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"Cooperation in R&D, firm size and type of partnership: Evidence for the Spanish automotive industry"

Erika Raquel Badillo, Francisco Llorente and Rosina Moreno

Research Institute of Applied Economics

Regional Quantitative Analysis Research Group

Abstract

This paper aims to analyse cooperation in R&D in the automobile industry in Spain. It first examines to what extent firms cooperate with external actors in the field of technological innovation, and if so, with what type of cooperation partner, paying special attention to the differentiation according to the size of the firms. Second, it aims to study how the firm's size may affect not only the decision of cooperating but also with which type of partner, while controlling for other determinants that have been considered in the literature as main drivers of collaborative activities in R&D. We use data provided by the Technological Innovation Panel in the 2006-2008 period for firms in the automotive sector. We estimate a bivariate probit model that takes into account the two types of cooperation mostly present in the automotive industry, vertical and institutional, explicitly considering the interdependencies that may arise in the simultaneous choice of both.

JEL classification: D22, O32, L24, L62
Keywords: Innovation, Cooperation in R&D, Partnership, Firm size, Automotive Industry

Erika Raquel Badillo. AQR Research Group-IREA. Department of Econometrics. University of Barcelona, Av. Diagonal 690, 08034 Barcelona, Spain. E-mail: ebadillo@ub.edu

Francisco Llorente. AQR Research Group-IREA. Department of Econometrics. University of Barcelona, Av. Diagonal 690, 08034 Barcelona, Spain. E-mail: fllorente@ub.edu

Rosina Moreno. AQR Research Group-IREA. Department of Econometrics. University of Barcelona, Av. Diagonal 690, 08034 Barcelona, Spain. E-mail: rmoreno@ub.edu

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1. INTRODUCTION

A firm may increase its technological capabilities either through internal efforts in R&D or though external activities such as hiring or cooperating in technological agreements. Firms seek to blend external sources of innovation with company-level competences and assets to incorporate new ideas (Chesbrough, 2003, 2006), allowing firms to gain greater technological innovation (Ili et al., 2010). In particular, R&D cooperation is a strategy of knowledge sharing and diffusion across firms that has increased importantly in recent decades. R&D cooperation allows knowledge to flow among different firms to create value and increase their competitive advantage (Frels et al, 2003). Indeed, the most common explanation for the formation of inter-organizational ties is that interdependence and resource complementarities matter for the firm's economic and innovative performance (Owen-Smith Powell, 2006). But cooperation partners can be of different types (customers, suppliers, competitors, firms in the group, universities and research institutes) and it is the case that firms collaborate with different types of partners at a time, as they bring in different sets of knowledge or complementary capabilities (Belderbos et al, 2004).

Cooperation agreements are particularly important in the automobile industry. The diffusion of lean production has implied that original equipment manufacturers (OEMs) move away from vertical integration so that suppliers assume more design tasks (MacDuffie and Helper, 2007). A car is a technologically complex system where various process and product technologies converge (Lara et al., 2005). In many instances, manufacturers and their suppliers lack the set of technological capabilities, resources and knowledge necessary to perform individually technological changes to be incorporated into the modules, systems and components of the cars in order to satisfy their clients, who are increasingly demanding more innovations in the new models without increasing the price. In addition, innovations are costly and must be recovered in less time. This is probably why, in recent years, the innovation strategies of the firms are characterised by an increasing importance attached to external sources of knowledge, thus establishing cooperation agreements in the field of R&D with external agents (Martínez and Pérez, 2003; Oliver Wyman, 2008).

Many automakers firms located in Spain do not perform R&D activities or they do it sparsely. There are exceptions, such as SEAT, the only OEM in Spain capable of designing and creating their own models (with around 1,000 people engaged in R&D in its Technical Center), followed by Nissan MI and the subsidiary of Fiat (Iveco Pegaso), and to a lesser extent Renault (R&D in motors) and Santana Motor[1]. The other assembly factories in Spain only develop process innovations, receiving product innovations from other technical centers in the group.[2] In the automobile industry, multinationals do not tend to make research in Spain but development in order to adapt their products to the local condition of the market (Berger, 2011).

Given the importance of R&D in the automotive sector and given than most of it is made by foreign capital in the Spanish case, in this paper we want to analyse to what extent firms in this sector follow cooperative strategies in their R&D activities in order to overcome the limitations they may encounter when performing R&D activities by themselves. We first examine to what extent firms cooperate with external actors in the field of technological innovation, and if so, with what type of cooperation partner, paying special attention to the role that the size of the firms may be playing. Second, we aim to study the factors that turn out to have a determining effect on the decision of firms to carry out such collaborative activities in R&D. Specifically, we study how the firm's size may affect not only the decision of cooperating but also with which type of partner, while controlling for other determinants that have been considered in the literature as main drivers of collaborative activities in R&D. We use data provided by the Technological Innovation Panel (PITEC) in the 2006-2008 period for firms in the automotive industry. We estimate a bivariate probit model that takes into account the two types of cooperation mostly used in such an industry, vertical and institutional, explicitly considering the interdependencies that may arise in the simultaneous choice of both.

[1] Until its closure as a firm in 2011, Santana Motor coordinated the Hercules project between 2006-2008, together with 4 other firms and 2 technological centres, to design a SUV hydrogen fuel cell.

[2] In Spain, most first-tier suppliers are of foreign capital and the R&D incorporated in their products tend to be developed out of Spain. Only few subsidiaries make product design and carry out part of its R&D in Spain (Lear, TRW, Valeo and Bosch). There are also some national capital groups that perform R&D themselves (e.g. Antolín Irausa, Ficosa International, Gestamp, CIE Automotive and Mondragón Automotive).

The paper is organized as follows. After this introduction, the second section provides a review of the literature on the theories that justify the firms' choice of performing R&D cooperation activities and the role of firm size in such decisions. The third section describes the data and provides a descriptive analysis of this phenomenon, while section four presents the results of the regressions on the determinants of R&D cooperation agreements for the different types of partnership. The last section offers the main conclusions.

2. LITERATURE REVIEW

In the literature there is no consensus regarding the effect of firm size on the probability of collaborating with external agents. Theoretically, according to Robertson and Gatignon (1998), to conduct R&D it is necessary to have sufficient amount of financial, technical and human resources, which is more often the case in large firms (Rothwell and Dogson 1991; Narula, 2004). In addition, to absorb the external knowledge offered by other agents, firms need to have an internal knowledge base and conduct internal R&D activities (Cohen and Levinthal, 1989; Veugelers and Cassiman, 2005), which tend to be higher in large firms (Tether, 2002). However, small firms are characterized by having lower economies of scale in R&D, reduced funding and scarce staff to carry out innovative activities as well as other innovation critical resources such as management skills to create and maintain innovation projects (Narula, 2004; Chun and Mun, 2012). Therefore, one could think that cooperation should enable them to overcome this reduced availability of funds (Hewitt-Dundas, 2006) and share with others the fixed costs associated with such projects (Busom and Fernández-Ribas, 2008).

According to Forrest and Martin (1992), when SMEs collaborate in R&D projects, they seek a quick scanning of new technologies, sharing the risks of developing new products and accessing new funding. In contrast, for large firms, the advantage of cooperation is to access the experience of the partner in R&D activities, have a window open to new technologies and develop products for specific market niches. It seems to follow, therefore, that although with different motivations, both large and small firms have incentives to embark on cooperation agreements for carrying out innovation activities. And from that point of view, firm size should not influence the propensity of firms to establish cooperation agreements in innovation. Is this conclusion corroborated at the empirical level? A large number of empirical studies conclude that large firms cooperate to a greater extent (e.g. Cassiman and Veugelers, 2002; Becker and Dietz, 2004; Miotti and Sachwald, 2003; Negassi, 2004), benefit more from cooperation (Veugelers, 1998) and innovate more openly than SMEs (De Backer, 2008). A clear exception is the study of Abramovsky et al. (2009), which in the case of a sample of firms from four European countries did not found that the size effect was significant in explaining innovation cooperation. For the Spanish case it has also been found that there is a greater propensity to cooperate in the case of large firms (Bayona et al., 2001; López, 2008). In the Spanish automotive supplier industry, Martínez and Pérez (2002) verified the existence of a positive relationship between the size of the firm and cooperation with customers. Also, for the Catalan case and in relation to cooperation with the direct suppliers of OEMs, Llorente (2012) obtained that large firms cooperate in R&D at a higher rate than smaller ones. Therefore, although there are theoretical arguments that motivate both large and small firms to take partnerships in innovation activities with external agents, evidence seems to suggest that large firms tend to do it more frequently, although this relation can vary according to the type of partnership.

When a firm in the automobile industry decides to cooperate to carry out R&D activities, it can be either with customers and suppliers (vertical cooperation), with firms of the same group, with universities and technology centers (institutional cooperation) or with competitors (horizontal cooperation). The motivation for choosing to cooperate in R&D may be different in each case and also in relation to the size of the firm.

In the case of *vertical cooperation,* the customer knows what he wants and needs, giving information to their suppliers to ease product innovations (Tether, 2002). Their mutual collaboration helps to identify market opportunities for technological development, reduces the risk of uncertainty associated with market introduction of new products from new ideas from collaboration with clients, and facilitates identifying new market trends (Kuen-Hung, 2009; Von Hippel et al., 1999). Cooperation with suppliers in new product development often allows improvements in the quality and cost reduction of products through process innovation (Hagedorrn, 1993) and reduces project development lead times (Clark 1989). In the automotive industry outsourced components can be classified as supplier proprietary parts, detail-controlled parts, or black-box part (Clark, 1989, Mikkola, 2003, Koufteros et al., 2007). The automakers have outsourced most of the R&D and production activities formerly done in-house to external suppliers (Clark and Fujimoto, 1991; Womack et al. (1990); Takeishi, 2001). The automakers accumulate global knowledge of the vehicle, while their suppliers have more technical knowledge about the components, systems and modules, so that manufacturers delegated more R&D to them.

The adjusted production model incorporates a close relationship between the manufacturer and part of its suppliers, which is a long term and based on (Womack et al., op. cit.; Sako and Helper, 1998). The first-tier suppliers cooperate with the OEMs in the dessign (Volpato, 2004) and co-development of new product development process (Liker et al., 1996). Even some suppliers involve themselves in the early phase of development of new concepts (Langner and Seidel, 2009; Kamat and Liker, 1994), although some automakers use the strategic segmentation across suppliers (Dyer et al., 1998). In any case, only a part of the suppliers maintain relationship with the automakers, whereas others keep competitive relationships (Helper and Sako, 1998). The trend in this century is to converge towards a hybrid “close but adversarial” model (Ro et al., 2008), from the models “Exit” and “Voice” to Hybrid Collaborative (MacDuffie and Helper, 2007).

The first-level suppliers tend to be large multinationals that are very often strategic partners of the assemblers; while when descending in the pyramid of suppliers, business size decreases and firms tend to carry out less R&D activities, since they have fewer resources to do them (human, technological and financial resources). They usually provide products with lower technological content which, as a consequence, reduce the interdependence between customers and suppliers giving place to more competitive relationships (Mahapatra et al., 2010).

In the case of the automotive industry, *cooperation with firms within the group* arises in some cases as a result of the fact that subsidiaries of foreign multinationals often have relevant technical centers located in the matrix or in subsidiaries in other countries where manufacturers have relevant technological centers (Llorente, 2011). In these cases, a competitive advantage of the group is the successful transfer of tacit knowledge from headquarters to subsidiaries (Rugraff, 2011).

With respect to institutional cooperation, universities and R&D centers are the main public research infrastructure which is incorporated in the system of innovation (Nelson, 1993), and one of the most important sources of technological spillovers (Benavides and Quintana, 2000).[3] On the one hand, universities and firms have increasingly been encouraged to collaborate in R&D activities on the basis of the triple-helix model (Etzkowitz and Leydesdorff, 2000). The need for basic research requires cooperation with public science institutions (Tether, 2002; Van Beers et al., 2008), and it has been said that the automotive firms depend on universities and public laboratories to undertake curiosity-driven basic research (Rutherford and Holmes, 2008). Universities provide access to new knowledge and research that enable the development of novel products (Hagerdoorn et al., 2000; Lee, 2000). Along with R&D centers, they bring new ideas and complex innovations (Fontana et al., 2006), creating new scientific and technological knowledge (Lundvall, 1992), which complement the applied research made by the firm (Chastenet et al., 1990). In recent years has increased demand at university for applied research (Miller et al., 2014). The collaboration with universities increases the probability of the introduction of innovations that are new to the market (Mojón and Waelbroeck, 2003) and are very useful in the development of high tech technologies and research located at the technological frontier (Van Looy et al., 2003; Miotti and Sachwald, 2003)[4]. Universities prefer to work with large firms, as they have higher financial resources for R&D and higher technological capabilities, giving them more prestige and greater opportunities for new research initiatives (Shapira et al., 1995; Beise and Stahl, 1999). On the other hand, technological centres focus their activity towards the generation, transfer and diffusion of technological

[3] In Spain, it encompasses Public Innovation Organizations (OPIs) along with universities, which are the core of the Spanish public research system, running most of the activities planned in the National Plan for Scientific Research, Development and Technological Innovation. At the Spanish level, the Scientific Research Center (CSIC), Centre for Energy, Environment and Technology (CIEMAT) and the National Institute for Aerospace Technology (INTA) work with the automotive industry.

[4] In the automotive industry, nanotechnology offers new technological possibilities, with a substantial supply of it in certain Spanish universities (e.g. the University of Barcelona and the Polytechnic University of Catalonia) and in the CSIC.

innovation in firms. Among their activities, we find the generation of R&D projects, consulting and technical assistance, technology diffusion and promotion of international cooperation. According to Santamaría (2001) and Bayona et al. (2002), technological centres seek knowledge which is more related to solve design problems and develop new products, whereas Gracia and Segura (2003) consider that they allow focusing the basic research carried out in universities and other research centres towards the improvement of businesses.[5] Globally, universities and technology centres also allow firms to access specialized equipment and infrastructure (Callejón et al., 2008), to make tests and trials, offering highly qualified researchers (Dooley and Kirk, 2007).

It is interesting to note that when taking into account institutional cooperation, the role of the firm's size turns out to be different if we refer to universities or to technological centres. Barge-Gil et al. (2011) show that firms that collaborate with technological centres tend to be smaller, probably due to its lower internal capacity for innovation as well as the main orientation towards technological development, and not basic research, of technological centres. By contrast, large firms tend to collaborate more frequently with universities, thanks to their greater internal capabilities and the fact of being more oriented towards the basic research carried out in universities. The same is observed in Japan, with large firms collaborating more with universities than small firms (Motohashi, 2004). Rasiah and Govindaraju (2009) verified the importance of university as a source of knowledge in the automotive industry of Malaysia. Size was inversely correlated with university-industry collaboration alliances. Closer examination showed higher university-industry collaboration means among medium size firms.

Horizontal cooperation is based on maintained cooperative relations between a firm and its competitors. The strategy of combining competition and cooperation deliberately with certain competitors is called coopetition (Brandenburger and Nalebuff, 1996) and the objective is to obtain a game of positive sum and a better outcome both individually and

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[5] In the Spanish case, in 2006 the CENIT projects were introduced to encourage public-private partnerships in industrial research, establishing technological alliances between companies located in Spain and Spanish universities and technological centers.

collectively (Bengtsson and Kock, 1999; Czakon, 2010). Firms can use collaboration with competitors to develop new technology for prospective markets and the need of to share risk (Miotti and Sachwald, 2003). However, coopetition can also be considered a risk because some competitors may have greater capacity to absorb external knowledge and thus access relevant information that can be used to their advantage in future research made individually. Cassiman and Veugelers (2002) show, for the case of Belgian firms, that cooperation with competitors is used scarcely, probably because it is more difficult to manage and also for the risk it entails (Röller et al., 2007). Nieto and Santamaría (2007) verified, in the case of Spanish firms that collaborating with suppliers, customers and research centres has a positive impact on innovation novelty, while the effect is negative when collaborating with competitors.

3. DESCRIPTIVE ANALYSIS

The database used is the Technological Innovation Panel (PITEC)[6], from which we selected the firms available for the automotive industry, which results in a sample of 196 firms. Next, we try to describe the cooperation activities carried out in the Spanish automotive industry paying special attention to the type of agents cooperating as well as to the firm's size.

To characterize the sample across firms' size and the type of capital, Table 1 shows that most firms have only domestic capital (64.8%) and are mainly SMEs (63.8% have less than 250 employees). Specifically, nearly one third (30.1%) are small firms (<100 employees) with only national capital. In contrast, large firms (> 500 employees) are characterized by having clear superior foreign capital participation, with 16.3% of firms in the automotive industry being large and 12% out of the total are big and of foreign capital.

[Insert Table 1 around here]

[6] PITEC is a panel developed jointly by the Institute of National Statistics of Spain (INE), the Spanish Foundation for Science and Technology (FECYT) and the Cotec Foundation.

In relation to the innovative activity carried out by Spanish automotive firms, figures in Table 2 offer the distribution of the internal R&D staff as a proxy of the innovation made by the firm. This gives a median of only 4 people devoted to research activities, with 25% of firms with at least 12 people and only 10% with more than 40 people. Indeed, these figures suggest, by and large, the existence of a very limited staff on innovation activities, with large firms (over 500 employees) having the best figures in this respect: a median of 36 persons, with around 10% of these firms having over 200 employees dedicated to innovation.

[Insert Table 2 around here]

Since firm size is a key aspect in this research, Table 3 summarizes the output of the innovation made by Spanish automotive firms according to their size. From this table we draw the following insights. Most large firms present product (93.7%) and process innovations (84.3%) as well as both simultaneously (81.2%). This is in considerable contrast to small firms, which innovate much less frequently (71.6, 72.1 and 50.7%, respectively). Testing the hypothesis of independence between the type of technological innovation and the firm's size (segmented into four categories), independence is rejected for all items except in the case of innovations on activities for supporting processes, where the differences in percentual points for the several sizes are very small. At the other extreme, in the case of innovations in manufacturing methods, the proportion is more than 25 points higher in large firms, probably as a consequence of seeking improvements in their processes to reduce costs, improve quality and increase flexibility. Even more, the proportion of firms that perform logistics innovation increases directly with firm size in spectacular proportions (7.5% of small firms versus 50% of large). A potential explanation is that large suppliers often have to supply OEMs through arranged in sequences, with daily deliveries, so that manufacturers search for logistics integration with module suppliers, sharing the technological systems that allow for this (Bennet and Klug, 2012). Furthermore, in this group of large firms, *full service* suppliers who design their supply chain have increased in number. Instead, small firms in auxiliary industries use JIT less frequently and assume more costs of inventory of their parts.

[Insert Table 3 around here]

Focusing on innovation cooperation activities (Table 4), firms with more than 250 employees collaborate to a greater extent than small firms. This is probably a result of the latter having less technologically complex products and that some small firms work according to design specifications, being the manufacturer or the supplier of a higher level the one that designs the product that must be manufactured and delivered afterwards. In addition and regardless of the size, the most common partner in the Spanish automotive industry are suppliers, being competitors the least frequent. This is hardly surprising given that collaborating with competitors seems to be considered by firms in the automotive industry more of a risk than an opportunity.

[Insert Table 4 around here]

Collaboration agreements with universities, consultants, commercial laboratories, private institutes and technological centres are not numerous. They are mainly performed by medium and large enterprises, since they are those that perform more research and product development.[7] Cooperation with technological centres is higher than with universities in all sizes, probably because technological centres focus more on applied research, more interesting for firms developing new products. 31.3% of firms with more than 500 workers collaborate with technological centres, followed by 28.8% of firms with at least 250 workers. Indeed, there is a clear association between firm size and each type of partnership, rejecting the null hypothesis of independence in all cases.

It is interesting to highlight that firms often make simultaneous cooperation agreements with different types of partners and that there are significant differences depending on the size of the firms. Among the various pairs of combinations of agents, we observe that

[7] Note that universities and technological centres provide firms with technological personnel and resources which are not available internally. So, a priori, one would think that small firms are those that could take higher advantage, although the results say the opposite. In this regard, some universities, as it is the case of the University of Barcelona (Llorente, 2012) offer the possibility for SMEs to incorporate a graduate student during six months at a reduced cost, with the aim of driving innovation in the firm, helping to understand the available supply of technological innovations in universities and reaching further agreements of collaboration.

collaborating with customers and suppliers, and if we add collaborating with firms within the group, are the most frequent agreements in the range of 251-500 workers (Table 5). Also, in the case of large firms, 31% made cooperation with suppliers and firms within the group, simultaneously. Small firms make less simultaneous cooperation agreements, due to their lower frequency to perform R&D in a collaborative manner; however, when they decide to cooperate, they do it with suppliers and customers. Again, this points to the fact that companies seem to find benefits in having different forms of cooperation agreements simultaneously.

[Insert Table 5 around here]

4. DETERMINANTS OF PARTNERSHIP AGREEMENTS IN THE AUTOMOTIVE INDUSTRY

4.1 Methodological issues

We plan now to analyze whether the determinants of R&D cooperation are different according to the different types of partners. To do so we estimate a bivariate probit model with two binary equations, each one for the main types of cooperation: Vertical and Institutional. Vertical cooperation includes cooperation with suppliers and/or customers whilst institutional cooperation includes cooperation with consultants, commercial labs or private R&D institutes, universities or other higher education institutions, public research organizations and technology centres. Cooperation with competitors is excluded from the analysis because very few automotive firms carry out this type of cooperation agreements (only 11 firms, representing 5.6% of the total). We also exclude cooperation with firms within the same group because only firms belonging to a group can have such kind of alliances, while all other types of cooperation may be chosen by all firms.

We have two latent variables y_{i1}^{*}, y_{i2}^{*} measuring the difference between the benefits and costs that firm *i* obtained by carrying out vertical and institutional cooperation, respectively. We assume that these differences depend linearly on a set of characteristics of the firms (x),

$$y_{ij}^* = x_{ij}^{'}\beta_j + \varepsilon_{ij}, \qquad\qquad j = 1, 2 \qquad\qquad (1)$$

where β_j is a vector of parameters including the constant term and ε_{ij} are error terms distributed as a bivariate normal, each with mean zero and variance-covariance matrix V, where V has values of one in the diagonal and correlations $\rho_{ij} = \rho_{ji}$ (j = 1, 2) as elements outside the diagonal.

Since the latent variables are not directly observable and only their signs can be accounted for, binary variables are defined that summarize such signs as the choice made by firms for a certain type of cooperation. Hence, the bivariate probit model specifies the binary variables as follows:

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

4.2 Determinants of cooperative R&D: Expected effect and definition of variables

Among the main factors influencing the decision of firms to participate in cooperation R&D agreements, on the one hand, economic literature highlights knowledge spillovers and the firms' absorptive capacity[8], while on the other hand, focuses on the importance of the costs, risks and complementarities present in the innovation process.[9]

On the side of knowledge spillovers it is argued that both incoming and outgoing spillovers operate as determinants of cooperation strategies in R&D. Incoming spillovers are external knowledge flows that a firm is able to capture and the information sources for them are usually situated in the public domain; whereas outgoing spillovers refer to the ability of the firm to control knowledge flowing across its borders. The idea is that in order to internalize the information flows that may occur in the processes of innovation and to manage more

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[8] Some of the main references in this approach are Katz (1986), D'Aspremont and Jacquemin (1988) and Kamien et al. (1992).

[9] The main ideas of such theories can be found in Pisano (1990), Das and Teng (2000) and Hagedoorn et al. (2000).

effectively these flows, firms decide to participate in cooperative agreements. To measure these factors, we followed Cassiman and Veugelers (2002) and defined *incoming spillovers* as the importance attributed by the firm to publicly available information for carrying out innovation activities (public information from conferences, trade fairs, exhibitions, scientific journals and trade/technical publications, professional and industry associations), and *legal protection* as a proxy of outgoing spillovers, which considers if the firm used at least one legal method for protecting innovations (patents, registered an industrial design, trademark or copyright).

At the empirical level, papers obtain predominantly positive results of incoming spillovers as determinants of cooperation agreements (Cassiman and Veugelers, 2002; Veugelers and Cassiman, 2005; Serrano-Bedia et al., 2010, Chun and Mun, 2012). This way, firms that place a higher value on incoming spillovers and externally generated knowledge in their innovative activity might have a greater scope for learning and gaining from knowledge exchange through cooperative agreements. In addition, when taking into account the type of partner, this relationship would be expected to be stronger in collaborations with research institutions and universities. As signaled by Abramovsky et al. (2009), it might be expected 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. Meanwhile, in the literature on outgoing spillovers, the effect of appropriability problems on firms' probability to engage in R&D cooperation agreements is ambiguous. On the one hand, a better appropriability of the results of innovation through protection may have a positive effect on cooperation in R&D, as firms can control outgoing information flows and there are less incentives for others to become a free rider on other firms' investments (Cassiman and Veugelers, 2002). However, excessive legal protection may hinder the internalization of the flows shared by the partners and may thus have a negative effect on R&D cooperation (Hernán et al., 2003; López, 2008). This result must be smoothed according to the partner, since Cassiman and Veugelers (2002) obtained that a better appropriability would increase the probability of cooperating with customers or suppliers whereas it is unrelated with research institutes. Among other reasons, it is sensible to think that the information which is commercially sensitive, result of more applied research projects, often leaks out to competitors through common suppliers or customers. Therefore, only those firms with enough protection of their information would be willing to engage in cooperation agreements at the vertical level.

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.

The absorptive capacity of the firm is another determinant of cooperation alliances in R&D. According to Cohen and Levinthal (1989), certain absorptive capacity is necessary to assimilate and exploit knowledge from the environment, so that a firm with more absorptive capacity is able to access a greater amount of knowledge than another with less capacity. Consequently, the first firm may draw greater benefits from cooperative innovation agreements. The absorptive capacity, approximated in the literature either as the ratio of internal expenditure on R&D, the number of employees in R&D or permanent R&D, has been found in many studies as an important feature of the firms with greater probability of cooperation (Bayona et al., 2001; Miotti and Sachwald, 2003; López, 2008;

Arranz and Arroyabe, 2008). However, one could also think that a greater absorptive capacity allows the firm to easily access external knowledge as well as getting benefit from it for free, thus having a lower incentive to cooperate. These arguments would be equally valid for any type of partner. Miotti and Sachwald (2003), for example, find a positive and significant impact of absorptive capacity on the probability of agreements with research institutions and with suppliers and customers. In this paper, *internal R&D intensity* is captured through the ratio between the intramural R&D expenditure and turnover.

On the other hand, according to the literature of strategic management, firms use research partnerships with the idea of accessing complementary knowledge, or in order to share risks or costs (Hagedoorn, 1993). However, existing empirical studies show mixed results regarding the effects of these factors on R&D cooperation. Sakakibara (1997) obtain that access to complementary knowledge is one of the motivations to cooperate in R&D, whereas Bayona et al. (2001) signal both risk- and cost-sharing factors are significant determinants of cooperation. In contrast, Miotti and Sachwald (2003) found that none of these factors influence the likelihood of cooperation. Distinguishing cooperative R&D by type of partner, Belderbos et al. (2004) find that the risks that firms experience as an obstacle to 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. It seems, therefore, that it is necessary to estimate one model for each type of partnership, since the sign and relevance of their impact can be different in each case. *Risk- and cost-sharing* are proxied through the rates that the firm attributed to the uncertain demand for innovative goods or services and the score of the importance of the lack of funds or the consideration of innovation costs too high, as factors hampering their innovation activities, respectively.

We also included *firm size* (<50 employees, 50-249, 250-499 and >500) and *public funding* of innovation, taking the value 1 if the firm belongs to the corresponding size range and has received any kind of public funding (local, regional or national), respectively, and zero otherwise. Large firms are expected to be more likely to be actively engaged in R&D cooperation agreements (Bayona, et al., 2001; Fritsch and Lukas, 2001; Tether, 2002;

Miotti and Sachwald, 2003). It is argued that firms need to have certain structure and resources to be able to face the commitment required in partnerships and to benefit from cooperation agreements, irrespectively of the type of partnership. This is more probably available in large firms than in small firms. In addition, firms obtaining public R&D subsidies 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 (Arranz and Fdez de Arroyabe, 2008; Busom, Fernández-Ribas, 2008; Abramovsky et al., 2009). There are also reasons to believe that public funding may have a greater impact on the likelihood to engage in university collaborations, since institutional incentives for university scientists to transfer knowledge and technology to firms might be weak. Table 6 summarizes the construction of the variables used in the regression analysis.

[Insert Table 6 around here]

4.3 Main Results

The results of the estimation of the binomial probit model are provided in Table 7. As shown in the bottom of the table, the assumption that ρ is zero is rejected, showing that the binomial probit is more suitable than the estimation of the equations separately, providing evidence that there are interdependences between the different cooperation strategies. The positive and significant estimated coefficient of correlation of the error terms (ρ) may be due to complementarities in R&D cooperation strategies but also to the existence of unobserved firm-specific factors affecting the decision regarding the different types of cooperation.

[Insert Table 7 around here]

With respect to the traditional determinants of cooperation, the estimates show a positive and significant relationship between in coming spillovers and the probability of cooperating in the two types of partnership. We obtain that if the firm gives more importance to information publicly available and useful for innovation processes, the firm tends to be more able to exploit spillovers in order to increase the productivity of its innovation activities and consequently obtain higher profits through cooperation agreements (Cassiman and Veugelers, 2002; López, 2008). Comparing both types of partners, we obtain a greater impact of incoming spillovers in the case of cooperation with institutions. This result is in accordance 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. This way, it seems fair to conclude that automotive firms benefit greatly from the information coming from external sources, especially when it comes through cooperation, and mainly through cooperation with university and research institutions.

In line with some previous empirical studies, we also find that the ability to appropriate the results of innovation positively affects the likelihood of cooperation in R&D (López, 2008; Abramovsky et al., 2009). This variable proxies for the possibility of the firm of appropriating the results of the innovation, known in the literature as outgoing spillovers or outgoing information flows. Our results show that making use of protection methods of the benefits of innovations, i.e. reducing the transmission of unintended information flows, the probability to cooperate with suppliers or customers increases, but it does not affect the probability to cooperate with research institutions. This can be probably due to the ambiguity of the impact of appropriability. Despite the argument in favour of a positive impact of appropriability on cooperative agreements, excessive legal protection may also hinder the internalization of the flows shared by the partners and may thus have a negative effect on R&D cooperation (Hernán et al., 2003; López, 2008). Also, and taking into account the type of partner, it is sensible to think that the information which is commercially sensitive, result of applied research projects, often leaks out to competitors through common suppliers or customers. Therefore, only those firms with enough protection of their information would be willing to engage in cooperation agreements at the vertical level. In other words, we might expect firms facing appropriability problems be less likely to engage in collaborative arrangements with suppliers or customers compared to agreements with more dissimilar partners, for instance with research institutes, where freeriding may be less feasible and the incentives to do it are lower given they are not competing in the same market.

For the automobile firms in Spain, the effect of the intensity of R&D activities is not relevant in the decision to participate neither in vertical nor in institutional cooperative agreements. This could be a consequence of the existence of arguments in favour and against the positive impact of R&D intensity on cooperation. As pointed out in the previous section, a certain absorptive capacity is required to assimilate and exploit knowledge in the environment. However, a greater absorptive capacity allows the firm to easily access external knowledge as well as getting benefit from it for free, thus having a lower incentive to cooperate. Additionally, another possible explanation for this non-significant result might be that the magnitude of internal R&D expenditure over turnover is not very high in the Spanish automotive firms.

We can also conclude that the problem associated to cost constraints to carry out innovation activities seems not to be relevant in the decision to participate in cooperation agreements (it is negative and marginally significant only in the case of vertical cooperation). Regarding the risk factor obstructing innovation activities, it appears that automobile firms that give greater value to risks as a factor hampering innovation are more likely to engage in cooperation agreements both with suppliers or customers and research institutions. Given their aversion to the risks inherent in innovation activities, by combining their efforts with research institutions or with customers and suppliers in a partnership agreement, firms can alleviate the barriers to innovation or at least share the risks inherent to innovation.

The estimation results also show that public financial support from local and national government is one of the main determinants of R&D collaboration in both types of cooperation agreements. This result is consistent with most previous empirical literature (Miotti and Sachwald, 2003; Arranz and Arroyabe, 2008; Busom and Fernandez-Ribas, 2008) who find that public subsidies for innovation have a particularly strong effect on increasing the partnerships with research institutions (universities, technological centres and/or public research organizations). This can be partly explained by the fact that often subsidies are designed to stimulate the relationship between enterprises and universities, which is corroborated by the larger magnitude of the coefficient in the case of institutional cooperation than in the vertical, although also significant in the latter.

The size of firms has a positive and significant effect on the probability of carrying out cooperation agreements in both types of partnerships. Thus, in the case of vertical cooperation, firms with more than 500 workers are most likely to make cooperative agreements in R&D. While in the case of institutional cooperation, firms with more than 250 employees are the ones having a higher probability of cooperating, other things equal. This higher propensity to cooperate of large firms can be explained by the fact that they are more able to face the commitment required in partnerships and to better reap the returns of cooperation agreements, thanks to the availability of a greater structure and greater resources. Despite small firms may need cooperation with other firms or institutions in order to manage innovation activities which otherwise could not carry out because of their limited resources, it seems that the evidence provided in our study also gives more support to the former theoretical argument, being big firms more likely to enter in R&D cooperation agreements, irrespectively of the type of partner.

5. Conclusions

In this study we examined cooperation in R&D in the automotive sector in Spain. Spanish firms in this sector are mainly characterized by innovating in products and processes, but generally have a small number of staff assigned to R&D, except large firms with over 500 workers, which perform more innovation in products. In contrast, small firms are less innovative, partly because this group is characterized by a higher proportion of firms receiving, already designed and developed by the customer, the product to be manufactured. In the case of process innovations, firms with more than 500 workers are also distinguished by developing more logistic innovations, due to the importance of logistics for their competitiveness and for the EOMs requirement to have an adequate integration, to make the JIT supply arrange in sequences efficiently.

Specifically, first, we analyze to what extent firms in the sector cooperate with various external actors in the field of technological innovation, and if so, with what type of cooperation partner*,* paying special attention to the role the size of the firms may play in this type of activities. In particular, we see that suppliers and firms in the group are the external agents with whom automotive firms cooperate the most. Instead, competitors are the least frequent, that is, the coopetition strategy is poorly implemented in the Spanish automobile case. The low collaboration with universities and research centers can be a result of the little awareness of SMEs about the real possibilities offered by the research groups at the universities. This can also be a consequence of the fact that most foreign capital multinationals that innovate in product in Spain, only carry out the product development phase in its Spanish subsidiaries, and make significantly less research and design of their products.

Small firms cooperate less frequently than big firms, despite having fewer resources to conduct R&D, which one would think as an incentive in favour of cooperation. On the contrary, we observe that large firms are those that offer higher rates of institutional cooperation. Simultaneous cooperation with different agents is very low in medium and large firms, being null in small firms.

In relation to the factors that have a determining effect on the decision of firms to carry out collaborative activities in R&D, we estimated a bivariate probit model that takes into account the two most common types of cooperation in the automotive industry, vertical and institutional cooperation, explicitly considering the interdependencies that may arise in the simultaneous choice of both. We obtain that when firms give more importance to information publicly available and useful for innovation processes, it is because they are better able to exploit spillovers in order to increase the productivity of their innovation activities and consequently obtain higher benefits through cooperation agreements, so that they do cooperate, being this determinant more clear in institutional cooperation agreements. Also, it seems that using legal protection methods and having public financial support from local and national government are important determinants of collaboration agreements, especially for the case of customers and suppliers. By contrast, in the case of automobile firms in Spain, the effect of the intensity of R&D activities is not relevant in the firms' decision to participate in vertical or institutional cooperation agreements, nor is the existence of cost constraints to carry out innovation activities. Instead, we observe that the automotive firms that give greater value to the risk factor as hampering innovation activities are more likely to engage in cooperation agreements with suppliers or customers and research institutions.

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Table 1. Number of firms by size and type of capital

	Public	Private without foreign capital	Private with participation of foreign capital < 10%	Private with participation of foreign capital 10% - 50%	Private with participation of foreign capital > 50%	Total
< 100	0 (0.0%)	59 (30.1%)	0 (0.0%)	1 (0.5%)	7 (3.6%)	67 (34.2%)
101-250	0 (0.0%)	37 (18.9%)	2 (1.0%)	1 (0.5%)	18 (8.7%)	58 (29.6%)
251-500	2 (1.0%)	20 (10.2%)	0 (0.0%)	3 (1.5%)	14 (7.1%)	39 (19.9%)
> 500	0 (0.0%)	9 (4.6%)	0 (0.0%)	1 (0.5%)	22 (11.2%)	32 (16.3%)
Total	2 (1.0%)	125 (63.8%)	2 (1.0%)	6 (3.1%)	61 (31.1%)	196 (100.0%)

Source: PITEC and own calculations
Note: Percentages are calculated over the number of total firms.

Table 2. Internal staff dedicated to R&D

	N	Mean	Var. Coef.	First quartile	Median	Third quartile	Ninth decile
Total firms	196	15.8	229.1%	0	4	12	40.0
< 50 employees	42	3.1	93.3%	0	3	5	7.7
50-100 employees	25	5.0	154.6%	0	3	7.5	13.8
< 100 employees	67	3.8	134.0%	0	3	5	9.2
101-250 employees	58	5.5	125.1%	0	3	9	14.8
251-500 employees	39	12.0	130.3%	0	8	17	47
> 500 employees	32	64	108.9%	9.2	36.5	91.2	207
With innovation in products	151	19.7	210.0%	0	6	15.5	48.4
With internal expenditure on R&D	134	23.1	181.2%	3.7	8.5	20.2	56.5

Source: PITEC and own calculations

Table 3. Type of technological innovation by firm size. Relative frequencies. Association between type of technological innovation and firm size.

	< 100	101-250	251-500	> 500	Chi-squared	p-value	V Cramer
Product Innovation	71.6%	74.1%	76.9%	93.7%	6.432	0.092 (†)	0.181
Process Innovation	71.6%	77.6%	82.1%	84.4%	2.654	0.448	0.116
Innov. in manufacturing methods	55.2%	65.5%	69.2%	81.2%	6.863	0.076 (†)	0.187
Innov. in logistics systems	7.5%	15.5	33.3%	50.0%	27.265	0.000 (**)	0.373
Innov. of support in processes	37.3%	37.9%	35.9%	46.9%	1.098	0.778	0.075
Product & process Innov.	50.7%	62.1%	71.1%	81.2%	9.975	0.019 (*)	0.226
# firms	67 (100%)	58 (100%)	39 (100%)	32 (100%)			

Source: PITEC and own calculations.
Note: Percentages are calculated with respect to the size group. (†) p <0.1, (*) p <0.05, (**) p <0.01

Table 4. Partners of R&D cooperation activities by firm size. Relative frequencies. Association between type of partner and firm size.

	< 100	101-250	251-500	> 500	Total	Chi-squared	p-value	Phi
Customers	3 (4.5%)	9 (15.5%)	**12 (30.8%)**	5 (15.6%)	29 (14.8%)	13.593	0.004	0.263 (**)
Suppliers	13 (19.4%)	**19 (32.8%)**	**13 (33.3%)**	**13 (40.6%)**	58 (29.6%)	5.749	0.,124	0.171
Firms in the group	5 (7.5%)	**18 (31.0%)**	**12 (30.8%)**	**13 (40.6%)**	48 (24.5%)	17.184	0.001	0.296 (**)
Universities	3 (4.5%)	11 (19.0%)	9 (23.1%)	7 (21.9%)	30 (15.3%)	9.541	0.023	0.221 (*)
OPIs	1 (1.5%)	5 (8.6%)	4 (10.3%)	6 (18.8%)	16 (8.2%)	9.005	0.029	0.214 (*)
Technological centers	5 (7.5%)	**12 (20.7%)**	**11 (28.2%)**	**10 (31.3%)**	38 (19.4%)	10.98	0.012	0.237 (*)
Consulting, laboratories and private institutions	3 (4.4%)	8 (14.0%)	**8 (20.5%)**	6 (18.8%)	25 (12.8%)	7.324	0.062	0.193
Competitors	2 (2.9%)	4 (6.9%)	3 (7.7%)	1 (3.1%)	10 (5.1%)	0.1805	0.614	0.096
Size of each sub-sample or sample	67 (100%)	58 (100%)	39 (100%)	32 (100%)	196			

Source: PITEC and own calculations.
Note: Percentages are calculated with respect to the size of all the firms (in the sample, cooperative and non-cooperative firms included).
(†) p <0.1, (*) p <0.05, (**) p <0.01

Table 5. Partners of R&D cooperation activities by firm size. Joint frequencies.

	< 100	101-250	251-500	> 500	Total
Customers + Suppliers	3 (4,5%)	7 (12,1%)	**10 (25,6%)**	4 (12,5%)	24 (12,2%)
Customers + Firms in the group	1(1,5%)	8 (13,8%)	**9 (23,1%)**	3 (9,4%)	21(10,7%)
Suppliers + Firms in the group	3 (4,5%)	**11 (19,0%)**	**7 (17,9%)**	**10 (31,2%)**	31 (15,8%)
Customers + Suppliers + Firms in the group	1 (1,5%)	6 (10,3%)	**7 (17,9%)**	3 (9,4%)	**17 (15,8%)**
Customers + Suppliers + Consulting, lab and private institutions	1 (1,4%)	4 (6,9%)	**6 (15,4%)**	3 (9,4%)	14 (7,1%)
Customers + Suppliers+ Firms in the group + Consulting, lab and private inst	1 (1,4%)	4 (8,8%)	4 (10,3%)	3 (9,4%)	12 (6,1%)
Customers + Suppliers + Competitors	0 (0,0%)	3 (5,2%)	3 (7,7%)	1 (3,1%)	7 (3,6%)
Customers + Suppliers + Firms in the group + Competitors	0 (0,0%)	2 (3,5%)	3 (7,7%)	1 (3,1%)	6 (3,1%)
Customers + Suppliers + Group + Consulting, lab and private inst + Competitors	0 (0,0%)	2 (3,5%)	2 (5,1%)	1 (3,1%)	5 (2,6%)
Universities + Technological centres	1 (1,4%)	7 (12,1%)	**6 (15,4%)**	**5 (15,5%)**	18 (9,2%)
Universities + OPIs	0 (0,0%)	4 (6,9%)	4 (10,3%)	**5 (15,5%)**	13 (6,6%)
Universities + OPIs + Technological centres	0 (0,0%)	3 (5,1%)	3 (7,7%)	**5 (15,6%)**	11 (5,6%)
Universities + Technological centres + Consulting, lab and private inst	0 (0,0%)	5 (8,6%)	4 (10,3%)	4 (12,5%)	13 (6,6%)
Universities + OPIs + Technological centres + Consulting, lab and private inst	0 (0,0%)	2 (3,5%)	2 (5,1%)	4 (12,5%)	8 (4,1%)
Suppliers + Universities	1 (1,5%)	8 (13,9%)	**9 (23,1%)**	6 (18,7%)	24 (12,2%)
Suppliers + Technological centres	2 (3,0%)	**10 (17,2%)**	**9 (23,1%)**	**7 (21,9%)**	**28 (14,3%)**
Customers + Universities	1 (1,5%)	6 (10,3%)	**8 (20,5%)**	2 (6,2%)	17 (8,7%)
Customers + Technological centres	0 (0,0%)	7 (12,1%)	**9 (23,1%)**	3 (9,4%)	19 (9,7%)
Suppliers + Universities + Technological centres	0 (0,0%)	7 (12,1%)	**6 (15,4%)**	4 (12,5%)	17 (8,7%)
Suppliers + Firms in the group + Universities + Technological centres	0 (0,0%)	6 (10,3%)	**5 (12,6%)**	4 (12,5%)	15 (7,6%)
Customers + Universities + Technological centres	0 (10,3%)	6 (10,3%)	**6 (15,4%)**	2 (6,3%)	14 (7,1%)
Customers + Suppliers + Universities + Technological centres	0 (0,0%)	6 (10,3%)	**6 (15,4%)**	2 (6,2%)	14 (7,1%)
Customers + Suppliers + Universities + OPIs + Technological centres	0 (0,40%)	3 (5,1%)	3 (7,7%)	2 (6,2%)	8 (4,1%)
Customers + Suppliers + Universities + OPIs + Technological centres + Consulting, lab and private inst	0 (0,0%)	2 (3,5%)	2 (5,1%)	2 (6,2%)	6 (3,1%)
Customers + Suppliers + Firms in the group + Universities + OPIs + Technological centres + Consulting, lab and private inst + Competitors	0 (0,0%)	2 (3,5%)	1 (2,6%)	1 (3,1(%)	4 (2,0%)
Sample	67 (100%)	58 (100%)	39 (100%)	32 (100%)	196 (100%)

Source: PITEC and own calculations.
Note: Percentages are calculated with respect to the size of all the firms (in the sample, cooperative and non-cooperative firms included).

Table 6. Definition of the variables included in the regression analysis

Variables	Definitions
Dependent	
Cooperation with Suppliers or Customers (Vertical)	= 1 if the firm cooperated in some of their innovation activities with suppliers of equipment, materials, components or software, or customers in the period 2006-2008 = 0 otherwise
Cooperation with Research Institutions (Institutional)	= 1 if the firm cooperated in some of their innovation activities with consultants, commercial labs or private institutes R&D, Universities or other higher education institutions, government or public research organizations (OPIs), and technology centres in the period 2006-2008 = 0 otherwise
Independent	
Incoming Spillovers	= 1 - sum of the score of importance that the firm attributed [number between 1 (high) and 4 (Not relevant / not employed)] to the source of information from conferences, trade fairs, exhibitions, scientific journals and trade/technical publications, professional and industry associations. Rescaled between 0 (unimportant) and 1 (crucial)
Legal Protection of Innovation	= 1 if the firm applied for a patent, registered an industrial design, registered a trademark, and / or claimed copyright = 0 otherwise
Internal R&D Intensity	Ratio between internal R&D expenditure and turnover of the firm
Risks	= 1 - the score of importance that the firm attributed [number between 1 (high) and 4 (Not relevant / not employed)] to the uncertain demand for innovative goods or services as a factor hampering their innovation activities. Rescaled between 0 (unimportant) and 1 (crucial)
Costs	= 1 - sum of the score of importance that the firm attributed [number between 1 (high) and 4 (Not relevant / not employed)] to the lack of funds within the group of firms, lack of funding from sources outside the firm, innovation cost too high as factors hampering their innovation activities. Rescaled between 0 (unimportant) and 1

	(crucial)
Public Funding of Innovation	= 1 if the firm received public financial support from local or regional government and / or central government for their innovation activities = 0 otherwise
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

Note: All explanatory variables come from PITEC 2006.

Table 7. Binomial probit model of R&D cooperation in the automotive sector

	Vertical Cooperation	**Institutional Cooperation**
Incoming Spillovers	0.7535 *	1.0839 **
	(0.395)	(0.435)
Legal Protection	0.5828 **	0.0557
	(0.246)	(0.245)
Internal R&D Intensity	-1.5508	-0.643
	(1.813)	(1.647)
Risks	0.9936 ***	0.9228 **
	(0.345)	(0.38)
Costs	-0.6939 *	-0.3781
	(0.412)	(0.438)
Public funding	0.6793 ***	1.1492 ***
	(0.216)	(0.234)
Firm Size (base <50 employees)		
50 - 249 employees	0.3423	0.4042
	0.287	(0.326)
250 - 499 employees	0.5176	0.7449 **
	(0.316)	(0.351)
500 or more employees	0.6754 **	0.711 *
	(0.343)	(0.378)
Constant	-1.699 ***	-2.3764 ***
	(0.375)	(0.424)
P	0.7610 *** (0.075)	
N	190	
LogL	-168.466	
Wald Test Ho: the coefficients are jointly = 0	Chi2(18) = 66.72 Prob>chi2 = 0.000	

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

Institut de Recerca en Economia Aplicada Regional i Públic
Research Institute of Applied Economics

WEBSITE: www.ub-irea.com • **CONTACT:** irea@ub.edu

Grup de Recerca Anàlisi Quantitativa Regional
Regional Quantitative Analysis Research Group

WEBSITE: www.ub.edu/aqr/ • **CONTACT:** aqr@ub.edu

Universitat de Barcelona
Av. Diagonal, 690 • 08034 Barcelona