UNIVERSIDAD EAFIT
Abierta al mundo

Escuela de Economía y Finanzas

Documentos de trabajo
Economía y Finanzas

Centro de Investigación
Económicas y Financieras

No. 18-05
2018

Obstacles to innovation and external sourcing of knowledge: Evidence for German and Spanish firms

Estefanía Gómez, Helena Huergo, Mery Patricia Tamayo

cief
Centro de Investigaciones Económicas y Financieras
Universidad EAFIT

Obstacles to innovation and external sourcing of knowledge: Evidence for German and Spanish firms

Estefanía Gómez[a], Elena Huergo[b,c] and Mery Patricia Tamayo[a,c]

April 2018

Abstract

The goal of this research is to empirically study the relationship between obstacles perceived by companies to carrying out their innovation activities and their decisions about external sourcing of knowledge through the outsourcing of R&D or technological cooperation. Using information on German and Spanish companies from the year 2010, we obtain that in both countries this association is positive, and that companies that assign greater importance to factors that impede their innovation activities are also more likely to engage in external sourcing of knowledge. This relationship seems to be especially strong in companies that do not engage in internal R&D activities or do so sporadically, while it is much weaker in companies that perform internal R&D continuously. Nonetheless, the importance that companies assign to the market power of established companies as a barrier to innovation is positively associated with technological cooperation especially in continuous R&D performers.

***Keywords*:** Obstacles to innovation, outsourcing, technological cooperation

J.E.L. Classification: L2, O3, O57

[a]Departamento de Economía, Universidad EAFIT, Medellín, Colombia; [b]GRIPICO-Universidad Complutense de Madrid, Madrid, Spain; [c]Facultad de CC. Económicas y Empresariales, Department of Economic Analysis, Universidad Complutense de Madrid, Madrid, Spain

This research has been partially funded by the Spanish Ministry of Economy and Competitiveness (project ECO2017-82445-R) and by the Autonomous Region of Madrid through project S2015HUM-3417 (INNCOMCON-CM), co-funded by the European Social Fund (European Union).

1. Introduction

To carry out their technological activities, companies sometimes look for productive and financial resources outside the company, and very often, outside the country itself. This is true of the offshoring of R&D and international technological cooperation, among others. These phenomena have been increasing in recent years. In Europe, for example, according to Eurostat data, in 2004, on average, 1285 companies performed external R&D activities, while in 2014, the number was 1899. Furthermore, also according to Eurostat figures, in 2004 approximately 66,891 companies carried out innovative activities in all the countries of the European Union, while by 2014 this number had grown to 94,569.

Recent studies attribute this increase in seeking resources outside the company to the beneficial effects it has on company performance. Along this line, Wagner (2011) researches the effect of offshoring on different aspects of the performance of German manufacturing firms and finds that the companies that offshore are larger and more productive, have more human capital and have a higher proportion of exports in total sales.[1] Likewise, in his study of the French manufacturing industry, Bertrand (2011) analyses the effect of offshoring on export performance and finds evidence that it increases the international competitiveness of multinational enterprises (MNEs), although the effect might be conditional on specific country and company characteristics. In particular, for the case of R&D services, Nieto and Rodríguez (2013) conclude on the basis of Spanish service and manufacturing firm data that R&D offshoring activities have a direct positive impact on productivity and an indirect positive impact through innovation.

As for technological cooperation, numerous authors conclude that the development of joint R&D activities complements resources available in the company for innovation, increasing internal capacities and fostering the acquisition of innovations (Mowery et al., 1998; Branstetter and Sakakibara, 2002; Scott, 2003; Becker and Dietz, 2004).

These positive effects of external technology sourcing justify a more detailed analysis of its determinants. In this regard, although it is growing, the empirical evidence is still scarce (Holl and Rama, 2014; Tamayo and Huergo, 2017; Murphy and Siedschlag, 2018).

[1] This author defines offshoring in his study as '*the relocation of processes to any foreign country without distinguishing whether the provider is external or affiliated with the firm, while outsourcing is defined as the relocation of processes to external providers regardless of the provider's location within the home country or in a foreign country'* (p. 218).

The objective of this work is to contribute to this analysis through the study of the relationship between the obstacles perceived by companies to the development of their innovation activities and the pursuit of these activities outside the company, whether through R&D outsourcing or technological cooperation. The study places special focus on the cases in which companies choose to carry out these activities internationally.

To this end, we work with data from the Technological Innovation Panel (PITEC) on 8,382 Spanish firms and from the Mannheim Innovation Panel (MIP) on 2,748 German firms for the year 2010. Both data bases are supported by the national versions of the Community Innovation Surveys, and as such there is a high degree of homogeneity in their basic contents. Furthermore, Germany and Spain are two of the largest countries in the European Union, but differ in their innovative environments, and therefore make a good field of analysis for studying the relationship between obstacles to innovation and the choice of strategies for external technology sourcing. Unfortunately, we only have a cross section for the analysis, which makes it difficult to address problems of endogeneity. As a consequence, the estimated coefficients can only be interpreted as correlations and not as indicative causal relationships.

The main results suggest that, regardless of the country analyzed, companies that place greater importance on factors that impede the development of their innovation activities are also more likely to engage in external sourcing of knowledge through R&D outsourcing or technological cooperation agreements. This positive association is especially strong in companies that do not perform internal R&D activities or do so sporadically, while it is much weaker in companies that perform internal R&D continuously.

The rest of the study is organised as follows: Section 2 presents a review of the literature; Section 3 provides the data and variables considered for the analysis; Section 4 explains the methodology; and the results and main conclusions are laid out in Sections 5 and 6.

2. Theoretical framework

The number of empirical studies that try to analyse the determinants of the decisions to externalise R&D activities has grown in recent years. Holl and Rama (2014), using information on Spanish firms for the period 2005-2009, compare the determinants of acquiring technology through R&D outsourcing, R&D outsource offshoring, domestic

cooperation for innovation and international cooperation for innovation by foreign affiliates and national companies. In particular, they examine whether foreign subsidiaries are more involved in the different ways to acquire technology than national companies. Their results confirm that there are significant complementarities among the different options for obtaining technological resources. They also find that the supply of external technological resources through the four channels analysed complements companies' internal efforts on R&D activities.

Also using data on Spanish companies, Tamayo and Huergo (2017) find that being an exporter, performing R&D continuously, applying for patents, being a foreign affiliate and company size are factors that positively influence the decision to engage in R&D offshoring. In addition, in the case of firms that belong to groups, they determine that greater importance given to internal sources of information for innovation than to market sources is positively (negatively) associated with the probability of R&D offshoring only through the group (market).

Another significant study is Murphy and Siedschlag's (2018). They find that, for the period 2001-2006, Irish companies that are integrated into international production and have innovation networks, and enterprises that use information and communication technologies more intensively are more likely to engage in R&D offshoring. In addition, in the case of foreign-owned enterprises and domestic exporters, the propensity to offshore R&D increases by three percentage points.

In this context, it could be assumed that certain obstacles perceived by companies when they carry out their technological activities internally are at the same time incentives to develop them outside the company. In this regard, D'Este et al. (2012a) distinguish two kinds of barriers that restrict the development of companies' innovation activities: revealed barriers, which refer to factors that hinder a company in reaching the goals of its innovation activities (according to the authors, those that have received the most attention in the literature); and deterring barriers, which impede companies from undertaking innovation activities. The latter are related to a lack of organisational skills, a lack of experience in the use of technology and the existence of adverse conditions related to the structure of the market.

The main results of D'Este et al. (2012a) suggest that there is a non-linear relationship between the importance that companies give to obstacles to innovation and the degree to

which companies pursue technological activities. Specifically, they obtain that barriers related to costs and the market dissuade some companies from pursuing innovative activities (deterring effects), while others learn from the direct experience gained through carrying out these activities (revealed effects). Keeping this in mind, companies that perceive large deterring barriers might find an efficient way to confront these obstacles in the outsourcing of their R&D activities outside the company.

The existence of deterring barriers related to lack of resources might also be a motive to cooperate on technological activities with other agents (companies, public research centres, universities, etc.). In this regard, Antonioli et al. (2017) examine whether cooperation with research organisations or private companies is associated with different kinds obstacles, such as financial restrictions, lack of human capital or uncertain market demand. The authors find that facing only one specific restriction leads companies to cooperate. However, the results show that having to confront different barriers is a deterring element to establishing cooperation agreements, especially when companies simultaneously lack financing, adequate knowledge and information about technology or markets. In general, according to the authors, the probability of cooperating is influenced by the perception of relevant barriers, that is, the propensity to cooperate is positively related to the presence of single barriers, which "induces" cooperation, while the joint and complementary presence of different barriers does not have a big impact.

Arranz and de Arroyabe (2008) also emphasize that the perception of the obstacles to innovation influences the propensity to cooperate with different agents. In particular, they find that market barriers and technological information are relevant for Spanish companies in order to cooperate with their peers in the European Union, and argue that the high costs associated with the development of innovation are one of the factors that have the greatest influence on the likelihood of cooperation. This statement is in line with what was proposed by authors such as López (2004).

Based on the foregoing, we formulate the following hypothesis:

H1: There is a positive association between company-perceived barriers to carrying out innovative activities and a company's propensity to do external technology sourcing through strategies like cooperation or outsourcing.

Additionally, we can expect the importance of foreign sourcing strategies to be especially important when the barriers to innovation are related to the power of companies established in the national market. Following Nieto and Rodríguez (2011), the foreign sourcing of technology would permit companies to have access to multiple markets, obtaining more diverse knowledge and generating more advantages for the development of innovation. In this regard, market conditions might require companies to learn strategies for offshoring part of their production process, with the aim of achieving positive returns in relation to the innovations (Love and Roper, 2001). Therefore, we formulate the following hypothesis:

H2: There is a positive association between the importance a company gives to the market power of established companies as a barrier to innovation and its propensity to undertake foreign technology sourcing through strategies like international cooperation or outsourcing.

Also following D'Este et al. (2012a), we might think that companies that continuously carry out internal R&D activities perceive different obstacles to innovation with regard to companies that do so sporadically or do not carry out these activities.

Along this line, Mohnen and Röller (2005) obtain that the effects of obstacles to innovation on the propensity to innovate (innovate or not) are different than the effects on innovative intensity (spending on innovation over sales). They find there is a substitution effect among obstacles on the propensity to innovate, while there are complementarities among the effects on innovative intensity.

Additionally, previous empirical literature suggests that the perception of obstacles increases as more R&D activities are conducted (Mohnen and Rosa, 2002; Galia and Legros, 2004; Iammarino et al., 2009). In particular, Galia and Legros (2004) find that '*while it might be expected that obstacles would be more frequently cited by non-users than users of activities dedicated to innovation, the opposite seems to prevail*'. They justify this fact in the learning process accompanying innovation, as '*it is plausible that certain problems are not effectively encountered until firms face them*'. Furthermore, these authors, on the basis of a sample of French manufacturers, obtain that companies that postpone their innovation projects give greater importance to obstacles related to economic risk, a lack of qualified personnel, innovation costs, a lack of customer response capacity, a lack of information about technology and organisational rigidities. However, companies that permanently abandon

projects tend to be more subject to economic barriers (costs, risks and customer response) than to technological or organisational barriers.

Iammarino et al. (2009) also find a positive association between firms' perception of obstacles and their innovation propensity, and interpret this result as due to innovators being more likely to have experimented these barriers, and therefore more likely to consider obstacles as relevant. However, as these authors also point out, we cannot reject that this relation could be explained by an endogeneity issue associated with reverse causality.

In this sense, if we think that external sourcing of knowledge is an efficient alternative for firms that perceive large obstacles to carry out their technological activities internally, we may expect a different R&D sourcing strategy of persistent R&D performers respect to occasional or non-R&D performers.

Based on the foregoing, we formulate the following hypothesis.

H3: The relationship between companies' perception of barriers to innovation and their probability of externalising their technological activities differs between companies that perform internal R&D activities continuously and those that perform them sporadically or not at all.

3. Empirical model and variables

To see the relationship between the perception that companies have of obstacles to innovation and their outsourcing and cooperation decisions, two types of specifications are considered. First, the decisions to outsource R&D and engage in international cooperation are analysed. Given the dichotomous nature of the variables that reflect these decisions and the fact that they might be correlated, this study is done via the estimation of a bivariate Probit model that is specified as follows:

$$\begin{cases} y_1^* = X'\beta_1 + \varepsilon_1 & \text{if } y_1 = 1(y_1^* > 0) \\ y_2^* = X'\beta_2 + \varepsilon_2 & \text{if } y_2 = 1(y_2^* > 0) \end{cases} \qquad [\varepsilon_1, \varepsilon_2] \sim BVN[0,0,1,1,\rho],$$

where ρ is the correlation coefficient between the error terms of the equations and X is the vector of explanatory variables that are described in detail in the following sections, and where obstacles to innovation play the main role.

Secondly, we examine whether these relationships change between national and international domains. Specifically, we consider four different strategies: domestic outsourcing, international outsourcing, domestic cooperation and international cooperation. As a consequence, in this case the relationships are analysed via the estimation of a multivariate Probit model, which allows for correlation in the adoption of the different strategies (Greene and Hensher, 2010).

Additionally, we carry out separate estimations for the sample of companies that perform R&D continuously and for the sample of those that do it occasionally (or not at all).

The data bases and the main variables used for the empirical analysis are described below.

3.1. Data bases

To carry out this analysis, we use two data bases with information about the innovative activity of German and Spanish companies. The data for Spain come from the Panel of Technological Innovation (PITEC), which is made by the Spanish Institute of Statistics (INE) with the support of the Spanish Foundation for Science and Technology (FECYT). This data base has compiled information for a representative sample of around 10,000 companies a year since 2003. For Germany, the information is taken from the Mannheim Innovation Panel (MIP), which has conducted an annual survey since 1993 and is supplied by the Centre for European Economic Research (ZEW). In both cases, the data compiled come from different waves of the national versions of the Community Innovation Survey (CIS), which guarantees homogeneity in the definition of most of the variables.

Both surveys contain representative samples of companies at the national level and collect ample information related to activities and development of innovation. They also allow us to identify different economic characteristics. Although the two data bases have a panel structure, with regard to external sourcing strategies they do not have the same variables in all the years, so it was necessary to carry out a preliminary analysis which allowed us to select the variables that coincide in both surveys so that they were comparable.[2] Because of this, the year 2010 was taken as the period of analysis, with a sample of 8,382 Spanish companies

[2] In addition, a previous homogenisation task was necessary in the definition of some variables. A differential factor of the surveys is that they have different methods of anonymisation to conserve the privacy of the company data, which include multiplicative error, quoting intensities and rates, truncation, grouping data, aggregation of information and withholding of data. In the case of the MIP, the anonymisation process includes removing all firms that respond on behalf of their entire group of companies and not just their own firm.

and 2,748 German companies. Information about each of the relevant variables for this study was available for these companies, and included non-innovating companies to avoid problems of selection bias.

3.2. Dependent variables

The main purpose of this research is to analyse some factors related to the decision to carry out technological activities outside the company. To this end, we define the following variables: *national outsourcing*, if the company buys R&D services from national suppliers; *international outsourcing*, if the company buys R&D services from international suppliers;[3] *national cooperation*, if the company cooperates with other national companies or entities to carry out technological activities; and *international cooperation*, if the company cooperates with other international companies or entities to carry out technological activities. Each of these variables has a binary character, taking the value 1 if the company pursued this strategy during the period considered, or 0 otherwise.

As can be seen in Table 1, according to the data on the sample, companies in both countries implement more strategies related to cooperation than to outsourcing. In Germany, for example, the data show that 15% of the companies perform domestic outsourcing and 2.8% perform international outsourcing. Comparing this data with the figures on cooperation, 18.5% cooperate in the same country and 6.9% cooperate on an international level. In Spain, 21.4% perform domestic outsourcing and 4.4% perform international outsourcing, compared with 26.3% of the companies in the sample that cooperate domestically and 10.4% that cooperate in another country. In general, it can be seen that Spanish companies do more cooperation and outsourcing than German companies.

Insert Table 1

3.3. Main independent variables: the obstacles to innovation

With the goal of verifying the hypotheses put forward herein, we analyse four factors that companies see as obstacles to carrying out innovative activities.[4] In the case of the PITEC, the variables for obstacles to innovation are defined on the basis of the following question:

[3] These R&D purchases might include purchases from other companies within the group. There is no information in the MIP with a greater degree of disaggregation. For the case of Spanish companies, we include a categorical variable as a control variable which indicates whether the companies are part of a business group.
[4] We select those factors that are present in both databases.

"In the period 2008-2010, what importance did the following factors have in making your innovation activities or projects difficult or in influencing the decision not to innovate?" The company can respond in one of the following ways: 1=High; 2=Medium; 3=Little; 4=Not relevant/not used; Blank=No information. In the case of the MIP, the question about obstacles is *"What effect did the following obstacles possibly have on your innovation activities from 2008 to 2010?"* The company can respond in one of two ways: 1 if the obstacle was very important, and 0 otherwise.

From among all the obstacles available, we chose those that appeared in both data bases:

- *Lack of external finance*: Companies have little access to financing from external entities.
- *Innovation costs too high*: Obstacles that companies relate to the high costs of carrying out innovation activities.
- *Lack of skilled labour*: Difficulties in obtaining resources of internal knowledge related to insufficiently qualified personnel.
- *Market dominated by incumbents*: The company perceives barriers to entering the market because it is dominated by other companies, generally incumbents.

So that the information was comparable in both data bases, the variables from the PITEC are also defined dichotomously, taking the value 1 when companies report that the importance of the factor was high, and 0 otherwise.

We can see in Figure 1 that, in general, Spanish companies are more aware of factors that impede innovation activities. In both countries, of the four factors considered, it is the obstacle of high costs that has the greatest impact on innovation activities, cited by 62.7% of the companies in Spain and 38.6% of the companies in Germany. Furthermore, in the case of Spanish companies, the least important obstacle is lack of qualified human capital (36.1%), while in Germany it is a market dominated by incumbents (15.5%).

Insert Figure 1

In Tables A.1.a and A.1.b of the Appendix, we can see that in both countries the perceptions that companies have about obstacles to innovation are highly correlated, with correlation coefficients between 0.2 and 0.6, and that those with the highest correlation are obstacles related to high costs and external financing. In Germany, this coefficient is 0.497, and in Spain it is 0.593. This relationship coincides with the results of Galia and Legros (2004) for

the case of France. This correlation will be considered in the estimation strategy, so that the estimations are made both by adding the four indicators simultaneously and including each factor individually.

3.4. Other control variables

Other factors that, according to previous literature, might be associated with decisions about outsourcing or cooperation in R&D are also included as control variables in the model.

First of all, the *exporting* nature of the company is considered, given that exposure of companies to international markets creates opportunities for offshoring or cooperation with other agents (Barajas and Huergo, 2010; Tamayo and Huergo, 2017).

Other technological activities carried out by companies are also considered. On this note, Vega-Jurado et al. (2009) consider that companies that continuously carry out R&D activities are more likely to acquire external knowledge because they have a greater ability to assimilate it. One of the main reasons is that internal knowledge increases the marginal performance of strategies for acquiring external knowledge (Cassiman and Veugelers, 2006). To capture these relationships, three variables are defined. The first is a binary variable that takes the value 1 if the company continuously carries out internal R&D activities, and 0 if it does so occasionally or not at all. In second place, the *intensity of spending on innovation* is considered. It is defined as the proportion of total spending on innovation over total company sales in period t. This variable is truncated in the MIP, taking the value 0.35 if the intensity is higher than this value. For this reason, the variable for the case of Spain has also been truncated, and a dummy has been added to indicate the cases in which information about the companies was truncated.

The literature also reveals a positive relationship between productivity and the implementation of strategies for outsourcing or cooperation. Specifically, Pelegrín and Bolancé (2013) find that companies that are more productive, more active in R&D, larger and have a higher intensity of human capital are more likely to transfer part of their productive activity abroad. According to the authors, the best companies self-select to carry out offshoring activities. For this reason, in this study we include a measure of *labour productivity*, defined as the ratio of the number of employees over total sales in period t. As in the case of intensity of spending on innovation, this variable is truncated in the MIP at the

value 0.6. As such, here also the definition in the PITEC has been standardised, and a second variable is used to indicate cases of truncation.

Lastly, dichotomous variables grouped by sector, region and size are also introduced. It is expected that companies that carry out their activity in highly technological sectors, having more human resources and funding for innovation, also have a greater capacity to absorb transfers of knowledge and, as such, benefit more from strategies for externalising part of the R&D activities (Escribano et al., 2009; Cassiman and Veugelers, 2006). In this study, we consider four sectoral groupings that classify companies into knowledge-intensive industries, other industries, knowledge-intensive services and other services.

Also, two regions in Germany (west and east) and three in Spain (Madrid, Catalonia and Andalusia) are defined to capture offshoring effects by companies in certain territories. In different territories, there are different institutional, cultural and social aspects that might be related to the probability of externalising activities (Antonioli et al., 2017; D'Este et al., 2012b). Antonioli et al. (2017) and Arranz and de Arroyabe (2008) also point out the level of industrial development and distance as important aspects that motivate cooperation between different agents.

Finally, three size dummies are defined, reflecting whether the company is small (fewer than 50 workers), medium-sized (with a number of employees between 50 and 249) or large (more than 250 workers). With regard to the effect of company size, Wagner (2011) finds that larger companies are more likely to externalise activities. De Faria et al. (2010) find the same relationship for the case of cooperation between external agents, arguing that large companies have more resources to invest in cooperation activities for the development of innovations.

4. Results

This section provides the results of the estimations of the models presented in Section 3. First of all, the relationship between obstacles to innovation and companies' decisions to externalise activities is analysed without distinguishing their area of operation (national or international). Secondly, the possible existence of specificities in the relationship between obstacles to innovation and the foreign sourcing of knowledge is studied. Finally, the same analysis is carried out with a distinction between companies that continuously perform R&D and those that do not perform R&D or do it occasionally.

4.1. Obstacles to innovation and external sourcing of knowledge

Table 2 shows the marginal effects obtained upon estimating the bivariate Probit model for decisions about R&D outsourcing and technological cooperation, with all the obstacles to innovation introduced simultaneously. For both Spain and Germany, the estimated correlation coefficient between the two strategies for external technology sourcing is statistically significant, suggesting there is some correlation in the adoption of these strategies.

Insert Table 2

Also in both countries, it is determined that, apart from obstacles to innovation, in general, the other company characteristics similarly affect the probability of externalising activities, which coincides with the economic literature. Being an exporter, the continuous performance of internal R&D and company size are positively associated with strategies for external sourcing of knowledge. Moreover, with the exception of being an exporter, the magnitude of these variables' marginal effects seems to be greater in the case of Spain.

In the specific case of spending on innovation and productivity, the marginal effects for the variables that show truncated values suggest the existence of non-linear relationships. The more companies invest in innovation and the more productive they are, the more likely they are to carry out outsourcing and cooperation activities. However, when the companies achieve values higher than the truncated values, the relationship is negative. In Spanish companies, the probabilities of performing R&D outsourcing and technological cooperation diminish by 12.7% and 13.7%, respectively, and in Germany, these values are 5.3% and 2.3%, respectively, when the relationship of spending on innovation over sales is greater than 0.35. Something similar happens in the case of productivity. When companies have values higher than 0.6, the probability of performing external outsourcing diminishes by 5.6% in Spain and 2.2% in Germany.

Furthermore, Spanish companies that belong to a business group are 3.3 percentage points more likely to perform R&D outsourcing and 6.2 percentage points more likely to engage in technological cooperation. Unfortunately, this variable is not available for Germany.

The results in Table 2 also seem to indicate that the importance of obstacles to innovation is different between the countries, although in both cases the obstacles present positive or non-significant coefficients. As for R&D outsourcing, in Germany, the barriers related to the high

costs of innovation are the only ones that show a positive effect, while in Spain, a lack of external financing and a market dominated by incumbent companies are the barriers that have the biggest influence on outsourcing. With regard to cooperation, there is no significant relationship found for German companies. Conversely, in Spain, it is the lack of external financing that is most associated with carrying out this strategy.

When the obstacles are inserted individually (Table 3), the results confirm that the high correlation between the different obstacles is influencing the lack of significance of several of these indicators in previous estimations.[5] With the exception of lack of qualified personnel in German companies, all the obstacles have a positive and significant effect on external sourcing of knowledge, regardless of the country. In light of this, it could be said that in Germany and Spain the results are consistent with Hypothesis 1, such that when companies perceive internal barriers to performing innovation activities, they tend to look for new technology externally through mechanisms like cooperation or outsourcing.

Insert Table 3

4.2. Foreign versus national sourcing of knowledge

In the previous section, the relationship between some obstacles to innovation and the decision to carry out external sourcing of knowledge through the outsourcing of R&D and technological cooperation is analysed without distinguishing whether these practices take place nationally or internationally. Bearing this distinction in mind, in this section, four different strategies for external knowledge outsourcing are considered, so the relationships are analysed via the estimation of a multivariate Probit model.

Given the high level of correlation among obstacles to innovation, the estimations in Table 4 correspond to the model where each obstacle is included separately.[6] The results that correspond to the model where all the obstacles are incorporated simultaneously are compiled in Table A.2 of the Appendix.

Insert Table 4

[5] For simplicity's sake, in this case the values estimated for other company characteristics, which are in line with the results in Table 3, are not shown.

[6] In all estimates, the hypothesis that the correlations between the error terms of each pair of equations are all zero can be rejected at a very high significance level, so the multivariate Probit model seems to be appropriate.

As Table 4 shows, the positive relationship between the obstacles to innovation considered and external sourcing of knowledge is confirmed. As for the outsourcing of R&D, in Germany the correlations with decisions on foreign outsourcing are especially strong, while in Spain the associations are captured to a greater extent when the outsourcing is done domestically. With regard to cooperation, in both countries the relationships to the obstacles are stronger in the case of national cooperation, with lack of financing and innovation costs the most important.

Furthermore, in both Germany and Spain we see a positive relationship between the importance companies give to the market power of established companies as a barrier to innovation and the likelihood of their engaging in foreign technology sourcing via international outsourcing. The relationship between this obstacle and the decision to cooperate internationally is even stronger in the case of German companies, but it is not statistically significant for Spanish companies. As such, these results are consistent with Hypothesis 2, although only partially.

4.3. Internal R&D, obstacles to innovation and external sourcing of knowledge

In this section, we analyze whether the association between obstacles to innovation and the probability of engaging in external sourcing of knowledge is different for companies that perform internal R&D activities continuously and those that do it occasionally or not at all. As can be seen in Table 5, in both countries the correlation between obstacles and external sourcing is stronger in the case of companies that perform internal R&D activities occasionally or not at all.[7] The four obstacles considered show a statistically positive association with both R&D outsourcing and international cooperation. This is consistent with the idea that these obstacles deter companies from carrying out internal innovation activities, while they motivate their hiring outside the company. The only exception is the perception of a market dominated by established companies, which in Germany does not seem to be related to technological cooperation.

Insert Table 5

[7] This table shows the results obtained when introducing the obstacles separately. In Table A.3 of the Appendix, the results that correspond to the model where the four obstacles are included simultaneously are compiled.

By contrast, when companies perform internal R&D activities continuously, obstacles linked to a lack of financing, the high costs of innovation and a lack of qualified personnel do not seem to be related to the outsourcing of R&D in either of the countries. The perception of a market dominated by incumbent companies shows a positive association only in the case of Spain. This same obstacle is the only one that is related positively to technological cooperation in German companies that are continuous R&D performers. In the case of Spanish companies, this factor is joined by the factors of cost and financing. In any event, these results are consistent with Hypothesis 3.

5. Conclusions

Parallel to the process of globalization, the phenomenon of external sourcing of knowledge by companies has been increasing in recent decades. Although recent studies attribute this increase in the search for technological resources outside the company to its beneficial effects on business performance (Wagner, 2011; Bertrand, 2011; Nieto and Rodríguez, 2013), empirical evidence about the factors that influence the choice of this kind of external sourcing strategy is still scarce.

The goal of this research is to contribute to this analysis by studying the effect of company-perceived obstacles to innovation activities on the external sourcing of knowledge through either the outsourcing of R&D or technological cooperation. To do this, we use information about German and Spanish companies for the year 2010 and we estimate multivariate probit models for decisions about different kinds of external sourcing, with obstacles to innovation as the main explanatory variables.

The results obtained suggest that, in both Germany and Spain, there is a positive association between the importance that companies give to factors that impede their innovation activities and the probability that they will engage in external sourcing of knowledge via R&D outsourcing or technological cooperation agreements. This positive relationship seems to be especially strong in companies that do not perform internal R&D activities or do so sporadically, while it is much weaker in companies that perform internal R&D continuously. However, the importance that companies give to the market power of established companies as a barrier to innovation is positively associated with international technological cooperation, especially in continuous R&D performers. These results are consistent with the

idea that the external sourcing of knowledge is, in part, a response to the difficulties that companies have in making their internal R&D activities profitable.

Our work has some limitations. First, the use of the same indicators of external sourcing of knowledge for Germany and Spain has entailed performing the analysis with only a cross section of information, so the estimated coefficients cannot be interpreted as indicative of causal relationships. Future studies that can establish the dynamic of these associations are needed. Secondly, it would also be useful to analyze whether the conclusions of this research can be extended to companies in other countries.

References

Amiti, M. & Konings, J. (2007). Trade liberalization, intermediate inputs, and productivity: Evidence from Indonesia. *The American Economic Review*, *97*(5), 1611-1638.

Antonioli, D., Marzucchi, A. & Savona, M. (2017). Pain shared, pain halved? Cooperation as a coping strategy for innovation barriers. *The Journal of Technology Transfer*, *42*(4), 841-864.

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

Barajas, A. & Huergo, E. (2010). International R&D cooperation within the EU Framework Programme: empirical evidence for Spanish firms. *Economics of Innovation and New Technology*, 19(1–2), 87–111.

Becker, W. & Dietz, J. (2004). R&D cooperation and innovation activities of firms—evidence for the German manufacturing industry. *Research policy*, *33*(2), 209-223.

Belderbos, R., Carree, M. & Lokshin, B. (2004). Cooperative R&D and firm performance. *Research policy*, *33*(10), 1477-1492.

Bertrand, O. (2011). What goes around comes around: Effects of offshore outsourcing on the export performance of firms. *Journal of International Business Studies*, *42*(2), 334-344.

Branstetter, L. G. & Sakakibara, M. (2002). When do research consortia work well and why? Evidence from Japanese Panel Data. *American Economic Review, 92*(1), 143–159.

Cassiman, B. & Veugelers, R. (2006). In search of complementarity in innovation strategy: Internal R&D and external knowledge acquisition. *Management science*, *52*(1), 68-82.

D'Este, P., Iammarino, S., Savona, M. & von Tunzelmann, N. (2012a). What hampers innovation? Revealed barriers versus deterring barriers. *Research policy*, *41*(2), 482-488.

D'Este, P., Guy, F. & Iammarino, S. (2012b). Shaping the formation of university–industry research collaborations: what type of proximity does really matter? *Journal of Economic Geography*, *13*(4), 537-558.

D'Este, P., Rentocchini, F. & Vega Jurado, J. (2010). Lowering barriers to engage in innovation: evidence from the Spanish innovation survey (No. 1020). *Public policies and local development*.

De Faria, P., Lima, F. & Santos, R. (2010). Cooperation in innovation activities: The importance of partners. *Research Policy*, *39*(8), 1082-1092.

Escribano, A., Fosfuri, A. & Tribó, J. A. (2009). Managing external knowledge flows: The moderating role of absorptive capacity. *Research policy*, *38*(1), 96-105.

Galia, F. & Legros, D. (2004). Complementarities between obstacles to innovation: evidence from France. *Research policy*, *33*(8), 1185-1199.

Görg, H., Hanley, A. & Strobl, E. (2008). Productivity effects of international outsourcing: evidence from plant-level data. *Canadian Journal of Economics/Revue canadienne d'économique*, *41*(2), 670-688.

Greene, W. H. & Hensher, D. A. (2010). *Modeling Ordered Choices: A Primer*. Cambridge University Press.

Holl, A. & Rama, R. (2014). Foreign subsidiaries and technology sourcing in Spain. *Industry and Innovation*, *21*(1), 43-64.

Iammarino, S., Sanna-Randaccio, F., & Savona, M. (2009). The perception of obstacles to innovation. Foreign multinationals and domestic firms in Italy. *Revue D'Économie Industrielle*, 125, 75-104.

Kedia, B. L. & Mukherjee, D. (2009). Understanding offshoring: A research framework based on disintegration, location and externalization advantages. *Journal of World Business*, 44(3), 250-261.

López, A. (2004). Determinants for R&D Cooperation: Evidence from Spanish Manufacturing. *Research Policy*, 31, 947-967.

Love, J. H. & Roper, S. (2001). Outsourcing in the innovation process: locational and strategic determinants. *Papers in Regional Science*, *80*(3), 317-336.

Mohnen, P. & Röller, L. H. (2005). Complementarities in innovation policy. *European Economic Review*, *49*(6), 1431-1450.

Mohnen, P. & Rosa, J. (2002), Barriers to innovation in service industries in Canada. In: Feldman, M. & Massard, N. (Eds.), *Institutions and Systems in the Geography of Innovation*. Kluwer Academic Publishers, Boston, pp. 231–250.

Mowery, D., Oxley, J. E. & Silverman, B. S. (1998). Technological overlap and interfirm cooperation: Implications for the resource-based view of the firm. *Research Policy, 27*(5), 507–523.

Murphy, G. & Siedschlag, I. (2018). Determinants of R&D offshoring. firm-level evidence from a small open economy. *Economia Politica*. https://doi.org/10.1007/s40888-018-0107-5.

Nieto, M. J. & Rodríguez, A. (2011). Offshoring of R&D: Looking abroad to improve innovation performance. *Journal of International Business Studies*, *42*(3), 345-361.

Nieto, M. J. & Rodríguez, A. (2013). The challenge of R&D offshoring: Implications for firm productivity. In: Pedersen T., Bals L., Ørberg Jensen P., Larsen M. (eds): *The Offshoring Challeng*e. Springer, London.

Pelegrín, A. & Bolancé, C. (2013). Offshoring and company characteristics: some evidence from the analysis of Spanish firm data. *The International Economy*, *16*, 15-36.

Scott, J. T. (2003). Absorptive capacity and the efficiency of research partnerships. *Technology Analysis and Strategic Management, 15*(2), 247–253.

Tamayo, M. P. & Huergo, E. (2017). Determinants of internal and external R&D offshoring: evidence from Spanish firms. *Industry and Innovation*, *24*(2), 143-164.

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

Wagner, J. (2011). Offshoring and firm performance: self-selection, effects on performance, or both? *Review of World Economics*, *147*(2), 217-247.

Figure 1. Average of obstacles to innovation by country

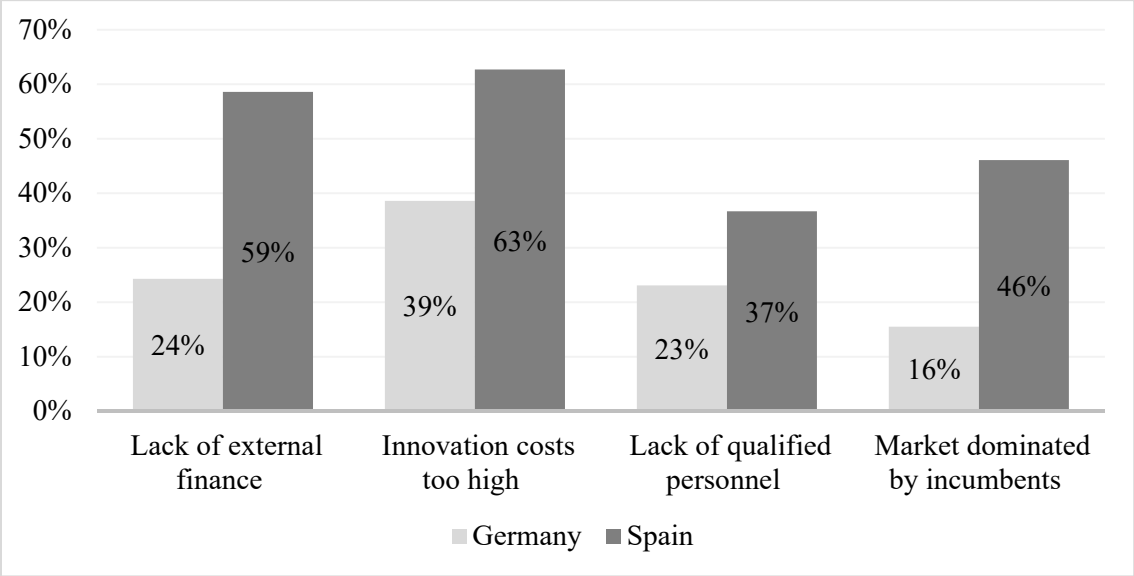

Table 1. Descriptives of main variables by country

	Germany Mean	Spain Mean	Minimum	Maximum
External technological strategies:				
Domestic R&D outsourcing (0/1)	0.150	0.214	0	1
	(0.357)	(0.410)		
International R&D outsourcing (0/1)	0.028	0.044	0	1
	(0.165)	(0.206)		
Domestic R&D cooperation (0/1)	0.185	0.263	0	1
	(0.389)	(0.441)		
International R&D cooperation (0/1)	0.069	0.104	0	1
	(0.253)	(0.305)		
Obstacles to innovation:				
Lack of external finance (0/1)	0.243	0.586	0	1
	(0.429)	(0.493)		
Innovation costs too high (0/1)	0.386	0.627	0	1
	(0.487)	(0.484)		
Lack of qualified personnel (0/1)	0.231	0.367	0	1
	(0.422)	(0.482)		
Market dominated by incumbents (0/1)	0.155	0.461	0	1
	(0.362)	(0.498)		
Other firm characteristics:				
Exporter (0/1)	0.470	0.540	0	1
	(0.499)	(0.498)		
Continuous internal R&D (0/1)	0.229	0.369	0	1
	(0.420)	(0.483)		
Innovation expenditure	0.032	0.044	0	0.35
	(0.069)	(0.091)		
Truncated value of innovation expenditure (0/1)	0.023	0.055	0	1
	(0.149)	(0.228)		
Medium enterprise (0/1)	0.265	0.289	0	1
	(0.441)	(0.453)		
Large enterprise (0/1)	0.097	0.224	0	1
	(0.296)	(0.417)		
Labour productivity	0.262	0.175	0	0.6
	(0.176)	(0.156)		
Truncated value of labour productivity (0/1)	0.116	0.021	0	1
	(0.321)	(0.144)		
Research-intensive manufacturing (0/1)	0.185	0.224	0	1
	(0.389)	(0.417)		
Other manufacturing (0/1)	0.437	0.329	0	1
	(0.496)	(0.470)		
Knowledge-intensive services (0/1)	0.215	0.114	0	1
	(0.411)	(0.318)		
Group (0/1)		0.412	0	1
		(0.492)		
No. observations	2,748	8,382		

Notes: (0/1) denotes dummy variable.

Table 2. External technological strategies: Outsourcing vs cooperation. Bivariate probit

	Germany		Spain	
	R&D outsourcing	Technological cooperation	R&D outsourcing	Technological cooperation
Obstacles to innovation:				
Lack of external finance	-0.002	0.029	0.032***	0.089***
	(0.014)	(0.020)	(0.010)	(0.012)
Innovation costs too high	0.057***	0.024	0.008	0.001
	(0.014)	(0.017)	(0.011)	(0.013)
Lack of qualified personnel	0.005	0.012	0.009	0.013
	(0.014)	(0.018)	(0.009)	(0.011)
Market dominated by incumbents	0.006	0.020	0.017*	0.011
	(0.016)	(0.021)	(0.009)	(0.011)
Other firm characteristics:				
Exporter	0.052***	0.097***	0.042***	0.043***
	(0.014)	(0.017)	(0.010)	(0.011)
Continuous internal R&D	0.192***	0.278***	0.219***	0.239***
	(0.023)	(0.027)	(0.011)	(0.013)
Innovation expenditure	0.740***	0.858***	1.494***	1.513***
	(0.107)	(0.133)	(0.083)	(0.100)
Truncated values of inn. expenditure	-0.053**	-0.023	-0.127***	-0.137***
	(0.022)	(0.048)	(0.011)	(0.021)
Medium enterprise	0.050***	0.045**	0.076***	0.057***
	(0.016)	(0.018)	(0.012)	(0.013)
Large enterprise	0.114***	0.207***	0.161***	0.144***
	(0.029)	(0.037)	(0.017)	(0.017)
Labour Productivity	0.250***	0.216***	0.355***	0.346***
	(0.047)	(0.057)	(0.032)	(0.038)
Truncated values of labour productivity	-0.022	-0.052**	-0.056**	-0.061**
	(0.019)	(0.022)	(0.023)	(0.030)
Research-intensive industry	0.020	0.036	0.100***	-0.016
	(0.024)	(0.031)	(0.016)	(0.015)
Other industry	-0.008	0.022	0.062***	0.007
	(0.019)	(0.024)	(0.013)	(0.014)
Knowledge-intensive services	-0.002	0.039	-0.031**	0.011
	(0.022)	(0.030)	(0.015)	(0.019)
Group			0.033***	0.062***
			(0.010)	(0.012)
ρ	0.691*** (0.054)		0.426*** (0.020)	
No. observations	2,748		8,382	

Notes: Marginal effects are reported at sample means. For dummy variables, the marginal effect corresponds to the discrete change from 0 to 1. Estimated standard errors in parentheses. All regressions include a constant and regional dummies. Coefficients significant at 1%***, 5%**, 10%*.

Table 3. External technological strategies: Outsourcing vs cooperation. Bivariate probit

	Germany		Spain	
	R&D outsourcing	Technological cooperation	R&D outsourcing	Technological cooperation
PANEL A:				
Lack of external finance	0.028*	0.050***	0.042***	0.095***
	(0.015)	(0.018)	(0.009)	(0.010)
ρ	0.691*** (0.054)		0.426*** (0.020)	
PANEL B:				
Innovation costs too high	0.059***	0.042***	0.032***	0.055***
	(0.012)	(0.015)	(0.009)	(0.010)
ρ	0.690*** (0.054)		0.426*** (0.020)	
PANEL C:				
Lack of qualified personnel	0.020	0.029	0.022**	0.036***
	(0.014)	(0.018)	(0.009)	(0.010)
ρ	0.692*** (0.054)		0.429*** (0.020)	
PANEL D:				
Market dominated by incumbents	0.029*	0.043**	0.029***	0.035***
	(0.017)	(0.020)	(0.009)	(0.010)
ρ	0.690*** (0.054)		0.431*** (0.020)	
No. observations	2,748		8,382	

Notes: Marginal effects are reported at sample means. For dummy variables, the marginal effect corresponds to the discrete change from 0 to 1. Estimated standard errors in parentheses. All regressions include the same control variables as in Table 2. ρ is the correlation coefficient across equations. Coefficients significant at 1%***, 5%**, 10%*.

Table 4. External technological strategies. Multivariate probit

	Germany				Spain			
	Domestic outsourcing	International outsourcing	Domestic cooperation	International cooperation	Domestic outsourcing	International outsourcing	Domestic cooperation	International cooperation
PANEL A:								
Lack of external finance	0.017	0.012**	0.046**	0.013	0.039***	0.004	0.081***	0.019***
	(0.012)	(0.004)	(0.014)	(0.007)	(0.008)	(0.003)	(0.009)	(0.005)
PANEL B:								
Innovation costs too high	0.046***	0.013***	0.035**	0.016*	0.030***	0.003	0.044***	0.005
	(0.010)	(0.004)	(0.012)	(0.006)	(0.008)	(0.003)	(0.009)	(0.005)
PANEL C:								
Lack of qualified personnel	0.015	0.008*	0.015	0.021**	0.020**	0.002	0.032***	0.003
	(0.011)	(0.003)	(0.014)	(0.007)	(0.008)	(0.003)	(0.009)	(0.005)
PANEL D:								
Market dominated by incumbents	0.013	0.014***	0.034*	0.028***	0.023***	0.007***	0.032***	0.005
	(0.013)	(0.004)	(0.016)	(0.008)	(0.008)	(0.003)	(0.009)	(0.004)
No. observations	2,748				8,382			

Notes: Marginal effects are reported at sample means. For dummy variables, the marginal effect corresponds to the discrete change from 0 to 1. Estimated standard errors in parentheses. Each row corresponds to a different estimate. Besides the specific obstacle to innovation, all regressions include the same explanatory variables as in Table A.2 of the Appendix. Coefficients significant at 1%***, 5%**, 10%*.

Table 5. External technological strategies by frequency of internal R&D. Bivariate probit

Frequency of internal R&D:	Continuous				Non-continuous			
	Germany		Spain		Germany		Spain	
	R&D outsourcing	Technological cooperation	R&D outsourcing	Technological cooperation	R&D outsourcing	Technological cooperation	R&D outsourcing	Technological cooperation
PANEL A:								
Lack of external finance	-0.011	0.063	0.033	0.094***	0.030**	0.032**	0.023***	0.063***
	(0.046)	(0.045)	(0.020)	(0.020)	(0.012)	(0.014)	(0.007)	(0.009)
	0.512*** (0.072)		0.412*** (0.027)		0.867*** (0.080)		0.401*** (0.033)	
PANEL B:								
Innovation costs too high	0.059	-0.014	0.017	0.036*	0.046***	0.043***	0.022***	0.044***
	(0.041)	(0.041)	(0.020)	(0.020)	(0.010)	(0.012)	(0.007)	(0.009)
	0.510*** (0 .072)		0.413*** (0.026)		0.858*** (0.080)		0.404*** (0.033)	
PANEL C:								
Lack of qualified personnel	-0.031	0.003	0.027	0.026	0.031**	0.034**	0.012*	0.031***
	(0.044)	(0.042)	(0.019)	(0.019)	(0.012)	(0.015)	(0.007)	(0.010)
	0.507*** (0.072)		0.413*** (0.026)		0.864*** (0.080)		0.407*** (0.033)	
PANEL D:								
Market dominated by incumbents	0.007	0.096**	0.045**	0.044**	0.033**	0.016	0.013*	0.021**
	(0.050)	(0.048)	(0.019)	(0.019)	(0.015)	(0.016)	(0.007)	(0.009)
	0.510***(0.072)		0.412*** (0.026)		0.871*** (0.080)		0.407*** (0.033)	
No. observations	629		3,092		2,119		5,290	

Notes: Marginal effects are reported at sample means. For dummy variables, the marginal effect corresponds to the discrete change from 0 to 1. Estimated standard errors in parentheses. Each row corresponds to a different estimate. Besides the specific obstacle to innovation, all regressions include the same explanatory variables as in Table A.4. ρ is the correlation coefficient across equations.Coefficients significant at 1%***, 5%**, 10%*.

Appendix: Complementary Tables

Table A.1.b. Pairwise correlation matrix. Germany

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]	[16]	[17]	[18]	[19]
[1] Domestic R&D outsourcing	1																		
[2] International R&D outsourcing	0.268*	1																	
[3] Domestic R&D cooperation	0.536*	0.186*	1																
[4] International R&D cooperation	0.332*	0.433*	0.444*	1															
[5] Lack of external finance	0.030	0.043	0.069*	0.0373	1														
[6] Innovation costs too high	0.147*	0.101*	0.128*	0.100*	0.497*	1													
[7] Lack of qualified personnel	0.124*	0.106*	0.129*	0.144*	0.249*	0.312*	1												
[8] Market dominated by incumbents	0.076*	0.116*	0.093*	0.118*	0.280*	0.341*	0.328*	1											
[9] Exporter	0.259*	0.141*	0.298*	0.228*	0.011	0.130*	0.133*	0.044	1										
[10] Continuous internal R&D	0.454*	0.207*	0.521*	0.362*	0.047	0.149*	0.184*	0.106*	0.391*	1									
[11] Innovation expenditure	0.309*	0.136*	0.358*	0.263*	0.116*	0.110*	0.153*	0.085*	0.180*	0.417*	1								
[12] TV of inn. expenditure	0.162*	0.048	0.211*	0.172*	0.091*	0.035	0.050*	0.023	0.053*	0.174*	0.696*	1							
[13] Medium enterprise	0.080*	0.033	0.058*	0.0519*	-0.061*	0.016	0.036	-0.018	0.211*	0.120*	-0.024	-0.047	1						
[14] Large enterprise	0.206*	0.138*	0.210*	0.241*	-0.071*	0.045	0.076*	0.026	0.149*	0.237*	-0.020	-0.025	-0.197*	1					
[15] Labour productivity	0.163*	0.131*	0.110*	0.131*	-0.110*	0.022	0.033	0.012	0.237*	0.137*	-0.058*	-0.063*	0.125*	0.211*	1				
[16] TV of labour productivity	0.085*	0.110*	0.028	0.067*	-0.076*	-0.030	-0.008	0.014	0.079*	0.045	-0.040	-0.032	0.029	0.141*	0.698*	1			
[17] Research-intensive manufact.	0.271*	0.169*	0.269*	0.196*	0.036	0.126*	0.169*	0.088*	0.379*	0.394*	0.209*	0.041	0.100*	0.147*	0.136*	0.026	1		
[18] Other manufacturing	-0.079*	-0.047	-0.070*	-0.065*	-0.004	0.009	-0.067*	-0.026	0.056*	-0.108*	-0.151*	-0.070*	0.037	-0.046	0.064*	0.010	-0.420*	1	
[19] Knowledge-intensive services	-0.059*	-0.057*	-0.039	-0.033	-0.023	-0.069*	-0.020	-0.035	-0.226*	-0.049	0.093*	0.076*	-0.131*	-0.076*	-0.153*	-0.082*	-0.249*	-0.460*	1

Notes: TV stands for truncated values. *correlation coefficient significant at the 5% level.

Table A.1.b. Pairwise correlation matrix. Spain

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]	[16]	[17]	[18]	[19]
[1] Domestic R&D outsourcing	1																		
[2] International R&D outsourcing	0.275*	1																	
[3] Domestic R&D cooperation	0.427*	0.174*	1																
[4] International R&D cooperation	0.300*	0.283*	0.485*	1															
[5] Lack of external finance	0.112*	0.030	0.148*	0.062*	1														
[6] Innovation costs too high	0.071*	0.014	0.081*	0.016	0.593*	1													
[7] Lack of qualified personnel	0.035	0.002	0.045*	0.004	0.284*	0.313*	1												
[8] Market dominated by incumbents	0.071*	0.043*	0.068*	0.031	0.309*	0.336*	0.300*	1											
[9] Exporter	0.166*	0.136*	0.129*	0.157*	0.087*	0.083*	0.053*	0.102*	1										
[10] Continuous internal R&D	0.437*	0.196*	0.402*	0.323*	0.165*	0.108*	0.048*	0.101*	0.259*	1									
[11] Innovation expenditure	0.319*	0.135*	0.332*	0.211*	0.180*	0.097*	0.032	0.080*	0.010	0.443*	1								
[12] TV of inn. expenditure	0.185*	0.098*	0.217*	0.157*	0.111*	0.037*	0.010	0.026	-0.060*	0.249*	0.810*	1							
[13] Medium enterprise	0.072*	0.034	0.048*	0.063*	-0.005	-0.008	0.006	-0.006	0.161*	0.115*	-0.063*	-0.064*	1						
[14] Large enterprise	0.027	0.086*	0.034	0.098*	-0.163*	-0.144*	-0.090*	-0.124*	-0.084*	-0.035	-0.175*	-0.107*	-0.342*	1					
[15] Labour productivity	0.110*	0.093*	0.078*	0.117*	-0.093*	-0.062*	-0.054*	-0.038*	0.239*	0.073*	-0.217*	-0.173*	0.108*	0.063*	1				
[16] TV of labour productivity	0.006	-0.003	0.005	0.010	-0.035	-0.022	-0.040*	-0.038*	0.032	-0.011	-0.058*	-0.032	0.005	0.017	0.399*	1			
[17] Research-intensive manufact.	0.139*	0.114*	0.050*	0.083*	0.055*	0.070*	0.035	0.105*	0.284*	0.210*	0.001	-0.078*	0.050*	-0.103*	0.102*	-0.005	1		
[18] Other manufacturing	-0.0105	-0.010	-0.019	-0.019	0.042*	0.053*	0.054*	0.017	0.181*	-0.033	-0.177*	-0.140*	0.083*	-0.103*	0.110*	-0.004	-0.376*	1	
[19] Knowledge-intensive services	0.051*	0.019	0.114*	0.070*	0.091*	0.047*	0.003	0.036	-0.105*	0.138*	0.396*	0.357*	-0.033	-0.078*	-0.179*	-0.035	-0.193*	-0.251*	1

Notes: TV stands for truncated values. *correlation coefficient significant at the 5% level.

Table A.2: External technological strategies. Multivariate Probit

	Germany				Spain			
	Domestic outsourcing	International outsourcing	Domestic cooperation	International cooperation	Domestic outsourcing	International outsourcing	Domestic cooperation	International cooperation
Obstacles to innovation:								
Lack of external finance	-0.007	0.007	0.033*	0.006	0.030***	0.003	0.076***	0.021***
	(0.013)	(0.004)	(0.016)	(0.008)	(0.009)	(0.003)	(0.011)	(0.005)
Innovation costs too high	0.048***	0.008*	0.018	0.007	0.008	-0.001	-0.003	-0.006
	(0.012)	(0.004)	(0.014)	(0.007)	(0.010)	(0.003)	(0.011)	(0.005)
Lack of qualified personnel	0.005	0.004	0.001	0.015*	0.008	0.000	0.014	0.000
	(0.012)	(0.003)	(0.014)	(0.007)	(0.008)	(0.003)	(0.009)	(0.005)
Market dominated by incumbents	-0.005	0.010*	0.018	0.020**	0.013	0.007**	0.013	0.002
	(0.014)	(0.004)	(0.017)	(0.008)	(0.008)	(0.003)	(0.009)	(0.005)
rho_12	0.449*** (0.082)				0.455*** (0.038)			
rho_13	0.704*** (0.053)				0.423*** (0.026)			
rho_14	0.331*** (0.058)				0.227*** (0.032)			
rho_23	0.209*** (0.076)				0.197*** (0.042)			
rho_24	0.943*** (0.100)				0.369*** (0.040)			
rho_34	0.711*** (0.068)				0.737*** (0.021)			
No. observations	2,748				8,382			

Notes: Marginal effects are reported at sample means. For dummy variables, the marginal effect corresponds to the discrete change from 0 to 1. Estimated standard errors in parentheses. TV stands for truncated values. All regressions include a constant and regional dummies. ρ_ij is the correlation coefficient across equations i and j, where i,j=1,2,3,4, that refer, respectively, to equations for domestic outsourcing, international outsourcing, domestic cooperation and international cooperation. Coefficients significant at 1%***, 5%**, 10%*.

Table A.2 cont.: External technological strategies. Multivariate probit

	Germany				Spain			
	Domestic outsourcing	International outsourcing	Domestic cooperation	International cooperation	Domestic outsourcing	International outsourcing	Domestic cooperation	International cooperation
Other firm characteristics:								
Exporter	0.043***	0.009	0.087***	0.043***	0.027**	0.020***	0.034***	0.038***
	(0.013)	(0.005)	(0.015)	(0.009)	(0.009)	(0.004)	(0.010)	(0.005)
Continuous internal R&D	0.127***	0.014**	0.188***	0.057***	0.182***	0.018***	0.193***	0.079***
	(0.013)	(0.004)	(0.016)	(0.008)	(0.009)	(0.003)	(0.011)	(0.006)
Innovation expenditure	0.640***	0.126***	0.697***	0.338***	1.268***	0.189***	1.235***	0.418***
	(0.098)	(0.031)	(0.117)	(0.060)	(0.076)	(0.025)	(0.086)	(0.042)
TV of innovation expenditure	-0.054	-0.018	0.01	-0.016	-0.156***	0.000	-0.128***	-0.019
	(0.037)	(0.010)	(0.049)	(0.020)	(0.024)	(0.007)	(0.029)	(0.013)
Medium enterprise	0.040**	0.005	0.034*	0.025**	0.061***	0.016***	0.048***	0.034***
	(0.012)	(0.004)	(0.015)	(0.008)	(0.010)	(0.003)	(0.011)	(0.006)
Large enterprise	0.090***	0.012*	0.127***	0.064***	0.109***	0.034***	0.112***	0.067***
	(0.017)	(0.005)	(0.021)	(0.010)	(0.012)	(0.004)	(0.013)	(0.007)
Labour Productivity	0.201***	0.045**	0.172***	0.086**	0.302***	0.053***	0.288***	0.124***
	(0.044)	(0.016)	(0.052)	(0.028)	(0.029)	(0.009)	(0.033)	(0.017)
TV of labour productivity	-0.018	0.004	-0.052*	-0.015	-0.051*	-0.020**	-0.048	-0.027*
	(0.020)	(0.006)	(0.025)	(0.012)	(0.027)	(0.009)	(0.031)	(0.015)
Research-intensive manufacturing	0.024	0.004	0.035	-0.019	0.069***	0.025***	-0.017	0.012*
	(0.020)	(0.007)	(0.025)	(0.013)	(0.012)	(0.004)	(0.013)	(0.007)
Other manufacturing	-0.002	-0.001	0.022	-0.018	0.045***	0.018***	0.002	0.008
	(0.018)	(0.007)	(0.022)	(0.013)	(0.011)	(0.004)	(0.012)	(0.007)
Knowledge-intensive services	0.002	-0.006	0.038	-0.01	-0.034**	0.004	0.013	0.006
	(0.020)	(0.008)	(0.024)	(0.014)	(0.014)	(0.005)	(0.016)	(0.008)
Group					0.021**	0.015***	0.049***	0.038***
					(0.009)	(0.003)	(0.010)	(0.005)
No. observations	2,748				8,382			

Notes: Marginal effects are reported at sample means. For dummy variables, the marginal effect corresponds to the discrete change from 0 to 1. Estimated standard errors in parentheses. TV stands for truncated values. All regressions include a constant and regional dummies. Coefficients significant at 1%***, 5%**, 10%*.

Table A.3. External technological strategies by frequency of internal R&D. Bivariate Probit

Frequency of internal R&D:	Continuous				Non-continuous			
	Germany		Spain		Germany		Spain	
	R&D outsourcing	Technological cooperation	R&D outsourcing	Technological cooperation	R&D outsourcing	Technological cooperation	R&D outsourcing	Technological cooperation
Obstacles to innovation:								
Lack of external finance	-0.042	0.075	0.028	0.093***	0.001	0.007	0.014*	0.056***
	(0.050)	(0.048)	(0.023)	(0.023)	(0.011)	(0.014)	(0.008)	(0.012)
Innovation costs too high	0.079*	-0.060	-0.006	-0.012	0.040***	0.037***	0.011	0.007
	(0.047)	(0.046)	(0.023)	(0.023)	(0.012)	(0.014)	(0.009)	(0.012)
Lack of qualified personnel	-0.044	-0.008	0.017	0.012	0.014	0.020	0.003	0.012
	(0.045)	(0.044)	(0.020)	(0.020)	(0.012)	(0.015)	(0.007)	(0.010)
Market dominated by incumbents	-0.003	0.108**	0.040**	0.033*	0.007	-0.009	0.004	-0.003
	(0.053)	(0.050)	(0.019)	(0.020)	(0.012)	(0.014)	(0.007)	(0.010)
Other firm characteristics:								
Exporter	0.111*	0.091	0.050**	0.038	0.026***	0.061***	0.027***	0.035***
	(0.060)	(0.065)	(0.023)	(0.023)	(0.010)	(0.013)	(0.008)	(0.010)
Innovation expenditure	1.072***	0.916**	1.986***	1.620***	0.562***	0.627***	1.096***	1.594***
	(0.359)	(0.371)	(0.168)	(0.168)	(0.081)	(0.102)	(0.076)	(0.115)
TV of innovation expenditures	0.089	0.204**	-0.195***	-0.103**	-0.041***	-0.051***	-0.060***	-0.115***
	(0.124)	(0.104)	(0.044)	(0.050)	(0.005)	(0.008)	(0.004)	(0.005)
Medium Enterprise	0.072	0.017	0.125***	0.148***	0.038***	0.039***	0.046***	0.008
	(0.052)	(0.050)	(0.024)	(0.023)	(0.012)	(0.014)	(0.010)	(0.012)
Large Enterprise	0.205***	0.221***	0.292***	0.283***	0.059**	0.160***	0.060***	0.045***
	(0.062)	(0.053)	(0.028)	(0.026)	(0.027)	(0.040)	(0.013)	(0.015)
Labour Productivity	0.394**	0.256	0.704***	0.586***	0.172***	0.149***	0.131***	0.159***
	(0.198)	(0.193)	(0.079)	(0.079)	(0.030)	(0.038)	(0.023)	(0.032)
TV of labour productivity	0.077	-0.069	-0.219***	-0.201***	-0.025***	-0.030**	0.004	-0.002
	(0.085)	(0.086)	(0.058)	(0.066)	(0.009)	(0.013)	(0.021)	(0.029)
Research-intensive Industry	-0.026	-0.034	0.067**	-0.112***	0.009	0.031	0.077***	0.007
	(0.162)	(0.157)	(0.030)	(0.029)	(0.016)	(0.023)	(0.016)	(0.015)
Other Industry	-0.089	0.006	0.046	-0.065**	-0.009	-0.001	0.030***	0.006
	(0.159)	(0.156)	(0.030)	(0.030)	(0.011)	(0.014)	(0.010)	(0.012)
Knowledge-intensive Services	-0.144	-0.133	-0.067**	-0.044	0.004	0.035*	-0.013	0.027
	(0.155)	(0.162)	(0.033)	(0.034)	(0.014)	(0.020)	(0.012)	(0.019)
Group			0.073***	0.071***			0.007	0.046***
			(0.022)	(0.022)			(0.008)	(0.011)
ρ	0.526***(0.073)		0.411*** (0.027)		0.859***(0.081)		0.401*** (0.033)	
No. observations	629		3,092		2,119		5,290	

Notes: Marginal effects are reported at sample means. For dummy variables, the marginal effect corresponds to the discrete change from 0 to 1. Estimated standard errors in parentheses. TV stands for truncated values. All regressions include a constant and regional dummies. ρ is the correlation coefficient across equations. Coefficients significant at 1%***, 5%**, 10%*.