
		1	0	Institutional + Horizontal	113	4.3
			1	Institutional + Horizontal + Group	19	0.7
	1	0	0	Institutional + Vertical	460	17.4
			1	Institutional + Vertical + Group	223	8.4
		1	0	Institutional + Vertical + Horizontal	200	7.6
			1	All strategies	151	5.7
Total innovative firms with at least a cooperative agreement					2,644	**35.9**
R&D Cooperation with firms in the same Group (G)*					739	28.0
Horizontal R&D cooperation (H)*					613	23.2
Vertical R&D cooperation (V)*					1,520	57.5
Institutional R&D cooperation (I)*					1,954	73.9

* G: Other enterprises within your enterprise group; H: Competitors; V: Suppliers 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	Group	Horizontal	Vertical	Institutional
Industrial	80.93	32.71	9.86	5.38	18.92	23.81
Services	61.30	41.32	10.34	13.30	23.57	31.17
Total	72.32	35.91	10.04	8.33	20.65	26.54

Table 3. Characteristics of innovative firms and their strategies of cooperation

Sector	Variables	Innovative Firms	Cooperative	Non-cooperative	Type of cooperation			
					Group	Horizontal	Vertical	Institutional
Industrial	N	4,625	1,513	3,112	456	249	875	1,101
	Incoming Spillovers	0.356	0.415	0.327	0.443	0.489	0.436	0.430
	Legal Protection	36%	43%	33%	45%	46%	44%	45%
	R&D Intensity	0.053	0.078	0.041	0.075	0.109	0.071	0.083
	Risks	0.518	0.531	0.511	0.507	0.531	0.539	0.540
	Costs	0.588	0.599	0.583	0.570	0.616	0.596	0.608
	Lack of HC	0.471	0.476	0.468	0.428	0.477	0.473	0.476
	Subsidies	42%	61%	33%	59%	70%	61%	67%
	Part of a Group	37%	49%	31%	93%	55%	51%	48%
	Less than 50 emp	48%	41%	51%	18%	35%	37%	42%
	50 - 249 emp	37%	37%	37%	38%	38%	38%	36%
	250 - 499 emp	9%	12%	8%	24%	15%	14%	12%
	500 or more emp	6%	10%	4%	20%	12%	11%	10%
Services	N	2,737	1,131	1,606	283	364	645	853
	Incoming Spillovers	0.365	0.436	0.315	0.443	0.485	0.454	0.460
	Legal Protection	33%	40%	28%	40%	45%	42%	43%
	R&D Intensity	0.274	0.415	0.174	0.325	0.468	0.451	0.476
	Risks	0.480	0.498	0.467	0.502	0.534	0.493	0.516
	Costs	0.589	0.621	0.566	0.575	0.639	0.613	0.643
	Lack of HC	0.442	0.468	0.423	0.495	0.497	0.476	0.481
	Subsidies	45%	64%	33%	58%	72%	64%	72%
	Part of a Group	36%	38%	34%	93%	37%	42%	34%
	Less than 50 emp	59%	59%	59%	36%	52%	51%	61%
	50 - 249 emp	21%	21%	21%	24%	28%	25%	22%
	250 - 499 emp	8%	7%	9%	13%	6%	7%	5%
	500 or more emp	12%	13%	11%	27%	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 Section 5.

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

Variables	Definitions
Dependent	
Cooperation with firms in the same Group (Group)	= 1 if the firm coopered in some of its innovation activities with other enterprises of the same group in the period 2006-2008 = 0 otherwise
Cooperation with competitors (Horizontal)	= 1 if the firm coopered 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 coopered 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 coopered 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 - 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 - 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: markets dominated by established enterprises; uncertain demand for innovative goods or services. Rescaled from 0 (unimportant) to 1 (crucial)
Costs	= 1 - 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 HC)	= 1 - 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 (Subsidies)	= 1 if the firm received funding from local or regional authorities; or from central government to carry out its innovation activities = 0 otherwise
Part of 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	
Basic R&D	= 1 - 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: conferences, trade fairs, exhibitions; scientific journals and trade/technical publications; professional and industry associations. Rescaled from 0 (unimportant) to 1 (crucial)
Export Intensity (Export)	Ratio between amount of export and turnover
Industry level of Incoming	Mean of incoming spillovers at the industry level according to 2-digit NACE-93

Spillovers (SpillSECT)	
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. Multivariate Probit Model of R&D cooperation corrected by endogeneity
Total firms

	Group Cooperation	Horizontal Cooperation	Vertical Cooperation	Institutional Cooperation
Incoming Spillovers	1.249***	1.898***	1.619***	3.087***
	(0.212)	(0.197)	(0.154)	(0.156)
Legal Protection	0.896***	-0.031	-0.443*	-0.231
	(0.325)	(0.310)	(0.241)	(0.240)
I+D Intensity	0.168	0.278***	0.363***	0.327***
	(0.105)	(0.095)	(0.082)	(0.088)
Risks	-0.207**	-0.128	-0.083	-0.247***
	(0.093)	(0.089)	(0.068)	(0.068)
Costs	0.043	-0.013	-0.035	-0.063
	(0.091)	(0.091)	(0.068)	(0.067)
Lack of HC	0.014	0.085	0.073	0.004
	(0.084)	(0.081)	(0.062)	(0.061)
Subsidies	0.270***	0.445***	0.435***	0.675***
	(0.056)	(0.053)	(0.041)	(0.040)
Part of a Group	1.533***	0.130**	0.204***	0.129***
	(0.066)	(0.052)	(0.040)	(0.040)
Size (base <50 employees)				
50 - 249 emp	0.022	0.145***	0.150***	-0.001
	(0.060)	(0.056)	(0.043)	(0.043)
250 - 499 emp	0.225***	0.144	0.275***	0.019
	(0.079)	(0.089)	(0.067)	(0.069)
500 or more emp	0.335***	0.342***	0.523***	0.309***
	(0.080)	(0.086)	(0.069)	(0.072)
Sector (=1 industrial)	-0.118**	-0.454***	-0.062	-0.130***
	(0.057)	(0.056)	(0.043)	(0.042)
Constant	-3.119***	-2.279***	-1.675***	-1.937***
	(0.104)	(0.091)	(0.068)	(0.067)
ρ_{21}	0.460***	ρ_{32}	0.546***	
	(0.031)		(0.023)	
ρ_{31}	0.646***	ρ_{42}	0.573***	
	(0.021)		(0.023)	
ρ_{41}	0.596***	ρ_{43}	0.662***	
	(0.023)		(0.015)	
N	7362			
LogL	-9307.2503			
Wald Test Ho: The coefficients are jointly = 0	Chi-sq(48) = 2243.1 Pval = 0.000			
Likelihood Test Ho:$\rho_{21}=\rho_{31}=\rho_{41}=\rho_{32}=\rho_{42}=\rho_{43}=0$	Chi-sq(6) = 2280.73 Pval = 0.000			

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

Table 6. Multivariate Probit Model of R&D cooperation corrected by endogeneity Industrial and Service Firms

	Group Cooperation		Horizontal Cooperation		Vertical Cooperation		Institutional Cooperation	
	Industrial	**Services**	**Industrial**	**Services**	**Industrial**	**Services**	**Industrial**	**Services**
Incoming Spillovers	1.892***	1.252***	1.982***	1.742***	1.429***	1.294***	3.722***	2.439***
	(0.454)	(0.345)	(0.521)	(0.268)	(0.340)	(0.244)	(0.346)	(0.241)
Legal Protection	-0.33	0.824	0.337	-0.235	1.008	-0.02	-0.272	-0.023
	(0.904)	(1.208)	(1.084)	(0.990)	(0.667)	(0.891)	(0.689)	(0.854)
I+D Intensity	0.074	0.139	0.289	0.114	0.289	0.198	-0.251	0.021
	(0.682)	(0.267)	(0.642)	(0.217)	(0.543)	(0.210)	(0.430)	(0.204)
Risks	-0.274***	-0.111	-0.280***	-0.059	-0.077	-0.217***	-0.300***	-0.233**
	(0.120)	(0.151)	(0.135)	(0.118)	(0.093)	(0.107)	(0.091)	(0.108)
Costs	0.156	-0.174	0.050	-0.091	-0.047	-0.062	-0.057	-0.149
	(0.117)	(0.206)	(0.131)	(0.166)	(0.088)	(0.143)	(0.088)	(0.141)
Lack of HC	-0.165	0.311**	0.035	0.244**	-0.072	0.239***	-0.138*	0.224**
	(0.110)	(0.147)	(0.123)	(0.113)	(0.084)	(0.103)	(0.082)	(0.102)
Subsidies	0.294***	0.332**	0.435***	0.479***	0.335***	0.454***	0.676***	0.717***
	(0.085)	(0.153)	(0.092)	(0.120)	(0.062)	(0.103)	(0.061)	(0.103)
Part of a Group	1.382***	1.761***	0.245***	-0.028	0.236***	0.134***	0.168***	0.028
	(0.081)	(0.113)	(0.076)	(0.078)	(0.052)	(0.065)	(0.053)	(0.066)
Size (base <50 employees)								
50 - 249 emp	0.137	-0.120	0.081	0.214**	0.061	0.187**	-0.036	-0.002
	(0.093)	(0.116)	(0.091)	(0.098)	(0.065)	(0.086)	(0.061)	(0.087)
250 - 499 emp	0.348***	0.219	0.101	0.087	0.167	0.198*	-0.005	-0.051
	(0.128)	(0.150)	(0.149)	(0.145)	(0.102)	(0.119)	(0.102)	(0.122)
500 or more emp	0.552***	0.287**	0.148	0.376***	0.273**	0.484***	0.348***	0.278***
	(0.164)	(0.141)	(0.194)	(0.134)	(0.129)	(0.116)	(0.131)	(0.115)
Constant	-2.963***	-3.083	-3.131***	-2.514***	-2.185***	-1.526***	-2.221***	-1.744***
	(0.232)	(0.351)	(0.264)	(0.455)	(0.171)	(0.274)	(0.171)	(0.257)

	Industrial				Services			
	ρ_{21}	0.490***	ρ_{32}	0.545***	ρ_{21}	0.432***	ρ_{32}	0.551***
		(0.042)		(0.033)		(0.049)		(0.032)
	ρ_{31}	0.673***	ρ_{42}	0.564***	ρ_{31}	0.623***	ρ_{42}	0.604***
		(0.026)		(0.033)		(0.037)		(0.031)
	ρ_{41}	0.596***	ρ_{43}	0.665***	ρ_{41}	0.613***	ρ_{43}	0.678***
		(0.029)		(0.019)		(0.038)		(0.024)
N	4625				2737			
LogL	-5355.6				-3767.2			
Likelihood Test	Chi-sq(6) = 1308.52				Chi-sq(6) = 958.16			
Ho: $\rho_{21}=\rho_{31}=\rho_{41}=\rho_{32}=\rho_{42}=\rho_{43}=0$	Pval = 0.000				Pval = 0.000			

( ) Heteroskedasticity-Robust Standard Errors *** p<0.01, ** p<0.05, * p<0.1
Fixed effects of sector are included in all estimations

Appendix

Table A1. Selection of sample

Total firms 2008	12,813
Firms with some incident and primary and construction sector	2,370
Non-innovative firms	2,532
Firms with some incident or anomaly in 2006	549
Final sample 2006-2008	7,362

Table A2. Correlation between explanatory variables

	Incoming Spillovers	Legal Protection	R&D Intensity	Risks	Costs	Lack of HC	Subsidies	Part of a Group
Incoming Spillovers	1							
Legal Protection	0.1483	1						
R&D Intensity	0.0628	0.0455	1					
Risks	0.178	0.0727	0.0083	1				
Costs	0.1512	0.0646	0.0528	0.4384	1			
Lack of HC	0.1059	0.0446	-0.0027	0.3714	0.4052	1		
Subsidies	0.1387	0.1089	0.1472	0.0789	0.1256	0.0485	1	
Part of a Group	0.0277	0.0102	-0.0621	-0.0776	-0.1566	-0.083	-0.0222	1

Table A3. 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**
Basic R&D	0.516***	0.153***	0.119***	0.493***	0.193***	0.062**	0.556***	0.083**	0.199***
	(0.012)	(0.023)	(0.033)	(0.015)	(0.030)	(0.026)	(0.020)	(0.037)	(0.073)
Export	0.0002	0.001***	0.0005	0.0002	0.001***	0.00002	0.0004	0.001	0.003
	(0.0001)	(0.0003)	(0.001)	(0.0002)	(0.0003)	(0.0004)	(0.0003)	(0.0007)	(0.003)
SpillSECT	0.555***	-0.192	-0.141	0.635***	-0.227	-0.087	0.403***	-0.460*	-0.544
	(0.075)	(0.148)	(0.185)	(0.100)	(0.201)	(0.241)	(0.133)	(0.251)	(0.488)
LegalProtSECT	-0.033	0.975***	-0.019	-0.016	1.066***	0.000	-0.017	0.896***	-0.076
	(0.042)	(0.074)	(0.094)	(0.064)	(0.117)	(0.131)	(0.061)	(0.109)	(0.157)
IntensSECT	-0.027*	-0.014	0.937***	0.053	0.060	0.874***	-0.036	0.008	0.928***
	(0.014)	(0.030)	(0.083)	(0.047)	(0.110)	(0.225)	(0.023)	(0.047)	(0.124)
Risks	0.088***	0.047**	-0.023	0.094***	0.070***	-0.017	0.076***	0.003	-0.043
	(0.011)	(0.021)	(0.025)	(0.013)	(0.026)	(0.025)	(0.018)	(0.033)	(0.053)
Costs	0.030***	0.046**	0.013	0.015	0.002	0.018	0.056***	0.116***	-0.004
	(0.011)	(0.021)	(0.027)	(0.013)	(0.027)	(0.023)	(0.018)	(0.034)	(0.061)
Lack of HC	0.022**	0.015	-0.022	0.037***	0.023	-0.030	-0.002	0.019	0.001
	(0.010)	(0.020)	(0.024)	(0.013)	(0.025)	(0.021)	(0.017)	(0.032)	(0.055)
Subsidies	-0.018***	0.068***	0.082***	-0.024***	0.047***	0.027**	-0.004	0.101***	0.183***
	(0.006)	(0.012)	(0.014)	(0.007)	(0.015)	(0.011)	(0.011)	(0.020)	(0.035)
Part of a Group	-0.003	-0.009	-0.009	-0.001	-0.008	-0.007	-0.004	-0.016	-0.013
	(0.007)	(0.013)	(0.016)	(0.008)	(0.017)	(0.016)	(0.011)	(0.020)	(0.034)
Size (base <50 employees)									
50 - 249 emp	0.011	0.019	-0.091***	0.006	0.021	-0.057***	0.027**	0.028	-0.150***
	(0.007)	(0.013)	(0.015)	(0.008)	(0.016)	(0.014)	(0.013)	(0.023)	(0.035)
250 - 499 emp	0.021*	0.041*	-0.114***	0.017	0.058**	-0.065***	0.031*	0.006	-0.159***
	(0.011)	(0.021)	(0.017)	(0.014)	(0.028)	(0.021)	(0.018)	(0.033)	(0.027)
500 or more emp	0.010	0.074***	-0.102***	-0.008	0.111***	-0.044	0.029*	0.041	-0.138***
	(0.011)	(0.022)	(0.024)	(0.015)	(0.033)	(0.041)	(0.016)	(0.031)	(0.029)
Constant	-0.033	-0.072	0.057	-0.066**	-0.096	0.052	0.002	0.043	0.188
	(0.023)	(0.047)	(0.056)	(0.029)	(0.059)	(0.053)	(0.045)	(0.088)	(0.178)
N	7362	7362	7362	4625	4625	4625	2737	2737	2737
R^2	0.276	0.051	0.161	0.254	0.050	0.037	0.314	0.061	0.177
Weak Instrument Test (Wooldridge, 2002, p. 90 - 92; Stock y Yogo, 2005)									
	F(5,7348)			F(5,4611)			F(5,2723)		
	F = 445.76 Pval = 0.000	F = 57.33 Pval = 0.000	F = 32.66 Pval = 0.000	F = 257.61 Pval = 0.000	F = 36.65 Pval = 0.000	F = 5.60 Pval = 0.000	F = 177.47 Pval = 0.000	F = 17.23 Pval = 0.000	F = 21.77 Pval = 0.000

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

Table A4. Durbin-Wu-Hausman Test for endogeneity

	Incoming Spillollers	Legal Protection	R&D Intensity
Ho: coefficient on the residuals = 0	Chi-sq(4) = 31.80 Pval = 0.000	Chi-sq(4) = 18.92 Pval = 0.001	Chi-sq(4) = 8.44 Pval = 0.077

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