Does absorptive capacity determine collaboration returns to innovation? A geographical dimension

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Abstract

This paper aims to estimate the impact of collaboration in innovation activities with partners in different geographical areas on innovative performance. By using the Spanish Technological Innovation Panel, this study provides evidence that the benefits of collaboration differ across different dimensions of the geography. We find that the impact of extra-European cooperation on innovation performance is larger than that of national and European cooperation, indicating that firms tend to benefit more from interaction with international collaborators as a way to access new technologies or specialized and novel knowledge that they are unable to find locally. We also find evidence of the positive role played by absorptive capacity, concluding that it implies a higher premium on the innovation returns to cooperation in the international case and mainly in the European one.

Keywords: Innovation cooperation; Technological partners; Geographical location; Performance; Absorptive Capacity; Spanish firms
JEL classification: L25; O31; O33; R1

1. Introduction

Knowledge diffusion between individuals and firms is critical for innovation and growth (Grossman and Helpman 1991; Lucas 1988; Romer 1986, 1990). Firms need to innovate continuously and rapidly to survive in today's competitive and global markets, thus the diffusion of new knowledge is of utmost importance. Knowledge is known to diffuse through a variety of mechanisms (Döring and Schnellenbach 2006), among which networks of collaboration in innovation activities are considered pivotal. The literature on collaborative networks, and their impact on knowledge diffusion and innovation and consequently on growth, has expanded greatly in recent years (see special issues by Autant-Bernard et al. in Papers in Regional Science, 2007; and by Bergman in The Annals of Regional Science, 2009).

This growing need for enhanced innovation capability through the use of new knowledge produced elsewhere is forcing firms to expand technology interaction with different and increasingly geographically dispersed actors. Indeed, collaboration with a broader range of external partners may enable innovating firms to acquire required information from a variety of sources which could lead to more synergies and intake of complementary knowledge, thus promoting innovation performance (Belderbos et al. 2006; Laursen and Salter 2006; Nieto and Santamaría 2007; van Beers and Zand 2014).

The present paper contributes to this literature. In particular, we focus on the geographical scope of R&D collaborators and study their differential impact on innovation performance. A priori, external collaboration with partners abroad provides access to unique resources of foreign partners, which can produce complementary knowledge that may be in short supply in the firm's home country. This is because collaborators abroad are embedded in different national innovation systems than collaborators in the domestic market (Miotti and Sachwald 2003; Lavie and Miller 2008; van Beers and Zand 2014). Therefore, we expect collaborations with partners from abroad to have higher impact on the firm's innovative performance than national collaborations. In addition, the underlying logic would state that when the external knowledge is similar to existing competences in the country, it can be absorbed easily, but will not add much to the existing local knowledge (Boschma and Iammarino 2009).

In sum, distant knowledge sources should allow individuals in innovative firms to make novel associations and linkages which increase their innovativeness.

Despite the extensive literature on the relationship between R&D collaboration and innovation performance, little attention has been placed on the impact that the geographical scope of such collaborations may have. There are some papers with national studies on the differences between national and international R&D alliances with respect to the impact on innovation output (Miotti and Sachwald 2003; Cincera et al. 2003; Lööf 2009; Arvanitis and Bolli 2013) which tend to conclude that innovation performance is positively and significantly influenced by international R&D cooperation, but remains unaffected or less affected by national cooperation. However, our study extends previous literature by disaggregating the geographical scope of the international alliances to explore the effect of collaboration in innovation activities with partners in particular geographic areas. Specifically, for knowledge that comes from abroad, we differentiate among collaborations maintained with European partners and those further away (the US, China, India, or other countries). The latter are theorized to provide less redundant pieces of knowledge, which would allow enhancing creativity and innovation to a greater extent than in the intra-European case. Indeed, Miotti and Sachwald (2003) conclude that French firms resort to transatlantic R&D alliances in order to access specific and complementary R&D resources, whereas cooperation with European partners is mainly motivated by cost economising. This being true, it is sensible to think that both transoceanic and intra-European cooperation have a positive influence on the share of innovative products, although cooperation with transoceanic partners can have a higher influence whenever firms conduct research at the technological frontier. The reasoning is that this difference is due to the complementarity of the resources of extra-EU partners with those of European firms, making this type of cooperation more efficient in terms of innovation, especially for more radical innovation.

Despite the general idea in favour of international cooperation providing new sources of attractive technologies and resources that are in short supply in the firm’s home country and therefore having a positive impact on innovation, the national differences between the local firm and its foreign partners can also imply barriers to efficient resource exchange, so that the final result is in doubt. According to Lavie and Miller (2008), the benefits and costs of cooperating in international contexts may vary according to the level of internationalization: the concept of alliance portfolio internationalization. This degree of internationalization refers to the cross-national differences between the firm's home country and its partners' countries of origin. Among the main reasons behind these differences, Ghemawat (2001) include cultural differences, geographical distance, institutional differences, and dissimilarities in levels of economic development. With proximate foreign collaborators, the firm may fail to recognise latent national differences that would hinder its ability to understand the technology in the foreign country. And the benefits of collaborating with proximate foreign partners can be not as high since the resources that can be reached thanks to cooperation agreements do not differ dramatically from those with domestic partners. Since for the Spanish case we will differentiate between close foreign partners, such as the European ones, and those further away as in the US and Asia, among others, we will provide evidence if the benefits of internationalization in cooperation more than compensates the organizational problems they imply, in line of the notion of the alliance portfolio internationalization given by Lavie and Miller. In tackling with the ideas above, we follow the literature on absorptive capacity and organizational learning applied to the study of alliance management (Levitt and March 1988; Kale et al. 2002, Sampson 2005) as well as that of internationalization (Lane et al. 2001).

The second issue in which this paper extends the existing empirical literature addresses the fact that firms can collaborate with agents from several geographical areas at a time. Previous literature has focused on the importance of diverse collaborative networks in terms of the type of partner –supplier, client, competitor, or research organisation– in achieving product innovations. In general terms, it is concluded that firms that obtain the greatest positive impact maintain external R&D collaboration with different types of partners. In other words, using a wide range of external actors helps the firm to achieve innovation since having a broader spectrum of experiences with diverse partners should allow for wider knowledge than collaboration with only one type of partner (Becker and Dietz 2004; Laursen and Salter 2006; Nieto and Santamaría 2007). We extend this reasoning to the geographical dimension. In principle, we hypothesize that collaborating with partners from diverse geographical areas should substantially boost innovation thanks to the amount and variety of knowledge that can be shared, allowing the alliance partners to fill out their initial resources and enabling the firm to make novel association and linkages. In contrast, additional alliances with the same partner may provide only redundant information and could result in inertia (Hoang and Rothaermel 2005), the same that additional alliances with partners in the same geographical area would imply information from the same regional or national innovation system. We can then argue that diverse geographical sources of knowledge provide opportunities for the firm to choose among different technological paths. Having a heterogeneous portfolio of partners enables access to diverse sources of information which facilitates firms to transfer and apply that knowledge (Ahuja and Katila, 2001). However, this heterogeneity implies high costs of international and inter-organizational coordination. Indeed, Frost and Zhou (2005), Lahiri (2010) and Duysters and Lokshin (2011), among others, have paid attention to the co-practice in effectively organizing for international R&D. In words of the latter, “each organization has a certain management capacity to deal with complexity which sets limits on the amount of alliance portfolio complexity than can be managed within the firm”. Thereby, we plan to evaluate the impact of conducting external collaboration with partners in at least two different geographical areas, which is assumed to provide greater diversity of the type of knowledge exchanged but also a higher degree of complexity to handle.

The third and main hypothesis of this paper states that firms’ absorptive capacity determines collaboration returns to innovation. Innovation is an evolutionary and cumulative process. In consequence, only with the necessary capability to identify, assimilate, and develop useful external knowledge can the host firms and regions effectively benefit from incoming technology flows through a network of collaborators. As discussed by Cohen and Levinthal (1990), the differential impact of external incoming knowledge flows depends mainly on firms’ absorptive capacity. In the present inquiry, we argue that absorptive capacity is needed to understand and transform inflows of knowledge into innovation. Those firms with higher levels of absorptive capacity can manage external knowledge flows more efficiently, and therefore, stimulate innovative outcomes (Escribano et al. 2009). Thus, even firms exposed to the same amount of external knowledge –within a cluster, for instance– might not enjoy the same benefits, because of their different endowments of absorptive capacity (Giuliani and Bell 2005). However, we plan to give a step forward and analyse if this absorptive capacity is equally important for national and international sources of external knowledge. A priori, investing in internal innovation activities and training employees add to the absorptive capacity of the firm and increase its ability to understand and assimilate any knowledge from external sources. However, when these sources originate in very distant geographical areas, with different economic and social backgrounds, absorptive capacity may play even a higher role than in the case of external knowledge originated within the same region or economic area.

We check the validity of these three hypotheses using data from the Spanish Technological Innovation Panel for the period 2004-2011, which contains detailed information on the innovative behaviour of Spanish firms. Since innovation performance can only be observed for firms which report at least one innovation, the empirical strategy consists of a two-stage selection model, estimated using the Wooldridge's (1995) consistent estimator for panel data with sample selection. The first equation is a selection equation indicating whether or not the firm was innovative. The second stage of the analysis captures the impact of collaboration with different and diverse geographical areas on innovative performance, taking into account how this impact may vary according to the absorptive capacity of the firm.

From a policy perspective, the results in this paper confirm that not only investments in R&D are important to generate innovations, but also the degree to which connectivity with the outside world, which gives access to global knowledge hotspots, is useful for innovation. Such connectivity, among other ideas, is at the core of the 'smart specialisation' strategy recently launched by the European Commission (McCann and Ortega-Argilés 2013). According to it, the "smart specialization strategy" should include an analysis of potential partners in other regions and avoid unnecessary duplication. It also needs to be based on a strong partnership between businesses, public entities and knowledge institutions (European Commission 2012). The empirical evidence presented in the present paper goes in this direction. However, the present paper also aims at showing to what extent the benefits of collaboration in innovation activities are likely to differ across different geographic scales. Understanding such differential impact of collaborations may help to identify the geographical areas from which the highest benefits can be obtained; which is critical to effectively promote regional economic growth and cohesion.

The outline of the paper is as follows. Section 2 offers the empirical model. The dataset, variables and a descriptive analysis are given in section 3 and section 4 provides the main results. Section 5 concludes.

2. Empirical model

We aim to estimate the impact of external collaboration in innovation activities with partners in different geographical areas on innovative performance. Since innovative performance can only be observed for firms that report at least one innovation, we follow a two-stage approach to address the potential selection bias on the estimation of the innovation performance equation. The first stage of our analysis consists of a binary selection model using all available observations and considering as dependent variable whether or not the firm was innovative (*d*). In the second stage, we estimate the innovation performance equation taking account of the selection process. In this second stage model, the dependent variable that proxies for innovative performance (*y*) is a measure of the share of sales due to new or significantly improved products.

The model has the following specification:

$$d_{it} = 1[z_{it}\gamma + \eta_i + u_{it} > 0], \qquad (1)$$

$$y_{it} = \begin{cases} x_{it}\beta + \alpha_i + \varepsilon_{it} & \text{if } d_{it} = 1 \\ 0 & \text{if } d_{it} = 0, \end{cases} \qquad (2)$$

where $i = 1, \ldots, N$, $t = 1, \ldots, T$, and 1[.] is an indicator function that takes on the value 1 if the expression between square brackets is true and 0 otherwise. In addition, γ and β are unknown parameter vectors to be estimated; z_{it} and x_{it} are vectors of explanatory variables with possibly common elements. In equation (2) we assume that there are valid exclusion restrictions. η_i and α_i are unobserved individual specific effects which may be correlated with z_{it} and x_{it}, respectively; and u_{it} and ε_{it} the idiosyncratic errors. The innovation performance variable (y_{it}) is only observable if the firm innovated (d_{it}=1) and the parameter vector of interest to estimate is β.

We estimate the model using Wooldridge's (1995) consistent estimator for panel data with sample selection. This approach allows for correlation between the individual effects and the explanatory variables by adding the means (over time) of the time-varying explanatory variables as control variables. The estimation method of the equation of interest augmented in such a way is estimated by pooled OLS. Specifically, this method consistently estimates β by first estimating a probit of d_i on z_i for each t and then saving the inverse Mills ratio, $\hat{\lambda}_{it}$. Next, we estimate by pooled OLS the equation of interest augmented by the inverse Mills ratio and the means of the time-varying explanatory variables using the selected sample. The resulting equation is (Wooldridge 2010):

$$y_{it} = x_{it}\beta + x_i\psi + \sum_{t=1}^{T} \rho_t D_t \hat{\lambda}_{it} + e_{it} \text{ for all } d_{it} = 1 \qquad (3)$$

where D_t is a time indicator variable and x_i represents a vector of means of the time-variant regressors.[1]

3. Dataset, variables and descriptive analysis

3.1 Dataset

The data come from the Spanish Technological Innovation Panel (PITEC) for the period 2004-2011. The data come from different successive waves of the Spanish Innovation Survey conducted every year by the Spanish National Statistical Institute (INE) in collaboration with the Spanish Foundation for Science and Technology (FECYT) and the Foundation for Technological Innovation (COTEC). The survey is constructed according to the same framework as the European Union Community Innovation Survey (CIS), which is based on the general guidelines set out in the Oslo Manual (OECD 2005). PITEC provides detailed information on innovation behaviour and firm characteristics over time and takes into account dynamic aspects of the innovation process.

[1] We assume that the conditional mean of the individual effects are a linear projection on the within individual means of the time-variant regressors (Mundlak 1978; Nijman and Verbeek 1992; Zabel 1992; Wooldridge 1995).

Our sample contains information on manufacturing and services firms with at least ten employees and positive sales. We use an unbalanced panel with 71,556 observations which represent about 10,902 firms for the whole period.[2] In order to minimise potential endogeneity problems, all the explanatory variables are lagged one-wave, that is, a lag for a variable in t refers to two to four years before t. This results in a dataset covering 10,012 firms and 70,182 observations.

3.2 Variables

Dependent variables

The dependent variable in the first stage is binary, indicating whether the firm has been engaged in any innovation activity during the period t-2 and t. In the second stage, the measure of innovation performance, observed at period t, is defined as the share of sales due to new or significantly improved products. This is a quantitative measure of innovation performance often used in the literature and its logarithmic transformation benefits from being closer to a normal distribution and being symmetric[3] (Klomp and van Leeuwen 2001; Mohnen et al. 2006; Raymond et al. 2010; Robin and Schubert 2013; Barge-Gil 2013).

Explanatory variables

Based on previous literature, we explain the probability of being an innovator as a function of the firm size and its squared term (in order to take nonlinearities into account), market share, belonging to a group and industry dummies (Veugelers and Cassiman 1999; Vega-Jurado et al. 2009; Raymond et al. 2010). We also allow for factors perceived as barriers to innovation activities using four Likert-type constraint variables: cost obstacles, knowledge obstacles, market obstacles, and other obstacles (see Table A1 in the Appendix for a detailed description of these variables). These variables are available for both innovative and non-innovative firms. Since the innovation indicator refers to the period between t-2 and t, we defined these explanatory variables in t-2. The variables market share, belonging to a group, and the four variables related to the obstacles to innovation presented above are considered as exclusion

[2] Further details of the PITEC survey can be found at the following link: http://icono.fecyt.es/PITEC/Paginas/por_que.aspx

[3] *log[y/(1-y)]* where the zero values are converted to 0.0001 and 100 per cent becomes 0.9999.

restrictions for the second stage. They are considered in the selection model as a likely influence on the decision to carry out innovation activities, but not as determinants of innovation performance.

In the second stage, to evaluate the impact of the geographical scope of research alliances on innovation performance, we constructed different sets of dummy variables indicating the geographic location of the collaboration partner. First, we distinguish between firms that collaborated in R&D activities exclusively with national partners (*National*) and those exclusively with international partners (*International*). Then, with the aim of disentangling the differential impact of international alliances, we distinguish among collaborations maintained exclusively with European partners (*European*) and exclusively with partners in other areas including the US, China and India (*extra-European*). Finally, we further divide the extra-European alliances category into two different variables, namely US alliances (*US*) and alliances with partners in Asia and elsewhere (*Asian/Others*). We use these mutually exclusive variables to avoid potential problems of multicollinearity and also to capture the impact of each partnership area more clearly by separating it from the effects attributable to other partnership areas. In all cases, the reference category which is omitted from the estimation is firms with no collaboration at all. Additionally, in all cases, for firms that collaborate with partners in at least two different geographical areas, we constructed the variable *Multiple areas*, which takes the value 1 in such cases, and 0 otherwise.

The second independent variable of interest in our model is absorptive capacity. In this study we use the proportion of internal R&D expenditures over total sales as a proxy for a firm's absorptive capacity. This measure is the most common proxy for absorptive capacity in the literature and accounts for the effort of a firm to build a stock of knowledge (Jones et al. 2001; Belderbos et al. 2004; Faems et al. 2005; Schoenmakers and Duysters 2006; Nieto and Santamaría 2007; Van Beers and Zand 2014). As discussed by Cohen and Levinthal (1989), the firm's stock of knowledge may play a dual role. First, it enables creation and assimilation of new knowledge which can be used for the development of new or enhanced products, thereby exerting a direct influence on innovation performance. A positive impact of this variable is therefore expected. Second, knowledge plays a role as a means to enhance the firm's ability to assimilate and exploit external sources of knowledge. Thus, those firms with greater

R&D capacity have a developed technology base that allows them to manage external knowledge flows more efficiently, and therefore, stimulate innovative output (Escribano et al. 2009). In our paper, this applies to knowledge acquired through collaborations with partners in different geographic locations; to evaluate this we included a cross-product term between each collaboration variable and the proxy for absorptive capacity.

Control variables in the second stage include a set of 2-digit industry dummies as well as several other variables often used in studies on the innovative performance of firms. Among them, firm size is measured by the logarithm of the number of firm employees and its squared term is also included in order to consider the existence of non-linearities in this relationship. The sign for the impact of firm size is not clear a priori. According to the Schumpeterian hypothesis (Schumpeter 1942) the size of the firm positively influences its innovative output. Large firms are more likely to have the necessary resources (infrastructure, financial resources, and production and marketing capabilities) to face the risks associated with innovation processes and hence, they are more likely than smaller firms to engage in innovative activities. While some empirical studies have supported the Schumpeterian hypothesis (Tsai 2009; Raymond et al. 2010), this is not always the case. A number of studies have found that small firms are more innovation-intensive than larger firms. Among other reasons, this is due to a lower degree of rigidity when faced with innovations (Acs and Audretsch 1988; Lööf 2009; Arvanitis and Bolli 2013).

A firm is considered a foreign-owned multinational if it has at least 50% of foreign capital and is headquartered outside Spain. Although the empirical evidence is not conclusive, previous studies suggest that the subsidiary of a foreign parent company may perform better in bringing new products to the market than a host company (Tsai 2009). The idea is that foreign-owned firms have the advantage of accessing specific knowledge and resources of a group of firms and therefore can transfer technology at lower cost, which enables them to create new products and services in their host country more easily and enjoy a higher turnover from these innovations than a domestically owned firm (Reis 2001; Dachs et al. 2008; Díaz-Díaz 2008). In order to control for the experience and knowledge accumulated from past R&D, we also include a binary variable indicating whether the firm conducted internal R&D activities continuously (*Permanent R&D*), which is argued to have a positive influence on innovation output through learning effects (Aschhoff and Schmidt 2008; Raymond et al. 2010; van Beers and Zand 2014). It is assumed that a firm that conducts R&D regularly has greater potential for detecting ideas for new products.

Further, recent literature considers that firms can better achieve and sustain innovation by adopting a diverse set of sources of information that are available and thus can be a proxy for unintentional externalities or spillovers. According to Duysters and Lokshin (2011) a greater access to external search channels allows firms to broaden the pool of technological opportunities and to draw on ideas from multiple external sources which can lead to a higher innovation performance. To measure the openness degree of a firm to these sources of information we follow a method similar to that of Laursen and Salter (2006) and Robin and Schubert (2013). We use the eight main sources of information available in the survey, each coded as a binary variable which is equal to 1 if the source was used and 0 otherwise. We exclude internal sources within the firm and university or public research institutes sources because, as in Laursen and Salter (2006) and Robin and Schubert (2013), most firms report no usage of these sources. These eight indicators are summed to construct a measure of openness which varies from 0 (no external sources used) and 8 (all external sources used); a higher value indicates a greater openness of a firm to external sources of information for innovation. However, this does not necessarily imply any formal cooperation, which in our case is measured through another set of variables. Finally, we include a demand-pull variable in the model. Following Raymond et al. (2010), we proxy it with a dummy variable that takes value 1 if at least one of the following objectives of innovation is scored as very important in the survey (where 1 is not used/not relevant and 4 is very important on a Likert scale), and 0 otherwise: extend product range, increase market or market share, and improve quality in goods and services. Most empirical studies find that firms that devote more effort to increasing demand for their products, and therefore to market expansion get higher sales of innovative products (Belderbos et al. 2004; Lööf and Broström 2008; Raymond et al. 2010).

Table A1 in the Appendix provides more details on the definitions of the variables that are used in this study. Table A2 shows the correlations between the explanatory variables of the model. We do not observe any indication of multicollinearity in our regressions even when the cross terms between the collaboration variables and absorptive capacity are considered.

3.3 Descriptive analysis

Table 1 provides summary statistics for the dependent and explanatory variables used in the empirical analysis. Panel A offers figures only for innovate firms, while Panel B includes all firms in our sample, both innovative and non-innovative. We observe that 76% of Spanish firms are innovative and their average share of innovative sales is 27%. Additionally, within the innovative firms, the average size is 317 employees (median size is 63 employees) and R&D expenditures over turnover represent about 7.3%. On average, nearly 11% of innovative firms are foreign multinationals, while over half of them are firms conducting internal R&D continuously.

[Insert Table 1 around here]

Table 2 displays the distribution of the types of alliance by geographical areas and their temporal pattern. This table reveals interesting results. About one-third of innovative firms maintained some type of research alliances, which although not negligible, implies that only a minority of firms engage in collaborative agreements as part of their innovative process. Concerning the geographical scope of such collaborative agreements, research alliances with local partners are much higher than with foreign partners. On average, more than 60% of collaborative firms maintain research alliances exclusively with national partners with a decreasing pattern from 2005. The national nature of the majority of technological partnerships is not exclusive to the Spanish case. Previous studies with similar figures include Miotti and Sachwald (2003) and Monjon and Waelbroeck (2003) for the French case, and van Beers and Zand (2014) for Dutch firms. The second most common type of alliance is that including both national and international partners which appears to be increasing over time, ranging from 27 to above 37 percent between 2005 and 2011. Within international alliances, collaboration with European partners exclusively is the most common although with a slightly decreasing trend. Contrarily, the proportion of alliances with partners in more distant geographical areas tend to increase along the period, although are less frequent than European alliances. In particular, the share of collaborations with China, India, and others grew from 7.2% in 2005 to 12% in 2011. This is consistent with the idea that technological knowledge is becoming more and more dispersed over the world and firms are increasing their efforts to benefit from new hubs of knowledge such as the ones in Asia (Duysters and Lokshin 2011). As stated by Bathelt el al. (2004) and Owen-Smith and Powell (2004), firms in regions build 'pipelines' in the form of alliances to benefit from knowledge hotspots around the world.

[Insert Table 2 around here]

4. Results and discussion

4.1 Innovation performance and the geographical scope of research alliances

The first step in our empirical model is to estimate the selection equation (the propensity to innovate) for each year (see Table A3 in the Appendix for the results of these regressions). From the estimation of these probit models we obtain the correction terms (the inverse Mill's ratio) which are included in the second stage, focused on the study of the impact of the geographical scope of external collaborations in innovation activities on the firms' innovative performance. Here the correction terms are included to account for the selection bias caused by the fact that we only observe the sales share of innovative products for firms that innovate. Through all the results presented below we perform two Wald tests: one on the joint significance of the six selection effects involved ($H_0: \rho_{2006} = 0, \ldots, \rho_{2011} = 0$) which can be interpreted as a test of selection bias; and the other for the joint significance of the coefficients on the within-individual means to check for the existence of correlated individual effects ($H_0: \psi = 0$). As presented in Table 3, the values for these test statistics are significantly different from zero which points to the necessity of correcting for sample selection bias and suggesting the presence of correlated effects.

[Insert Table 3 around here]

Table 3 shows the results for different specifications of our main model of innovation performance. Column 1 contains the control variables plus our proxy of absorptive capacity. As we observe, R&D expenses exert a significant and positive impact on innovation performance, a finding in line with the absorptive capacity literature, where it is argued that R&D expenditures stimulate firm's innovation output. Regarding the control variables, the results are robust through all our estimates. Our results indicate a negative and non-linear relationship between firm size and innovation performance, in consonance with other studies (Lööf 2009; Vega-Jurado et al. 2009; Robin and Schubert 2013; Arvanitis and Bolli 2013; Arvanitis et al. 2013). Also, the variable capturing the experience and knowledge accumulated from past R&D (*Permanent R&D*) has the expected positive sign. Thus, firms that undertook R&D continuously reach a larger share of innovative sales through learning mechanisms. In line with previous studies, the degree of openness of the firm and the demand pull indicator are positively associated with the intensity of product innovation (Belderbos et al. 2004; Duysters and Lokshin 2011). In addition, we find that the variable capturing the foreign multinational nature of the firm is not significant, leading to the conclusion that foreign-owned firms are not necessarily different from their domestic counterparts when it comes to innovation output (in line with the results in Tsai 2009 and Arvanitis and Bolli 2013).

Column 2 of Table 3 presents the results when the collaboration variables are included. In a first instance, we are interested in assessing the difference in the impact of external collaboration with partners located in the firm's home country compared with partners abroad. As can be seen from Table 3, collaborations exclusively with national partners and those exclusively with international partners are found to be positive and statistically significant, pointing to a positive benefit from cooperation with external firms or institutions. Moreover, our results conclude that firms maintaining collaborations with partners abroad increase the share of innovative sales more than those that collaborate only with partners located in the same geographical area. Indeed, we performed a Wald test for the equality of the coefficients to test if these effects are significantly different from each other. We reject the null hypothesis at a 5% significance level (χ^2 =5.90; *p-val*=0.015). This can be explained by the fact that collaboration with partners abroad can improve access to new or complementary technologies and resources that provide less redundant pieces of knowledge, which would allow enhancing innovation. This is also consistent with the theoretical expectations that partners abroad are embedded in different national innovation systems than partners in the local market and therefore such international collaboration would allow firms to have access to complementary knowledge that is in short supply in their home region (Miotti and Sachwald 2003).[4]

We now disaggregate the variable of international research alliances to distinguish the differential impact of collaborations maintained with European partners, with which, a priori, not only geographical distance is smaller but also cognitive and technological distance, than with partners in more remote areas (US, China, India, or other countries). The results are reported in Column 3. We obtain that collaborations exclusively with European partners do not significantly promote innovation sales, whereas when such alliances are formed exclusively with partners in very distant areas, the impact on innovation performance is found to be highly significant. Two main explanations can be found for this difference.

First, since technological specializations are closer between European countries than European countries and the US, cooperation with US partners follow more knowledge-oriented motives, such as the utilization of technological synergies or access to specialized technologies where US firms tend to have strong competitive advantages. As Miotti and Sachwald (2003) obtain, French firms seek transatlantic rather than European partners whenever they conduct research at the technological frontier. On the contrary, intra-European partnerships seem to be used by French firms to share costs rather than access specific R&D resources. That is, the main drivers of international cooperation seem to differ for intra- and extra-European cases. Further, as Arvanitis (2012) found, resource motives seem to enhance innovation performance more strongly than cost-oriented motives (such as saving R&D costs). Thus it is straightforward that the impact of extra-European cooperation on innovation can be larger than that of national or European cooperation.

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[4] A criticism to the results obtained is that collaboration is assumed to impact upon innovation performance, with a one-way causality interpretation. However, the opposite direction of causality could also be considered. For instance, one could think that some Spanish located multinational firms with a strong innovation performance could develop activities in China or other countries on the basis of unique capabilities. This problem of direction of causality cannot be easily solved. One potential solution is to use historic measures as instruments. However, since our observation units are firms, the panel data cover a relatively short number of time periods and PITEC cannot be matched with other sources, finding reliable instruments is a challenging task. As pointed by López (2008), it is difficult to find perfectly exogenous instruments within a survey (CIS in his case, PITEC in ours), where every question is closely related. Admittedly, suitable instruments still have to be found and so further research along these lines must be undertaken. For the moment being, we have lagged variables in the right hand side of the models in order to help to reduce simultaneity bias inherent to this analysis. We thank a referee for raising this point.

A second explanation of the different impact between intra- and extra-European cooperation may be found on the idea given by Lavie and Miller (2008) that the benefits and costs of cooperating in international contexts may vary according to the level of internationalization. Indeed, as commented above, international cooperation may provide new sources of attractive technologies and resources that are in short supply in the firm's home country, giving unique opportunities that domestic partners may not be able to offer. However, the national differences between the local firm and its foreign partner can also imply barriers to efficient resource exchange. These benefits and costs of cooperating in international contexts may vary according to the level of internationalization. Given the economic, social and institutional similarity between European firms, the resources and skills that can be gained thanks to cooperation agreements among them do not differ dramatically from those with domestic partners. However, at this low level of internationalization, the notion of psychic distance paradox may take place (O'Grady and Lane 1996). That is, instead of identifying and understanding subtle but existing national differences with partners from other countries in Europe, a firm deciding to collaborate with a European partner may tend to implement managerial methods used when cooperating with national partners under the belief that these methods will also be applicable. In Lavie and Miller's (2008) words:

> Perceived similarities between the firm's home country and proximate countries reduce managers' uncertainty about the nature of the foreign environment and thus lead them to believe that conducting business in these countries would be relatively easy. Consequently, managers pay limited attention to latent yet critical national differences, which hinders their ability to fully understand the foreign countries from which their partners originate (p. 626).

In sum, although cooperating with European partners may imply benefits for innovative output, the benefits are not as high as in the case of more distant partners and, more importantly for the Spanish case, they seem not to surpass the costs of cooperating in an international context. In contrast, having non-European partners, despite the high costs involved, gives firms access to non-redundant ties that provide access to new information and resources that are sufficiently distinctive from the firm's local knowledge base.

In any case, in relation to the impact of European cooperation, it should be taken into account that only around 4% of the firms in our sample cooperate exclusively with European partners (see Table 2). In most cases, those firms that cooperate with Europe also carry out some other type of cooperation (for instance, more than 17% of firms cooperate simultaneously with European and national partners). And in those cases of multiple cooperation, as we will see in next subsection, firms obtain a positive impact which is of a higher magnitude that cooperating with national partners exclusively. Therefore, the non-significant parameter of European cooperation should be mitigated, when having these figures in mind.

In Column 4 of Table 3, we observe that among firms with extra-European cooperative agreements, it is not only those linked with the US exclusively, but also with Asian/other partners that positively influence the innovative performance of Spanish firms, although it is of a higher magnitude for the US case. Firms with all kind of extra-European partners benefit from the higher difference in cultural, social, institutional and economic background of such collaborations. However, when cooperating with US firms, national and cultural differences are important but not as excessive as with Asia, so that firms can manage this internationalization by identifying and following opportunities. The firm and the US partners can communicate and engage in effective collaboration due to this cultural and social compatibility. In contrast, in the case of Asian or other partners, substantial national and cultural dissimilarities may imply an increase of the costs of cooperation. In any case, in light of the results, the benefits of such collaboration still far surpass the costs involved, yielding very fruitful relations for the generation of innovation.

4.2 Innovation performance and the diversity of research alliances

We account now for the fact the firms can establish relationships simultaneously with partners from different geographical areas. In Column 2 (Table 3), the *Multiple* variable has a value one if the firm has undertaken both national and international alliances at the same time. Whereas in Columns 3 and 4, the Multiple variable takes the value 1 for firms that either have collaborations nationally and in a foreign region at the same time, or have collaboration agreements with several foreign regions. Thus, in all the cases, the Multiple variable implies that firms cooperate with at least two of the partnership categories in the respective estimation. The variable is therefore capturing the effect of the geographical heterogeneity of the network. According to the results, it seems that in the Spanish case, establishing collaboration agreements in innovation activities simultaneously with partners established in different geographical zones at the same time influences positively and significantly the firm's innovative performance.[5]

However, this diversity of partnership only leads to better innovation performance than that of innovating firms cooperating exclusively with national or exclusively with European partners. This suggests that collaborating with partners from several areas enhances innovation due to the amount and variety of knowledge to be shared, leading to more synergies and intake of complementary knowledge. Still, this effect is mainly due to the international nature of the collaboration agreements and thus, the access to non-local, non-redundant ties to achieve access to novel information, and not simply to their geographical diversity. This finding can be related to the fact signalled in the introduction, that while on the one hand, diversity facilitates learning and innovativeness, on the other hand, each firm has a certain management capacity to handle such diversity. A greater geographical diversity involves increased management costs and risk, resulting in lower benefits (Duysters and Lokshin 2011). Although we do not check for the veracity of such assumption, among other potential explanations, it could be the case that Spanish firms may have reached a point after which marginal costs of managing more complex and heterogeneous networks are higher than the expected benefits from this increased heterogeneity. In any case, maintaining multiple partners enables firms to fill out their initial resources and skill endowments which definitely contribute to innovation performance in the Spanish case.

4.3 Geographical dimension in research cooperation and absorptive capacity

We now turn to the analysis of the role of firms' absorptive capacity in managing external knowledge flows derived from research alliances. Recall that, as argued by the economic literature, knowledge is absorbed more easily by firms that already have a

[5] Following a referee's suggestion, we split the Multiple variable in column (4) of Table 3 into two: A first one referring to firms with collaborations both at home and in foreign countries; and the second one referring to firms with collaborations in multiple foreign countries but not at home. Both variables are significant and positive, the same that we obtained with one multiple variable alone. The results are not presented to save space but can be provided upon request. We thank the referee for the suggestion.

relatively large pool of knowledge. The benefits of cooperation are not automatic but instead depend on the extent to which firms can acquire and assimilate the new knowledge coming from the external collaborator and transform and exploit it (Zahra and George 2002). Hence, we hypothesize that those firms with large absorptive capacity, measured here as the share of internal R&D expenditures over total sales, obtain an innovation premium from alliances with other partners. The question is whether this premium is higher in the case of international alliances than for national ones. We account for this role of R&D by including interactions between R&D expenditures and the cooperation variables among the right hand side variables of our model. The direction and significance of the parameters of the cross-terms will indicate the extent to which firms' absorptive capacity is important to make the most of external knowledge flows conveyed by cooperation networks.

The results provided in Table 4 are broadly supportive of the general hypothesis above. The interaction term between R&D and the national cooperation variable is positive and significant at 10% level, whereas the estimated interaction with the international one is also positive and significant but now at 1% level. This evidence provides support to the proposition on the role of absorptive capacity in the assimilation of incoming knowledge flows stemming from cooperation. Firms with high absorptive capacity are more able to translate external knowledge coming from cooperative agreements into new, specific commercial applications more efficiently than in the absence of this feature. However, firms' absorptive capacity is especially efficient when the partner is from an international context, probably due to the fact that such absorptive capacity gives them the ability to understand and assimilate better the knowledge that comes from other national systems of innovation. A firm can learn more from its foreign partners, with their different cultures and environments and, therefore, different resources, values, norms, and beliefs. If the organization possesses the potential capacity to acquire and assimilate such new knowledge, the benefit from this international cooperation increases.

[Insert Table 4 around here]

Interestingly enough, when we go deeper in the disaggregation of the international area, (see columns 2 and 3, Table 4), interactions between R&D and cooperation are also positive and significant for the European case, but are neither for the US or the rest of the world. At first glance there is no clear explanation, but a closer look at the data for the measure of absorptive capacity, which is the share of internal R&D expenditure over sales, provides some insight. In the case of cooperating firms, the average value is 12%, whereas it is 4% for those cooperating exclusively within Europe and 14% in the case of doing it exclusively with US firms. In other words, absorptive capacity is lower for firms cooperating in Europe, if compared with the average cooperative firm. These data, together with the non-significant parameter of European alliances, could lead us to think that although cooperating with European partners may imply benefits, they do not surpass the costs of this international cooperation, probably because the average firm cooperating in this context presents a relatively low average capacity. However, when the firm has sufficient absorptive capacity to reduce the barriers posed by the national differences, then the firms extract an innovation benefit from such alliances.

On the contrary, firms cooperating exclusively with US partners already have, on average, a high absorptive capacity (the share of internal R&D expenditure over sales is 14% versus the 12% of the average cooperating firm). Therefore, the representative Spanish firm cooperating with US partners already obtains a significant and high innovative premium from such cooperation agreements, so that a larger absorptive capacity does not signify an innovation premium. Most of those firms already have the capability to understand and exploit the non-redundant knowledge, information, and resources that can be provided by extra-European partners, so that an increase in this capacity does not make a difference. All in all, these results would point to the existence of a threshold R&D level for firms to absorb external knowledge. Innovative performance would increase with R&D intensity when the level of R&D is very low (as in our intra-European cooperation case) until it reaches an intermediary intensity where increments of R&D would not make a difference (extra-European cooperation).

As a robustness check to study the stability and significance of the estimated parameters and the results encountered so far with respect to the impact of cooperation, we estimated our main equation with the variable R&D computed as the proportion of R&D employees over total employment, which has also been used in the literature as a measure of absorptive capacity although not as commonly as the share of expenditures in R&D. The coefficients and resulting conclusions are virtually unchanged. The results can be provided by the authors upon request.

In sum, this section has provided evidence on the dual role of R&D and we have confirmed our third hypothesis that R&D of firms not only contributes directly to innovation but also helps building up firms' absorptive capacity. This contributes to making innovative activities more productive, especially for firms that cooperate with European partners. The benefits of cooperation depend on the extent to which organizations possess the potential capacity to acquire and assimilate new knowledge and the realized capacity to transform and exploit this new knowledge.

5. Conclusions

This paper examines the impact of the geographical scope of research alliances on innovative performance. Research alliances can be seen as a vehicle for voluntary knowledge exchanges and in this paper we assume that partners geographically distant can provide firms with non-redundant information that gives access to new information and therefore stimulates innovation performance. Descriptive statistics, based on our sample of Spanish firms, show that the proportion of international alliances with partners in more distant geographical areas (US, China, India and other countries), although lower in number if compared to research alliances with geographically closest partners, has increased over the period 2004-2011. This suggests that firms are expanding technological interaction with different and increasingly geographically dispersed actors.

Empirical results show that maintaining collaborative agreements with partners outside the firm's home country borders exerts a significant and positive effect on innovative performance. This impact is found to be larger than that of national collaborative research. By and large, this supports the idea that firms benefit from interaction with international partners as a way to access new technologies and the specialized and novel knowledge they are unable to find locally. Our findings also showed that extra-European alliances, especially with US partners, impact on innovation more importantly probably due to the fact that in some sectors, the US conducts research at the technological frontier. But also cooperation with other areas has a greater impact on innovative performance than national alliances. Moreover, we provide evidence that in the Spanish case, although establishing simultaneous collaboration agreements with partners located in different geographical areas positively and significantly influences the firm's innovative performance, it only improves innovation performance in comparison to firms cooperating exclusively with national or European partners. This can be related to the fact that a greater geographic diversity of partners involves increased management costs and risks, so that the benefits may not be as high as expected.

In addition, we confirm the role played by firms' absorptive capacity in determining collaborative research returns. Firms that have high absorptive capacity are more efficient at translating external knowledge from cooperative agreements into new, specific commercial applications. Further, this absorptive capacity seems especially efficient when the partner is international, probably due to the fact that such absorptive capacity gives the ability to better understand and assimilate the knowledge from a different national system of innovation. Interestingly enough, we obtain that although cooperating exclusively with European partners may imply benefits, they do not seem to surpass the costs of managing such international cooperation unless the firm combines it with a higher absorptive capacity to reduce the barriers posed by national differences.

All in all, these findings lead to conclude that although knowledge and innovation are well recognized as critical pillars of 'smart growth' in Europe, the right strategies to help move the continent in this direction are not so obvious. According to our results, a viable element to ensure the generation of new knowledge lies in accessing external sources of knowledge and facilitating interactive learning and interaction in innovation. This knowledge flow can take place through diffusion patterns based on knowledge externalities, relying on informal transmission channels that are relatively bounded in space, but also through intentional relations such as collaboration in innovation. Hence, from a policy perspective, these results illustrate that although R&D and human capital efforts are of clear importance, the degree of connectivity of agents with the outside world and access to global knowledge hotspots is also useful for innovative outcomes. Such connectivity, among other ideas, is precisely at the core of the 'smart specialisation' strategy recently launched by the European Commission (McCann and Ortega-Argilés 2013).

This paper also shows that the benefits of collaboration in innovation activities are likely to differ across different dimensions of the geography. According to our results, the connectivity gained through cooperation agreements between firms can have an important return to innovation performance, not only at national, but especially at the international level. The promotion of cooperation is therefore advisable, especially in linking inventors who are geographically distant: enhancing firms' collaboration in innovation activities between Europe and other regions in the world can be used as an instrument for increasing effective innovation. Finally, the results align with the thinking that innovation policies which neglect the absorptive capacity of firms and regions are problematic – or at least incomplete.

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Tables

Table 1. Summary statistics on the variables used in the econometric analysis

	Mean	S.D. Overall	S.D. Between	S.D. Within
Dependent variables				
Innovation *(n=70,182)*	0.762	0.426	0.358	0.235
% of total innovative sales *(if innovation=1, n=53,502)*	27.11	36.08	26.38	25.45
Explanatory variables				
Panel A. Main equation (if innovation=1)				
RD	0.073	0.246	0.222	0.107
Size	317.1	1484.3	1495.1	366.0
Permanent R&D	0.537	0.498	0.404	0.301
Foreign multinational	0.110	0.313	0.285	0.120
Openness	5.083	2.744	2.157	1.855
Demand pull	0.628	0.483	0.365	0.338
Panel B. Selection equation (all obs., n = 70,182)				
Size	345.64	1533.0	1438.1	405.41
Cost obstacles	0.537	0.340	0.269	0.210
Knowledge obstacles	0.462	0.326	0.249	0.213
Market obstacles	0.631	0.266	0.203	0.172
Other obstacles	0.735	0.275	0.200	0.191
Market share (%)	0.570	2.287	1.998	0.987
Belonging to a group	0.418	0.493	0.458	0.179

Table 2. Percentage of cooperative firms by type of alliance

	2005	2007	2009	2011
% Cooperative firms over innovative firms	0.358	0.339	0.353	0.378
Geographical areas of alliances (% of each category over cooperative firms)				
National exclusively	67.76	64.20	62.53	58.18
International exclusively	5.12	5.25	4.32	4.46
National & International	27.12	30.54	33.15	37.36
Total	100	100	100	100
International alliances				
European exclusively	79.86	71.09	75.49	69.57
US exclusively	3.60	7.03	6.86	6.52
Asian/Others exclusively	7.19	6.25	9.80	11.96
Multiple foreign areas (at least two)	9.35	15.63	7.84	11.96
Total	100	100	100	100

Table 3. Impact of the geographical scope of research alliances on innovation performance

	(1)	(2)	(3)	(4)
RD	1.502***	1.421***	1.420***	1.419***
	(0.183)	(0.184)	(0.184)	(0.184)
Size	-0.409***	-0.413***	-0.409***	-0.408***
	(0.107)	(0.107)	(0.107)	(0.107)
Size^2	0.032***	0.031***	0.030***	0.030***
	(0.010)	(0.010)	(0.010)	(0.010)
Permanent R&D	0.444***	0.435***	0.434***	0.434***
	(0.125)	(0.125)	(0.125)	(0.125)
Foreign multinational	0.061	0.084	0.087	0.091
	(0.235)	(0.235)	(0.235)	(0.236)
Openness	0.069***	0.059***	0.058***	0.058***
	(0.012)	(0.012)	(0.012)	(0.012)
Demand pull	0.445***	0.444***	0.446***	0.447***
	(0.092)	(0.092)	(0.092)	(0.093)
Collaboration in innovation				
National		0.344***	0.346***	0.346***
		(0.067)	(0.067)	(0.067)
International		0.946***		
		(0.242)		
European			0.422	0.423
			(0.263)	(0.263)
extra-European			3.132***	
			(0.669)	
US				3.912***
				(1.028)
Asian/Others				2.636***
				(0.997)
Multiple areas		0.494***	0.510***	0.511***
		(0.086)	(0.083)	(0.083)
Constant	-4.532***	-4.519***	-4.524***	-4.524***
	(0.296)	(0.295)	(0.297)	(0.297)
Industry dummies	Yes	Yes	Yes	Yes
Inverse Mills ratios	Yes	Yes	Yes	Yes
Means-fixed effects	Yes	Yes	Yes	Yes
Wald Test (Selection)	χ^2 =95.63 *P-val=0.000*	χ^2 =94.41 *P-val=0.000*	χ^2 =95.33 *P-val=0.000*	χ^2 =95.08 *P-val=0.000*
Wald Test (Means-fixed effects)	χ^2 =410.23 *P-val=0.000*	χ^2 =392.87 *P-val=0.000*	χ^2 =391.97 *P-val=0.000*	χ^2 =391.94 *P-val=0.000*
R-squared	0.095	0.096	0.096	0.096
Observations	35,865	35,865	35,865	35,865

Bootstrapped standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table 4. Impact of the geographical scope of research alliances on innovation performance: The role of absorptive capacity

	(1)	(2)	(3)
RD	0.796***	0.805***	0.805***
	(0.287)	(0.288)	(0.287)
Size	-0.432***	-0.428***	-0.428***
	(0.107)	(0.107)	(0.108)
Size^2	0.032***	0.032***	0.032***
	(0.010)	(0.010)	(0.010)
Permanent R&D	0.448***	0.446***	0.446***
	(0.126)	(0.126)	(0.125)
Foreign multinational	0.081	0.084	0.088
	(0.235)	(0.235)	(0.236)
Openness	0.059***	0.058***	0.058***
	(0.012)	(0.012)	(0.012)
Demand pull	0.442***	0.445***	0.446***
	(0.092)	(0.092)	(0.093)
Collaboration in innnovation			
National	0.303***	0.305***	0.305***
	(0.070)	(0.070)	(0.071)
International	0.773***		
	(0.245)		
European		0.278	0.279
		(0.269)	(0.268)
extra-European		2.876***	
		(0.723)	
US			3.551***
			(1.126)
Asian/Others			2.577**
			(1.219)
Multiple areas	0.399***	0.416***	0.417***
	(0.088)	(0.087)	(0.087)
National * RD	0.753*	0.750*	0.750*
	(0.396)	(0.396)	(0.396)
International * RD	3.200***		
	(1.042)		
European * RD		2.908*	2.907*
		(1.568)	(1.569)
extra-European * RD		4.150	
		(5.138)	
US * RD			3.935
			(6.744)
Asian/Others * RD			1.231
			(19.053)
Multiple areas * RD	0.926***	0.924***	0.923***
	(0.338)	(0.340)	(0.340)
Constant	-4.460***	-4.464***	-4.463***
	(0.295)	(0.296)	(0.297)
Industry dummies	Yes	Yes	Yes
Inverse Mills ratios	Yes	Yes	Yes
Means-fixed effects	Yes	Yes	Yes
Wald Test (Selection)	χ^2 =94.11 *P-val=0.000*	χ^2 =95.12 *P-val=0.000*	χ^2 =95.15 *P-val=0.000*
Wald Test (Means-fixed effects)	χ^2 =394.96 *P-val=0.000*	χ^2 =393.69 *P-val=0.000*	χ^2 =393.49 *P-val=0.000*
R-squared	0.096	0.097	0.097
Observations	35,865	35,865	35,865

Bootstrapped standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Appendix

Table A1. Definition of the variables included in the empirical analysis

Variables	Definition
Dependent	
Innovation	1 if the firm develop or introduced new or improved products or processes into the market; 0 otherwise
Innovation sales	Sales share of new or significantly improved products (log[share of sales due new or significantly improved products/(1-share of sales due new or significantly improved products)])
Independent	
RD	Ratio between intramural R&D expenditure and turnover
Size	Logarithm of number of employees (and its squared term)
Permanent R&D	1 if the firm reported that it performed internal R&D continuously; 0 otherwise
Foreign multinational	1 if the headquarter of the firm is outside Spain and it has at least a 50% of foreign capital; 0 otherwise
Openness	Number of information sources for innovations that a firm reported it had used (from within the firm or group, suppliers, clients, competitors, private R&D institutions, conferences, scientific reviews or professional associations)
Demand pull	1 if at least one of the following demand-enhancing objectives for the firm's innovations is given the highest score [number between 1 (not important) and 4 (very important)]; 0 otherwise: extend product range; increase market or market share; improve quality in goods and services
National	1 if the firm reported engagement in collaborative agreements exclusively with partners located in Spain; 0 otherwise
International	1 if the firm reported engagement in collaborative agreements exclusively with partners located outside Spain; 0 otherwise
European	1 if the firm reported engagement in collaborative agreements exclusively with partners located in the rest of Europe; 0 otherwise
extra-European	1 if the firm reported engagement in collaborative agreements exclusively with partners located in the US, China, India and other countries (not Spain, not the rest of Europe); 0 otherwise
US	1 if the firm reported engagement in collaborative agreements exclusively with partners located in the US; 0 otherwise
Asian/Others	1 if the firm reported engagement in collaborative agreements exclusively with partners located in China, India and other countries (not Spain, not the rest of Europe, not the US); 0 otherwise
Multiple areas	1 if the firm reported engagement in collaborative agreements with partners located in more than one area; 0 otherwise
Cost obstacles	Sum of the scores of importance that the firm attributed [number between 1 (not important) and 4 (very important)] to the following factors that hampered its innovation activities: lack of funds within the enterprise or enterprise group; lack of finance from sources outside the enterprise; innovation costs too high. Rescaled from 0 (unimportant) to 1 (crucial)
Knowledge obstacles	Sum of the scores of importance that the firm attributed [number between 1 (not important) and 4 (very important)] to the following factors that hampered its innovation activities: lack of qualified personnel; lack of information on technology; lack of information on markets; difficulty in finding cooperation partners for innovation. Rescaled from 0 (unimportant) to 1 (crucial)
Market obstacles	Sum of the scores of importance that the firm attributed [number between 1 (not important) and 4 (very important)] to the following factors that hampered its innovation activities: markets dominated by established enterprises; uncertain demand for innovative goods or services. Rescaled from 0 (unimportant) to 1 (crucial)
Other obstacles	Sum of the scores of importance that the firm attributed [number between 1 (not important) and 4 (very important)] to the following factors that hampered its innovation activities: not necessary due to previous innovations; not necessary due to the absence of demand. Rescaled from 0 (unimportant) to 1 (crucial)
Market share	Ratio of the sales of a firm over the total sales of the two-digit industry it belongs to
Belonging to a group	1 if the firm belongs to a group of enterprises; 0 otherwise

Table A2. Correlation matrix of variables used in the second stage

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1 RD	1																			
2 Size	-0.146	1																		
3 Permanent R&D	0.219	0.013	1																	
4 Foreign multinational	-0.077	0.281	-0.003	1																
5 Openness	0.127	0.050	0.335	-0.021	1															
6 Demand pull	0.066	-0.029	0.264	-0.013	0.318	1														
7 National	0.031	0.002	0.080	-0.098	0.113	0.064	1													
8 International	-0.010	0.047	0.024	0.120	0.008	0.011	-0.071	1												
9 European	-0.012	0.038	0.015	0.111	0.003	0.015	-0.061	0.865	1											
10 extra-European	-0.002	0.021	0.013	0.019	0.004	-0.012	-0.027	0.381	-0.006	1										
11 US	0.003	0.024	0.005	0.014	0.005	-0.015	-0.017	0.239	-0.004	0.629	1									
12 Asian/Others	-0.005	0.008	0.013	0.014	0.002	-0.004	-0.021	0.293	-0.004	0.770	-0.001	1								
13 Multiple areas	0.205	0.151	0.225	0.113	0.212	0.129	-0.202	-0.008	-0.043	-0.017	-0.012	-0.015	1							
14 National * RD	0.267	-0.160	0.172	-0.074	0.116	0.084	0.502	-0.036	-0.031	-0.014	-0.009	-0.010	-0.101	1						
15 International * RD	0.044	-0.028	0.049	0.022	0.022	0.009	-0.036	0.502	0.377	0.294	0.148	0.260	-0.001	-0.018	1					
16 European * RD	0.035	-0.022	0.043	0.031	0.015	0.015	-0.032	0.451	0.522	-0.003	-0.002	-0.002	-0.023	-0.016	0.726	1				
17 extra-European * RD	0.017	-0.012	0.021	-0.004	0.011	-0.008	-0.014	0.192	-0.003	0.504	0.255	0.446	-0.010	-0.007	0.587	-0.002	1			
18 US * RD	0.031	-0.009	0.013	-0.001	0.012	-0.007	-0.009	0.121	-0.002	0.316	0.503	-0.001	-0.006	-0.004	0.298	-0.001	0.507	1		
19 Asian/Others * RD	0.002	-0.009	0.016	-0.004	0.006	-0.005	-0.011	0.152	-0.002	0.399	-0.001	0.518	-0.008	-0.005	0.506	-0.001	0.862	0.000	1	
20 Multiple areas * RD	0.513	-0.034	0.180	-0.021	0.152	0.088	-0.117	-0.015	-0.025	-0.011	-0.007	-0.009	0.580	-0.059	0.014	-0.013	-0.006	-0.004	-0.004	1

Table A3. Estimates of the first stage: selection equations

	T=2006	T=2007	T=2008	T=2009	T=2010	T=2011
Size	0.014	0.062	0.067	0.117*	0.036	0.077
	(0.069)	(0.067)	(0.064)	(0.069)	(0.067)	(0.065)
Size^2	0.002	-0.006	-0.004	-0.007	0.002	0.001
	(0.007)	(0.007)	(0.006)	(0.007)	(0.007)	(0.006)
Cost obstacles	0.353***	0.520***	0.594***	0.509***	0.573***	0.417***
	(0.073)	(0.069)	(0.069)	(0.073)	(0.071)	(0.065)
Market obstacles	0.540***	0.332***	0.178**	0.318***	0.415***	0.358***
	(0.077)	(0.071)	(0.071)	(0.075)	(0.074)	(0.069)
Knowledge obstacles	0.235**	0.363***	0.412***	0.536***	0.289***	0.415***
	(0.098)	(0.092)	(0.091)	(0.096)	(0.096)	(0.089)
Other obstacles	-1.152***	-1.243***	-1.211***	-1.210***	-1.218***	-1.231***
	(0.064)	(0.062)	(0.061)	(0.063)	(0.064)	(0.062)
Market share	1.039	0.710	2.736**	4.695***	2.886**	2.451**
	(0.891)	(1.035)	(1.088)	(1.267)	(1.183)	(1.006)
Belonging to a group	0.189***	0.165***	0.212***	0.184***	0.198***	0.219***
	(0.041)	(0.040)	(0.039)	(0.041)	(0.041)	(0.039)
Constant	0.468***	0.605***	0.470***	0.194	0.389**	-0.108
	(0.179)	(0.173)	(0.166)	(0.178)	(0.178)	(0.169)
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	7764	8858	8805	8308	8065	7704
Log L	-3315.806	-3566.012	-3699.859	-3396.220	-3310.735	-3790.015
Pseudo R2	0.235	0.240	0.229	0.236	0.237	0.198

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1