Cooperation in R&D, firm size and type of partnership

Evidence for the Spanish automotive industry

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Abstract

Purpose – The purpose of this paper is 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.

Design/methodology/approach – The data in this study came from the surveys done in 2010 and 2013 by the Technological Innovation Panel (PITEC) for firms in the automotive industry. The paper estimates a bivariate probit model that takes into account the two types of cooperation mostly present in such an industry, vertical and institutional, explicitly considering the interdependencies that may arise in their simultaneous choice.

Findings – The empirical study confirms that small firms cooperate less frequently than big firms and that giving more importance to information publicly available and having public financial support from local and national governments are important determinants of collaboration agreements, mainly in the case of customers and suppliers.

Originality/value – This paper contributes to the understanding of the motivations of the automotive industry for engaging in R&D cooperation agreements. The authors study how the firm's size may affect not only the decision of cooperating but also with which type of partner.

Keywords Innovation, Partnership, Automotive industry, Firm size, Cooperation in R&D

Paper type Research paper

1. Introduction

A firm may increase its technological capabilities through either internal efforts in R&D or external activities such as cooperating in technological agreements. Firms seek to blend external sources of innovation with company-level competences and assets to incorporate new ideas (Chesbrough, 2006), allowing firms to gain greater technological innovation (Ili *et al.*, 2010) and improve efficiency (Montoro, 2005). In particular, R&D cooperation is a strategy of knowledge sharing and diffusion across firms that has increased in importance in recent decades. R&D cooperation allows knowledge to flow among different firms to increase their competitive advantage (Frels *et al.*, 2003)[1]. Cooperation partners can be of

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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, 2006). A car is a technologically complex system where various process and product technologies converge (Lara *et al.*, 2005)[2]. In recent years, the innovation strategies of the firms are characterized 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; Wyman, 2007).

Many automakers located in Spain do not perform R&D activities or they do it so scarcely. There are exceptions, such as SEAT, the only OEM in Spain capable of designing and creating on their own, followed by Nissan MI and the subsidiary of Fiat (Iveco Pegaso), and to a lesser extent Renault (R&D in motors). The other assembly factories in Spain only develop process innovations, receiving product innovations from other technical centres in the group[3]. In the automobile industry, multinationals do not tend to conduct research in Spain but development in order to adapt their products to the local condition of the market (Berger *et al.*, 2011).

Given the complexity of the automotive sector and the various challenges it faces, it is often no longer sufficient to rely only on in-house innovation, and firms are forced to improve their innovation capability through interactions with other economic agents. Through cooperation with different actors, firms may enable to acquire required information from a variety of sources which could lead to more synergies and intake of complementary knowledge (Belderbos *et al.*, 2006; Laursen and Salter, 2006; Nieto and Santamaría, 2007; Van Beers and Zand, 2014; Badillo and Moreno, 2015). Despite its relevance for firms and that it constitutes an important goal of innovation policy (López, 2008; Boardman and Gray, 2010), the studies on R&D cooperation of the Spanish automotive industry are scarce.

In this context, this study contributes to the understanding of the motivations of the automotive industry for engaging in R&D cooperation agreements in two ways. First, we 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 analyse 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 the main drivers of collaborative activities in R&D.

To this end, we use data provided by the Technological Innovation Panel (PITEC), using the surveys of 2010 and 2013 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. With regard to theoretical approach, we follow the most important lines of thinking examining the determining factors on the decision of firms to establish R&D cooperation agreements: the resource-based view, transaction cost theory and industrial organization theory.

The paper is organized as follows: after introduction, Section 2 provides a review of the literature on the theories that justify the firms' choice of performing R&D cooperation activities and exposes the main hypotheses of the paper. Section 3 describes the data and provides a descriptive analysis of this phenomenon, while Section 4 presents the results of the regressions on the determinants of R&D cooperation agreements for the different types of partnership. Section 5 offers the main conclusions.

2. Literature review and hypothesis

2.1 Cooperation with external agents

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 centres (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 due to collaboration with clients and facilitates identifying new market trends (Tsai, 2009; Von Hippel *et al.*, 1999). Cooperation with suppliers in new product development often allows improvements in the quality and cost reduction through process innovation (Hagedoorn, 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 parts (Clark, 1989; Mikkola, 2003; Koufteros *et al.*, 2007). Automakers have outsourced most of the R&D activities formerly done in-house to external suppliers (Clark and Fujimoto, 1991; Takeishi, 2001; Womack *et al.*, 2007) because they have more technical knowledge about the components, systems and modules.

The adjusted production model incorporates a close relationship between the manufacturer and its suppliers, which is a long-term one (Sako and Helper, 1998; Womack *et al.*, 2007). The first-tier suppliers cooperate with the OEMs in the design (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; Kamath and Liker, 1994), although some automakers use the strategic segmentation across suppliers (Dyer, 1996). In any case, only some suppliers maintain relationship with the automakers, whereas others keep competitive relationships (Sako and Helper, 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, 2006).

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 (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 centres located in the matrix or in subsidiaries in other countries (Llorente, 2011). In these cases, a competitive advantage of the group is the successful transfer of tacit knowledge from headquarters to subsidiaries (Rugraff, 2012).

With respect to institutional cooperation, universities and R&D centres 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)[4]. 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 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 (Hagedoorn *et al.*, 2000; Lee, 2000). Along with R&D centres, 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, demand at university for applied research has increased (Miller *et al.*, 2014). The collaboration with universities increases the probability of the introduction of innovations that are new to the market (Monjon and Waelbroeck, 2003), and such collaborations 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). 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 innovation to 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 solving design problems and develop new products, whereas Gracia and Segura (2003) consider that they allow focusing on 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 co-opetition (Brandenburger and Nalebuff, 1997), and the objective is to obtain a game of positive sum and a better outcome both individually and 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, co-opetition 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.

2.2 The effect of firm size on cooperative R&D

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 find 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. These arguments lead to our first hypothesis:

H1. Large automotive firms are more likely to engage in cooperative R&D agreements.

2.3 Other determinants of cooperative R&D

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[6], while on the other hand, it focuses on the importance of the costs, risks and complementarities present in the innovation process[7].

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 beyond 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 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 and 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.*, 1995; 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, as a 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.

Based on the above-mentioned arguments, we can pose the next hypothesis:

H2. Automotive firms that rate available external information sources as more important inputs to their innovation process are more likely to engage in cooperative R&D agreements.

And the following two competing hypotheses:

H3. Automotive firms that use at least one method to protect the results of their innovations are more likely to engage in cooperative R&D agreements.

H4. The use of methods to protect the results of innovations decreases the probability to engage in cooperative R&D agreements.

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 get 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 line with these ideas, the following hypothesis arises:

H5. Automotive firms with high levels of R&D intensity have a higher probability to engage in R&D cooperation with research institutions and with suppliers and customers.

Public funding encourages R&D cooperation (Peterson, 1993). 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 Arroyabe, 2008; Busom and Fernández-Ribas, 2008; Abramovsky *et al.*, 2009). Also, many times public support programmes for R&D activities aim to ease cooperative innovation agreements by firms that would otherwise not engage in such activity. Thus, we put forward our final hypothesis:

H6. Automotive firms that receive public financial support for their innovation activities have a higher probability to engage in R&D cooperation agreements.

3. Descriptive analysis

The database used is the Technological Innovation Panel (PITEC)[8], from which we selected the firms available for the automotive industry. Specifically, the variables for R&D cooperation (dependent variables) are taken from the 2013 survey (wave 2013-2010), while the explanatory variables correspond to the 2010 survey (wave 2010-2008)[9]. This results in a sample of 148 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 firms' size.

To characterize the sample across firms' sizes and the type of capital, Table I shows that most firms have only domestic capital (64.9 per cent) and are mainly SMEs (64.9 per cent have less than 250 employees). Specifically, half of firms (50.3 per cent) are SMEs (< 250 employees) with only national capital. In contrast, large firms (> 500 employees) are characterized by having clear superior foreign capital participation, with 16.2 per cent of firms in the automotive industry being large, and 12.9 per cent out of the total are big and have foreign capital.

In relation to the innovative activity carried out by Spanish automotive firms, figures in Table II 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 6 people devoted to research activities, with 25 per cent of firms with at least 18 people and only 10 per cent with more than 48 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 42 persons, with around 10 per cent of these firms having over 400 employees dedicated to innovation.

Table I. 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
< 50	0 (0.0%)	27 (18.2%)	0 (0.0%)	0 (0.0%)	1 (0.7%)	28 (18.9%)
50-249	1 (0.7%)	48 (32.4%)	2 (1.4%)	0 (0.0%)	17 (11.5%)	68 (45.9%)
250-499	1 (0.7%)	16 (10.8%)	1 (0.7%)	0 (0.0%)	10 (6.8%)	28 (18.9%)
⩾ 500	0 (0.0%)	3 (2.0%)	2 (1.4%)	2 (1.4%)	17 (11.5%)	24 (16.2%)
Total	2 (1.4%)	94 (63.5%)	5 (3.4%)	2 (1.4%)	45 (30.4%)	148 (100.0%)

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

Table II. Internal staff dedicated to R&D

	n	Mean	Var. coef. (%)	First quartile	Median	Third quartile	Ninth decile
Total firms	148	26.6	276.5	0	6.5	18.75	48.2
< 50 employees	28	4.0	139.6	0	2	5	12.6
50-249 employees	68	7.6	128.9	0	4	12.0	21.1
250-499 employees	28	14.6	130.3	0	12.5	21.5	34.4
⩾ 500 employees	24	121	125.0	19.25	42.5	247.5	403
With innovation in products	95	36.9	240.6	1	10.0	24.5	57.6
With internal expenditure on R&D	100	39.4	220.1	6.0	13.5	26.25	59.6

Source: PITEC and own calculations

Since firm size is a key aspect in this research, Table III 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 (83.3 per cent) and process innovations (78.9 per cent) as well as both simultaneously (62.5 per cent). This is in considerable contrast to small firms, which innovate much less frequently (57.1, 70.0 and 42.9 per cent, respectively). When considering only process innovation, the proportion is higher for firms with at least 250 employees. Even more, the proportion of firms that

Table III. Type of technological innovation by firm size

	< 50	50-249	250-499	⩾ 500	χ^2	p-value	Cramer's V
Product innovation	57.1%	58.8%	67.9%	83.3%	5.447	0.142	0.182
Process innovation	64.3%	61.8%	71.4%	62.5%	2.654	0.448	0.116
Innovation in manufacturing methods	46.4%	50.0%	64.3%	62.5%	2.975	0.395	0.142
Innovation in logistics systems	3.6%	17.6	42.9%	41.7%	17.644	0.001**	0.345
Innovation of support in processes	32.1%	25.0%	42.9%	33.3%	3.058	0.383	0.144
Product and process innovation	42.9%	35.3%	53.6%	62.5%	6.442	0.092***	0.209
Total firms	28 (100%)	68 (100%)	28 (100%)	24 (100%)			

Notes: Relative frequencies. Association between type of technological innovation and firm size. Percentages are calculated with respect to the size group. $*p < 0.05$; $**p < 0.01$; $***p < 0.1$
Source: PITEC and own calculations

perform logistics innovation increases directly with firm size in spectacular proportions (3.6 per cent of small firms vs 42 per cent 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.

Focusing on innovation cooperation activities (Table IV), 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 firms in the same group, followed by suppliers, with competitors being 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.

Collaboration agreements with universities, research centres, consultants and commercial laboratories are not numerous. They are mainly performed by medium and large enterprises, since they perform more research and product development[10]. Cooperation with private or public research centres is higher than with universities in all sizes, probably because those research centres focuses more on applied research, more interesting for firms developing new products. Overall, 35.7 per cent of firms with at least 250 workers collaborate with private or public research centres, followed by 33.3 per cent of firms with more than 500 workers. Indeed, there is a clear association between firm size and each type of partnership, rejecting the null hypothesis of independence in all cases.

Finally, Table V provides summary statistics for the variables used in the regression analysis. We observe that automotive firms that engage in cooperation agreements are more

	< 50	50-249	250-500	$\geqslant 500$	Total	χ^2	p-value	φ
Customers	2 (7.1%)	10 (14.7%)	6 (21.4%)	4 (16.7%)	22 (14.9%)	2.335	0.506	0.125
Suppliers	2 (7.1%)	15 (22.1%)	9 (32.1%)	11 (45.8%)	37 (25.0%)	11.230	0.011*	0.257
Firms in the same group	1 (3.6%)	22 (32.4%)	13 (46.4%)	17 (70.8%)	53 (35.8%)	27.194	0.000**	0.429
Universities or other higher education institutions	1 (3.6%)	8 (11.8%)	4 (14.3%)	4 (16.7%)	17 (11.5%)	2.580	0.461	0.132
Private or public research centres	0 (0.0%)	10 (14.7%)	10 (35.7%)	8 (33.3%)	28 (18.9%)	15.721	0.029*	0.328
Consultants or commercial laboratories	2 (7.1%)	5 (7.4%)	3 (10.7%)	5 (20.8%)	15 (10.1%)	3.979	0.275	0.162
Competitors	2 (7.1%)	6 (8.8%)	0 (0.0%)	6 (25.0%)	14 (9.5%)	9.900	0.019**	0.260
Vertical cooperation	2 (7.1%)	16 (23.5%)	10 (35.7%)	11 (45.8%)	39 (26.4%)	11.581	0.009**	0.279
Institutional cooperation	2 (7.1%)	13 (19.1%)	11 (39.3%)	10 (41.7%)	36 (24.3%)	12.818	0.005**	0.294
Size of each sub-sample or sample	28 (100%)	68 (100%)	28 (100%)	24 (100%)	148			

Notes: Relative frequencies. Association between type of partner and firm size. Percentages are calculated with respect to the size of all the firms (in the sample, cooperative and non-cooperative firms included). $*p < 0.05$; $**p < 0.01$; $***p < 0.1$
Source: PITEC and own calculations

Table IV. Partners of R&D cooperation activities by firm size

Table V.
Descriptive statistics of the variables used in the regression analysis[a] (mean values)

Variables	Total sample	Cooperative	Non-cooperative	Type of cooperation Vertical	Institutional
Incoming spillovers	0.266	0.316	0.219	0.368	0.370
Legal protection	18.9%	23.9%	14.3%	23.1%	30.6%
R&D intensity	0.107	0.183	0.036	0.022	0.021
Risks	0.477	0.493	0.463	0.521	0.444
Costs	0.583	0.609	0.560	0.664	0.617
Public funding	38.5%	52.1%	26.0%	56.4%	55.6%
Less than 50 employees	18.9%	5.6%	31.2%	5.1%	5.6%
50-249 employees	45.9%	43.7%	48.1%	41.0%	36.1%
250-499 employees	18.9%	23.9%	14.3%	25.6%	30.6%
500 or more employees	16.2%	26.8%	6.5%	28.2%	27.8%

Note: [a]The definition of the variables is presented in Table AI
Source: PITEC and own calculations

likely to place higher importance on incoming spillovers and to use some form of legal protection than those which do not cooperate (for instance, around 24 per cent of firms that cooperate use at least one method of legal protection to protect their innovation returns vs 14 per cent in the group of firms that do not cooperate); they also tend to have a higher mean of internal R&D intensity, and receive public funding for innovation. Related to size, Table V shows that big firms show a greater propensity to cooperate than smaller firms.

4. Determinants of partnership agreements in the automotive industry

4.1 Methodological issues

We plan now to analyse whether the determinants of R&D cooperation in the automotive firms 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 laboratories 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 per cent 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[11].

4.2 Determinants of cooperative R&D: definition of variables

In our model, we include the main factors that have traditionally been considered in the literature as influencing the decisions to engage in innovation alliances. In this paper, we focus on firm size, the roles of incoming spillovers, legal protection and cooperation as a means of overcoming constraints (i.e. risks and costs). We also control for some firm's characteristics such as absorptive capacity and the receipt of public funding for innovation. The variables used in the regression analysis as well as their construction are mainly based on previous studies on the topic of R&D cooperation such as Cassiman and Veugelers (2002), López (2008), Arranz and Arroyabe (2008) and Badillo and Moreno (2016).

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 asked in PITEC were conferences, trade fairs, exhibitions, scientific journals and trade/technical publications and 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). 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. 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.

In this paper, internal R&D intensity is captured through the ratio between the intramural R&D expenditure and turnover. 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.

Firm size (< 50 employees, 50-249, 250-499 and > 500) and public funding of innovation are included 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 0 otherwise. Table AI shows the matrix of correlation between variables used in the regression analysis, and Table AII summarizes the construction of these variables.

4.3 Main results

The results of the estimation of the binomial probit model are provided in Table VI. As shown in the bottom of the table, the assumption that ρ is 0 is rejected, showing that the binomial probit is more suitable than the estimation of the equations separately, providing evidence that there are interdependencies 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.

With respect to the traditional determinants of cooperation, the estimates show a positive and significant relationship between incoming spillovers and the probability of cooperating in the two types of partnership, giving full statistical support to our second hypothesis.

	Vertical cooperation	Institutional cooperation
Incoming spillovers	1.491*** (0.505)	1.117** (0.463)
Legal protection	0.122 (0.250)	0.427 (0.266)
Internal R&D intensity	−2.996 (4.528)	−1.468 (4.259)
Risks	0.082 (0.407)	−0.077 (0.382)
Costs	0.394 (0.453)	0.062 (0.444)
Public funding	0.514** (0.259)	0.315 (0.263)
Firm size (base < 50 employees)		
50-249 employees	0.577 (0.432)	0.114 (0.420)
250-499 employees	0.928* (0.483)	0.790* (0.459)
500 or more employees	1.246*** (0.476)	0.782* (0.470)
Constant	−2.423*** (0.610)	−1.729*** (0.496)
ρ	0.898*** (0.048)	
n	148	
Log L	−113.34	
Wald test	$\chi^2(18) = 42.18$	
H_0: the coefficients are jointly = 0	Prob. > $\chi^2 = 0.000$	

Notes: Heteroskedasticity-robust standard errors. *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$

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

In line with some previous empirical studies, 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). 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.

We also find that the ability to appropriate the results of innovation do not affect the probability to cooperate with any type of partners considered. 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, do not affect the probability to cooperate with suppliers and customers or with universities or research institutions, in such a case we do not obtain sufficient evidence to support our fourth or fifth hypothesis. This can be probably due to the ambiguity of the impact of appropriability and due to the fact this variable may be more closely related to cooperation with competitors, where free-rider concerns might be the most likely to come into play.

For the automobile firms in Spain, the effect of the intensity of R&D activities is not relevant in the decision to participate in neither vertical nor 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 and risks constraints to carry out innovation activities seems not to be relevant in the decision to participate in cooperation agreements.

The estimation results also show that public financial support from local and national government is one of the main determinants of vertical R&D collaboration, while it does not affect the probability to cooperate with universities or research institutions.

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). In the Spanish automobile case, we do not find any significant impact of such risks and costs. Indeed, existing empirical studies show mixed results regarding the effects of these factors on R&D cooperation. Bayona *et al.* (2001) signal both risk- and cost-sharing factors are significant determinants of cooperation, whereas 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.

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 evidence gives support to our first hypothesis. 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

This paper provides evidence on the determinants of cooperation in R&D in the automotive sector in Spain.

First, we analyse 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 co-opetition strategy is poorly implemented in the Spanish automobile case. The low collaboration with universities and research centres 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, making significantly few 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. In addition, 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 their simultaneous choice. According to the literature, we obtain that when firms give more importance to information publicly available and useful for innovation processes, 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: as a result, they do cooperate, being this determinant, in the automotive industry, more clear in vertical cooperation agreements. Also, it seems that having public financial support from local and national governments is an important determinant 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 or risk constraints to carry out innovation activities.

The results in this study are of considerable interest for public policy in their efforts to promote R&D cooperation activities. According our results, the effectiveness of such policies, in the case of automotive firms, could be enhanced if there are technological spillovers that can be internalized by cooperating firms. According to Cohen and Levinthal (1989), firms can improved their capacity to use information which is available externally by investing in own R&D. However, in this study, we have noted that the automotive firms' R&D intensity is very low. Besides, our results suggest that automotive firms need certain resources and abilities that small firms do not have in order to establish a cooperation agreement with other agents. As a consequence, policy measures need to be more addressed at smaller firms.

Our study is not without limitations. The principal limitation of this study derives from the data available. In PITEC, certain firms that are part of the value chain in the automotive industry are not classified as belonging to this sector. They may be incorporated in diverse sectors such as textiles, chemistry or plastic; however, the majority of its sales volume focuses on the automotive sector. It also conditioned the way in which we constructed some of our variables, for instance, the variables on cooperation are dummies or we cannot include a measure of the location of this sector in industrial parks. In terms of future research, it would be interesting to know the intensity of collaboration or to know if the firms are OEM, tier one, tier two, and so on. On the other hand, it would be interesting to analyse the impact of R&D cooperation with different partners on innovation performance of automotive firms, in order to get a better understanding about the role of this strategy for promoting innovation in the automotive industry.

Notes

1. Nevertheless, it has also been pointed that there may be potential disadvantages of cooperation agreements, to a large extent resulting from opportunistic behaviours by partners (Williamson, 1985; Gulati, 1995). Cooperation may also lead to a loss of autonomy and control of research results, as well as a loss of know-how as a company relies more on other partners (Quélin and Duhamel, 2003; Hoecht and Trott, 2006; Kremic *et al.*, 2006).
2. The automotive sector comprises manufacture of motor vehicles, manufacture of bodies and manufacture of components, parts and accessories. This sector presents a typical pyramidal structure with the automakers at the top. The first-tier suppliers supply modules and systems to the OEMs, which are becoming increasingly more technologically complex and have assumed more responsibility for R&D in the development of new models.
3. 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).
4. 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.
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.
6. Some of the main references in this approach are Katz (1986) and Kamien *et al.* (1992).
7. The main ideas of such theories can be found in Pisano (1990), Das and Teng (2000) and Hagedoorn *et al.* (2000).
8. 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.
9. We lagged explanatory variables in order to limit the simultaneity bias inherent to this kind of studies.
10. Note that universities or other higher education institutions 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.

11. Note that, although PITEC has a panel structure, we carried out a cross-sectional analysis because of the complexity of the estimation strategy. More details of the estimation method can be found in Badillo and Moreno (2016).

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(The Appendix follows overleaf.)

Appendix

Table AI. Association between variables used in the regression analysis

		1	2	3	4	5	6	7	8	9
1	Incoming spillovers	1.00	0.064	0.128	0.396***	0.059	1,586.3***	1,940.5***	1,321.5***	1,381.0
2	Risks		1.00	0.413***	0.111	–0.133	2,093.0	2,642.0	8,114.0	2,011.0
3	Costs			1.00	0.153	–0.189	2,221.5	2,430.0	7,943.5	1,872.0
4	R&D intensity				1.00	–0.089	*0.140*	*0.086*	*0.052*	*0.055*
5	Size					1.00	*0.213*	*0.004*	*0.214*	*0.118*
6	Legal protection						**1.00**	**0.258*** **	**0.134**	**0.202**
7	Public funding							**1.00**	**0.282*** **	**0.214*** **
8	Vertical cooperation								**1.00**	**0.698*** **
9	Institutional cooperation									**1.00**

Notes: To test the degree of association between variables we estimated the more appropriate coefficient in each case, depending on the types of variables. Correlations between continuous variables (4, 5) and continuous variables versus ordinal variables (1, 2, 3) are calculated with the Spearman's rank correlation method. Values in bold are computed with the φ coefficient in order to test correlation between dichotomous variables (6, 7, 8, 9). While values in italics, obtained with the η correlation method, correspond to correlations between dichotomous versus continuous variables. To test the association of ordinal variables versus dichotomous variables we used the Mann-Whitney *U* coefficient, whose values are provided in the box. Although this latter test is a statistical comparison of the mean, it is assumed that if there are no differences in the media there is no significant relationship between these two variables. ***$p<0.01$
Source: PITEC and own calculations

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 2013-2010 0 otherwise
Cooperation with research institutions (institutional)	1 if the firm cooperated in some of their innovation activities with consultants, commercial laboratories or private institutes R&D, universities or other higher education institutions, government or public research organizations (OPIs), and technology centres in the period 2013-2010 0 otherwise
Independent	
Incoming spillovers	1 minus 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 and 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 minus 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 minus 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 2010

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

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