COOPERATION INNOVATION ACTIVITIES: THE IMPORTANCE OF PARTNERS

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Abstract:

This paper analyses the importance of cooperation partners in the success of innovation activities. We contribute to the literature on cooperation on innovation activities that seeks to identify the characteristics that differentiate cooperative firms from non-cooperative firms, but propose a different approach. We construct an ordered model using the Portuguese Third Community Innovation Survey data, which allows distinguishing firms according to the evaluation of cooperation partners in the success of innovation. Our estimation results show that firms with higher levels of absorptive capacity, exports share, R&D engagement, innovation intensity, and that rate spillovers management as important, place greater value on cooperation partners in the innovation process.

Keywords: Innovation, Cooperation, Community Innovation Survey
JEL Codes: C25, L20, O31, O32

1. Introduction

The increased complexity of knowledge processes, which are the backbone of new technologies and innovation, leads firms to search beyond their own organization for valuable knowledge and skills, in order to complement their own capabilities (Becker and Dietz, 2004). Since the 1980s, the increasing instability of the competitive environment, with shorter product and technological life cycles, has forced firms to reconsider their innovation strategy in order to widen their technology base (Nijssen et al., 2001). In this context, cooperation has gained an important role in the innovation process at the firm level, since innovation cooperation activities are considered an efficient means for industrial organization of complex R&D and innovation processes. Cooperation activities with other firms or institutions are opportunities to access complementary technological resources (such as skill sharing) for faster development of innovations, to improve market access, to realize economies of scale and scope, to share costs and spread risk (Ahuja, 2000; Cassiman and Veugelers, 2002; Hagedoorn, 2002 López, 2006). Such cooperation activities are characterized by intensive knowledge exchange and learning processes, basically by combining complementary assets and building synergies (Dachs et al., 2004; Becker and Dietz, 2004). Since innovation cooperative agreements favour knowledge accumulation that might be converted into new technological and organizational innovations, the firms' decision to cooperate opens the range of their technological options (Mowery et al., 1998; Caloghirou et al., 2003). In other words, and as argued by Gomes-Cassares et al. (2006), firms enrolled in cooperation activities or alliances are involved in denser knowledge flows than are non-allied firms.

Since the mid-1990s, and as described by Rosenfeld (1996) and Hagedoorn et al. (2000), not only multinational firms but also small- and medium-sized firms are structuring more and tighter relationships with other companies in order to achieve economies of scale, market strength, or to exploit new opportunities. Firms have started to engage, both formally and informally, in joint activities such as co-marketing, co-production, shared resources, or joint development (Bönte and Keilbach, 2005). The boundaries of innovation are shifting from a situation where firms perform R&D activities mainly internally (Mowery, 1983; Nelson, 1990) to a reality where corporate partnering, collaboration and external sourcing in R&D are widespread. In this new context, internal and external sourcing of innovation inputs, such as R&D, are seen not as substitutes, but as complements, since internal innovation activities are not incompatible (and can be synergetic) with agreements with other firms, research agreements with universities, investments in the capital stock of new firms, and acquisition of small firms (Arora and Gambardella 1990; Cassiman and Veugelers, 2002; Hagedoorn and van Kranenburg, 2003; Adams and Marcu, 2004).

Another way to look at the decision to cooperate is as an equilibrium between achieving a high level of knowledge flow and the protection of internal knowledge from leaking out (Schmidt, 2005). Only firms that can protect their vital information are willing to engage in cooperative agreements, an issue which may be less present in cooperative agreements with research institutes and universities than in cooperation with other firms (Belderbos et al., 2003). In other words, cooperation in innovation activities can be analysed as a trade-off between spillovers: firms generate and receive spillovers to and from their cooperation partners. So, firms must manage the external information flows in order to maximize the incoming spillovers from partners and non-partners while, at the same time, control the spillovers to non-partners. In order to do so, firms must try to increase the extent of incoming spillovers by investing in “absorptive capacity”. As argued by Cohen and Levinthal (1989; 1990), external knowledge is more effective for the innovation process when the firm undertakes its own R&D, that is, its internal capacities (Cassiman and Veugelers, 2002). The higher a firm’s absorptive capacity, the more able it should be to access and implement a greater amount of knowledge (Negassi, 2004; Schmidt, 2005). The capacity of firms to take advantage of knowledge generated elsewhere has a positive effect on the probability of being a successful innovator, and is associated with the decision to undertake formal collaborative research with other firms and institutions (Abramovsky et al., 2005).

In this context and considering the increasing role of cooperative agreements on firm-level innovation processes, the goal of this paper is to analyse the importance of cooperation partners to the success of innovation activities. We use information only collected in the Portuguese version of the Third Community Innovation Survey (CIS III) questionnaire to identify which firms considered cooperation as an important component of the innovation process. The firm is asked to identify the partners’ level of importance for the development of innovation activities, from zero or low importance to high importance. This level of importance provides a mapping of the benefits of cooperation for the innovation process. We construct an ordered model where the importance of cooperation partners is linked with firm characteristics, namely, the engagement in R&D activities, qualification of human resources (as related to absorptive capacity and to the ability to optimize on spillovers), firm size, and competitiveness. The results of the estimation confirm the importance of these variables to determine the scope of the partner contribution to the success of the cooperation innovation activities. Moreover, they stress the value of internal capability of the firm to capture the benefits of its decision to cooperate. This analysis is new and adds empirical evidence on the importance of cooperation. Moreover, previous studies that use CIS from other countries do not examine the success of cooperation.

The paper is organized as follows. In Section 2 we review the literature focused on innovation cooperation activities. Section 3 describes the model and data specification. Section 4 presents and analyses the results. Section 5 concludes.

2. Empirical Studies on Innovation Cooperation Activities

Reflecting the increased role of cooperation activities in the innovation processes, many studies focus on the role, the determinants and the efficiency of innovation cooperation activities. In this section we discuss the main results reported in the literature.

One strand of analyses seeks to measure the effects of cooperation on the overall performance of firms and on the innovation and R&D performance. Most of these studies reach the conclusion that cooperative firms overall have higher performance levels than do non-cooperative firms (Abramovsky et al., 2005). On one hand, the joint R&D enhances firms' R&D intensity and a high number of cooperation partners positively affects the R&D commitment (Becker and Dietz, 2004; Sampson, 2007) and, on the other, the engagement in cooperation activities and the subsequent knowledge management increases the profitability of R&D (Belderbos et al., 2003). Regarding different kinds of cooperation partners, supplier and competitor cooperation have a considerable impact on labour productivity growth, while cooperation with universities, research institutes and competitors positively affects growth in sales per employee of products and services new to the market (Belderbos et al., 2004b). Freel and Harrison (2006) found that cooperation with different kinds of partners also has different effects on innovation success: cooperation with customers and public sector institutions is positively related to product innovation, and cooperation with suppliers and universities influences process innovation.

Complementing the studies that stress the positive effect of cooperation in innovation activities on the performance of firms, several studies have sought to identify the determinants behind the decision to cooperate in the specific areas of R&D and innovation. They can be summarized along three lines of argument: pertaining to the kinds of partners and spillovers; to the characteristics of the firms (including their ability to control and take advantage of spillovers); and to the different kinds of innovative activities.

Vertical spillovers, associated with suppliers and customers, enhance R&D performance and welfare, while horizontal spillovers, linked to universities, research institutes and competitors may have either a positive or negative effect on them (Atallah, 2002). As Belderbos et al. (2004a) found using two consecutive CIS surveys (1996 and 1998) from the Netherlands, competitor spillovers are not an essential factor when firms decide to cooperate horizontally and spillovers from universities and research institutes stimulate cooperation of all types equally. Focussing on the firm cooperation with universities and government labs, Mohen and Hoareau (2003) and Fontana et al. (2006) found that large firms, firms that patent and/or receive public funding for innovation are those more likely to be engaged in these kinds of activities. Bercovitz and Feldman (2007) analysed the relationship between firms' innovation strategy and the propensity to cooperate with universities, concluding that firms with research driven by exploratory, centralized and intellectual property protection strategies prefer university partners. The firm and industry characteristics associated with cooperation with universities were also the focus of Veugelers and Cassiman (2005). They found that this kind of cooperation does not stand alone when risk is not an important obstacle to innovation or in order to share costs, complementing other R&D and innovation activities, such as, own R&D, cooperation with other partners and the search for publicly available knowledge.

Using CIS I data for Belgium, Cassiman and Veugelers (2002), explored the effects of knowledge flows on R&D cooperation, with a special focus on the distinction between two measures of knowledge flows: incoming spillovers and appropriability. They found that there is a significant relationship between external information flows and the decision to cooperate in R&D; firms that rate the general availability of incoming spillovers as more important inputs to their innovation process are also more likely to be actively engaged in cooperative R&D agreements; firms that are more effective in appropriating the results from their innovation processes are also more likely to cooperate in R&D. Incoming spillovers and appropriability have important effects: firms with higher incoming spillovers and better appropriation have a higher probability of cooperating in R&D. Abramovsky et al. (2005) extended this study to the service sector using data from the CIS III for France, Germany, Spain and the United Kingdom. In line with the previous authors, they show that the likelihood of firms undertaking cooperative R&D agreements is positively affected by the firms' ability to take advantage of incoming spillovers in the form of publicly available knowledge, and to limit outgoing spillovers and appropriate the returns to their innovative efforts. Using Spanish firm-level data, López (2006) had similar findings concerning incoming spillovers, but found a negative relationship between a high level of legal protection and R&D cooperation.

Based on a sample of 1800 German manufacturing enterprises, Fritsch and Lukas (2001) analysed the characteristics of manufacturing enterprises that maintain different forms of R&D cooperation in contrast to those enterprises that do not cooperate on

R&D. According to their results, enterprises that maintain such relationships tend to be relatively large and have a high share of R&D. This is also the finding of Negassi (2004), where R&D cooperation increases with size and R&D intensity, but not with market share. Cooperative arrangements for innovation are also more common amongst firms that introduced innovations that were new not only to the firm, but also to the market. Furthermore, the intensity of R&D activities tends to increase the likelihood of a firm having cooperative arrangements for innovation with external partners (Tether, 2002). The search for external partners is normally associated with more complex innovation processes, usually those that combine both process and product innovation (Piga and Vivarelli, 2004).

Finally, related to the scope and complexity of the innovation activities, several authors, such as Bayona et al. (2001) and Miotti and Sachwald (2003), provide evidence that firms in more technology-intensive sectors have a greater propensity to establish cooperative R&D and innovation agreements. As Dachs et al. (2004) observed, due to the higher degree of complexity as well as a faster speed of knowledge generation and use processes, collaborative behaviour is more likely in high-technology industries. Illustrating the influence of the technology intensity of firms, Caloghirou et al. (2003) remind us that, during most of the 1970s (when biotechnology and advanced-materials research were not developed), high-technology sectors were responsible for 40 percent of the innovation cooperation partnerships, growing to almost 60 percent during the late 1970s and early 1980s. And, according to the most recent data, about 80 percent of the inter-firm research relationships are established in high-technology areas.

A firm’s decision to cooperate in innovation is driven by the fact that cooperation is an efficient way to improve the probability of success of innovation projects. According to this, studies were conducted in order to identify the factors influencing the success of cooperation activities. Amongst the most important reported in the literature, we find engagement in R&D activities, qualification of human resources (as related to absorptive capacity and to the ability to optimize on spillovers), firm size, and competitiveness. Concerning the innovative activities themselves, the most important seem to be their complexity and how radical they are.

We strive to go beyond the analysis of the firm decision to cooperate and study directly the benefits of that cooperation as perceived by the firm. We intend to capture these benefits through the importance attributed by the firm to the cooperation arrangement. Instead of merely observing the decision to cooperate, we consider in particular the outcome of that decision as measured by the importance of the partner to the innovation activity. The reviewed literature guides us on the variables we should consider when specifying the model, which is presented in the next section.

3. Data and Model Specification

This section describes the data used to address the research questions. In addition, it presents the model specification and the methodological issues associated with it.

3.1. Data

The database used in this paper is the Portuguese Community Innovation Survey III database, a micro dataset with detailed firm-level matching information on innovation behaviour, cooperation and other firm characteristics. The CIS, executed under the supervision of Eurostat, focused on the observation and collection of quantitative data on technological innovation. The dataset is representative of the population of the manufacturing sector and also of five selected service sectors (only those firms with more than 10 employees were considered). The usual consistency and logical tests, as well as corrections for possible bias associated with non-responses, were performed by each country at the firm level.

Developed under the guiding principles of the Oslo Innovation Manual (OECD, 1992), the survey aims to collect data on innovation understood from a broad firm perspective, rather than examining just the invention process. Thus, the CIS captures a variety of innovation activities other than simply R&D expenditures, including the acquisition of patents and licenses, product design, personnel training, trial production, market analysis, and innovative output that is not reflected in patent applications, including the introduction of innovative production processes and organizational changes.

The survey asks the firm to report if it has introduced at least one innovation in the period from 1998 to 2000[1]. If the answer to this question was no, it asked if the firm had tried to innovate. To the firm that either introduced or attempted to introduce an innovation, a number of questions associated with the innovation process followed. Of the 1875 firms that returned valid questionnaires, we used the 821 that had been engaged in innovative activities (successful or unsuccessful).[2] This restriction is necessary because only firms engaged in innovation activities were required to answer questions regarding their cooperative behaviour and other questions related to innovation activities. Out of the subset of innovative firms, only 27.6 percent (237 firms) cooperated, which suggests that cooperative arrangements are far from the norm amongst Portuguese innovative firms.

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[1] This query was complemented by an additional question, which asked firms to describe the innovations in order to control for misinterpretations of the innovation definition.

[2] Limiting the sample to firms engaged in innovation activities may raise some issues of sample selection if we consider that cooperating firms base their innovation activities only on the links with other institutions. Since the majority of cooperative firms in our database also are engaged in other innovation strategies (in particular R&D), the hypothesis of sample selection can be excluded (Cassiman and Veugelers, 2002).

The information on the importance of cooperation innovation activities was collected in the Portuguese version of the CIS III questionnaire. The question, specific to the Portuguese version, was the following: "Please indicate the partner's level of importance for the development of innovation activities (low; medium; high): other enterprises within your enterprise group; suppliers of equipment, materials, services, or software; clients or customers; competitors or other enterprises in your industry; consultants; commercial labs, or private R&D institutes; universities or other higher education institutions; government or public research institutes." In our analysis, we used three different categories: firms that did not consider any cooperation partner important to innovation activities, firms that had at least one type of cooperation partner that was rated of low or medium importance, and firms that had at least one type of cooperation partner that was highly important to innovation activities.

Table 1 presents the descriptive statistics (mean and standard deviation) of the CIS III database.[3] The descriptive statistics show that there are differences between firms that value cooperation on innovation activities differently. On average, cooperative firms that attribute more importance to cooperation partners have more employees with university-level education and attribute more importance to the knowledge spillover management. In addition, being part of a group and being engaged in R&D activities are characteristics associated with the high level of importance attributed to cooperation. Surprisingly, the average innovation intensity (total expenditure on innovation activities as a percentage of total turnover) and the exports share do not follow the same trend as the other variables. This finding may be explained by the fact that firms that invest more in innovation may not feel the necessity to search for resources outside their boundaries. The analysis in the following sections will highlight this issue.

[3] See Table A-1 for a complete description of the variables.

(Insert Table 1)

The correlation matrix is presented in Table 2. Correlations are generally low to moderate given an indication that with this set of variables there is a low risk of facing collinearity issues or redundancies. Namely, the variables innovation intensity and R&D engagement could be considered as measuring the same phenomenon and thus redundant as regressors, but the low correlation between them confirms that innovation and R&D are two independent concepts that deserve to be analysed separately.

(Insert Table 2)

3.2. An Ordered Probit Model for the Importance of Cooperation Partners

The Portuguese CIS III database provides information on the innovative performance of manufacturing and service firms and specific information on innovation cooperation activities in the period between 1998 and 2000.[4] The survey asked whether the firm cooperated formally in any innovation activity with other enterprises or institutions and, complementing this question, the type, location and level of importance of such cooperation activities.[5]

[4] We are not able to explore a longitudinal version of this model, given that the CIS survey is not designed as a panel of firms. The studies using the same data for other countries face the same restriction (e.g. Cassiman and Veugelers, 2002). Furthermore, the decision to cooperate belongs to an intermediate class of management decisions contributing to a final objective – the firm performance. As such, there is a potential endogeneity problem with some of the right-hand side variables (more stringent than when dealing with the decisions of launching an innovative product or choosing the level of production). We discuss these issues when estimating the model in the next section.

[5] However, informal cooperative activities, such as sporadic exchanges of knowledge and social relationships, are not captured in this survey.

A model was built to differentiate firms based on the success of innovation cooperative activities. We analyse the variable that measures the level of importance the firm attributed to innovation cooperation activities, operationalized as a categorical and ordered variable with three classes: no partner was important for the development of innovation activities (NI; “not important”); at least one partner had low or medium importance in the innovation activities (LMI; “medium importance”); and at least one partner was highly important for the development of innovations (HI; “highly important”).[6]

The level of importance attributed to cooperation allows us to make a partition of the space defined by the benefits of cooperating. We are not measuring the firm decision to cooperate or not, but instead the benefits of cooperation. In this respect, the variable is a measure of the firm performance concerning the innovation cooperation activities. That is, we observe the outcome variable y, which takes the value zero for those firms that consider cooperation as not important for innovation and the values one and two for medium and high importance, respectively. This ordinal specification employs a latent variable y_i^* to an observable dependent variable y_i (importance of cooperation) according to the rule

$$y_i = \begin{cases} 0 \rightarrow NI & \text{if} \quad y_i^* \leq \tau_1 \\ 1 \rightarrow LMI & \text{if} \quad \tau_1 < y_i^* \leq \tau_2 \\ 2 \rightarrow HI & \text{if} \quad y_i^* > \tau_2 \end{cases} \tag{1}$$

where the unknown thresholds τ_1 and τ_2 are estimated and $\tau_1 < \tau_2$. Therefore, when the latent y_i^* crosses a threshold, the observed category changes accordingly. The latent variable y_i^* has the following specification,

[6] As referred above, this information was only collected in the Portuguese version of the CIS III questionnaire.

$$y_i^* = x_i\beta + \varepsilon_i\,, \qquad (2)$$

where x_i is a vector of individual values of the independent variables, β is a vector of structural coefficients, and ε_i is a stochastic disturbance. We assume that the latent variable is the unobservable result of the firm's maximizing behaviour pertaining to the importance of cooperation. The vector of regressors x_i comprises the determinants of the firm behaviour. From the review of the literature, the importance of innovation cooperation partners can be considered to be affected by firm size, engagement in R&D activities, absorptive capacity, spillovers and appropriability, industry and associated technological level, and innovation intensity.

The response probabilities for each category are

$$\Pr(y_i = 0 \mid x_i) = F(\tau_1 - x_i\beta)$$

$$\Pr(y_i = 1 \mid x_i) = F(\tau_2 - x_i\beta) - F(\tau_1 - x_i\beta)$$

$$\Pr(y_i = 2 \mid x_i) = 1 - F(\tau_2 - x_i\beta)$$

where F is the cdf for ε_i. Assuming ε_i distributed normally with mean zero and $\mathrm{Var}(\varepsilon_i)$ = 1, the above specification leads to an ordered probit model and we are able to estimate the effects of x_i on the importance of cooperation innovation activities.

3.3. Independent variables

The independent variables included in the model were chosen considering the firm characteristics and the different variables used in the reviewed literature.[7] The objective

[7] Note once again that the previous studies focused on the decision to cooperate, not on the importance attributed to cooperation. Thus we are not analysing the firm decision but rather a measure of the outcome of that decision.

of the model is to reveal which are the firm characteristics that determine the importance of cooperation innovation activities.

As argued by Cohen and Levinthal (1989; 1990), Cassiman and Veugelers (2002), Piga and Vivarelli (2004) and Lambertini et al. (2004), it is expected that firms with high levels of absorptive capacity are better prepared to be part of an innovation project with other partners. In other words, firms with a higher internal technological capacity might be better at absorbing incoming spillovers, and more effective at protecting appropriability through secrecy, complexity or lead time (Cassiman and Veugelers, 2002). Stressing the role of absorptive capacity in the decision to cooperate, Frenz et al. (2004) found that the payback that firms can take from cooperation with universities depends of its absorptive capacity (skills of the personnel and the degree of internal R&D). Two of the independent variables are measures of the firms' absorptive capacity: level of education of the working force (logarithm of the number of employees with university-level education); and the engagement in internal or external R&D activities in the period 1998-2000 (dummy variable).

Following Abramovsky et al. (2005), a firm-level measure of export attitude (share of exports in turnover) was also included in order to capture the intensity of competition that a firm faces. This variable can also be considered a proxy for the firm competitiveness since more export-intensive firms typically face a more competitive environment (Cassiman and Veugelers, 2002), and firms that sell large parts of their production abroad are also more likely to be engaged in R&D collaboration (Dachs et al., 2004).

Being part of a group can also influence the firm propensity to cooperate and, in particular, to be engaged in innovation and R&D cooperation activities (Dachs et al., 2004). A dummy variable was included to capture this effect.

Firm size is considered in the model as a likely influence on cooperation in innovation activities (log of the number of employees in 1998 with university-level education and log of the number of employees in 1998 without university-level education). The relationship between these two aspects is not clear, since, on one hand, large firms are expected to have a higher absorptive capacity and can devote the necessary resources to partner search (Cohen and Levinthal, 1990), while on the other, they are also more likely to have the necessary technical and financial capabilities to carry out innovation processes by themselves (Cassiman and Veugelers, 2002).

We also include a variable measuring the innovation intensity of a firm defined as the innovation expenditure share of sales. Innovation expenditure is taken directly from a question on different types of innovation activities, including in-house R&D, external R&D, acquisition of machinery and acquisition of knowledge for innovation, training for innovations and preparation of the market for the introduction of innovations. We include the innovation intensity also as a squared term to allow for a non-linear relationship between innovation expenditure and the likelihood of collaborating with domestic or foreign partners. Firms spending more funds on innovation activities relative to their turnover may be less likely to collaborate on innovation activities in general, because they are at the knowledge frontier and cannot find adequate partners or because they are able to satisfy their needs with their own in-house innovation activities.

Following Cassiman and Veugelers (2002), we include two measures of knowledge spillovers: the importance of incoming knowledge spillovers; and the prevention of outgoing spillovers. Incoming knowledge spillovers are measured using the data from a question on information sources a firm uses for its innovation activities where the importance a firm assigns to publicly available information from professional conferences, meetings, journals, exhibitions and trade fairs is asked for. Firms assigning a high importance to external knowledge have an incentive to cooperate in order to internalize spillovers, and so this variable is assumed to have a positive effect on innovation cooperation in general. Nevertheless, it is also conceivable that it has a negative impact on the likelihood of attributing high importance to innovation cooperation. If the firm assigns major importance to freely available knowledge it might be less inclined to cooperate since it can obtain external knowledge without cooperating on R&D and innovation. The prevention of outgoing spillovers is measured by the importance firms attribute to patents and secrecy, giving an indication of firms' strategies with respect to the protection of valuable firm-specific competitive advantages. If a firm assigns a high value to protection methods it might be less likely to cooperate and unwilling to expose its valuable assets to third parties. [8]

Finally, following the findings of Bayona et al. (2001), Miotti and Sachwald (2003), and the argument by Dachs et al. (2004), the technological level of the firms was also included (dummy variables for each technological level), taking into consideration the Standard Industry Aggregation by Technological Level of the OECD.[9]

4. Results and Discussion

In this section we present the results of the estimation. We first analyse the coefficients of the ordered probit model for the entire sample. As there may be considerable differences between manufacturing and services, we also run the model separately, in spite of the possible problems with the number of firms included in the sample. The section ends with a further inspection of the effects obtained for the full sample by

[8] We also intended to introduce variables measuring cost obstacles to innovation, lack of technological information, and basicness of R&D, but due to problems with missing values it was not possible.
[9] See Table A-1 for details on this classification.

calculating the predicted probabilities for several firm-specific cases and by estimating the change in the probabilities for a subset of the independent variables. The structure of the ordered probit model imposes this procedure, as will become apparent in the analysis below.

The results obtained when running the ordered probit model for the importance of the cooperation partner are presented in Table 3. As mentioned above, the dependent variable is defined as three categories: “cooperation partners had no importance for innovation”; “at least one partner had low or medium importance in the innovation activities”; and “partners were highly important for innovation”.

We have chosen two specifications for the model using the explanatory variables discussed in the previous section. The first specification includes variables that proxy the main characteristics of the firm: number of employees with and without university-level education, exports share and being part of a group. The second specification adds variables linked to the innovation process itself: engagement in R&D, innovation intensity (second order polynomial), incoming knowledge spillovers, and outgoing knowledge spillovers. We also control separately for industry fixed effects and for technological level.[10]

The four estimated models presented in Table 3 show that the ordered probit is a suitable model for analysing the importance of cooperation partners. The significance levels of the individual independent variables and of the overall equation show acceptable levels. Moreover, the results for the cut off levels confirm the ordered structure of our dependent variable. [11]

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[10] The industry fixed effects are defined at the two digit level; the technological level is introduced as variables for technological intensity. The definition of the technological level based on the industry codes implies that the two controls are almost collinear, which precludes the simultaneous use in the estimation.
[11] It could be argued that we face a possible endogeneity problem if the decisions about cooperation, R&D investments and spillovers management are taken simultaneously, as addressed by Cassiman and

(Insert Table 3)

The variables for the number of employees are positively related to the importance of cooperating in innovation activities, but the number of employees with university-level education has a higher impact. When adding the variables linked to the innovation strategy of the firm, these variables lose significance, showing that the influence of size and of workforce qualification on the importance of cooperation activities is closely associated with the absorptive capacity and innovation strategy of the firm. Nevertheless, it can be concluded that larger firms are more associated with cooperation importance than are small firms, since they have more resources to invest in this kind of activity. Resources to invest in cooperation and/or higher spillover control seem, in this case, to outweigh the influence of resources to perform innovation in-house.

The exports share variable has a similar behaviour, as the associated coefficient is positive. Firms exposed to more-competitive markets are more likely to take advantage of knowledge outside their boundaries. In the last specification the variable is not significant, indicating that it is not the main determinant of the importance of cooperation partners. The concentration of exports in certain industries and the fact that the variables linked to the innovation process are more important in determining the behaviour of the dependent variable, explains this result. As expected, being part of a

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Veugelers (2002). However, in our case, it is not the cooperation decision that is being analysed but the outcome of that decision as measured by the importance of cooperation partners to the innovation activities, which mitigates the possible endogeneity problem. However, we tested the exogeneity using as instruments the average of the independent variables by industries. These tests led to not rejecting exogeneity.

group is a condition that favours successful cooperation activities, since the existence of an in-group network of firms can stimulate the cooperation in innovation activities.[12]

The coefficients on R&D engagement, as expected, are positive and highly significant. Firms that create or manage new knowledge are better prepared to absorb incoming spillovers, and more effective at protecting appropriability, and thus attribute more importance to cooperation partners. Innovation intensity is positive and highly significant and, since the quadratic term is negative, its positive effect decreases for higher values of the variable. This result shows the existence of a relationship between innovation intensity and the importance attributed to cooperation partners, clarifying the inconclusive empirical evidence from the descriptive statistics (Table 1). The variables R&D engagement and innovation intensity measure two different aspects of the innovation process, the first indicates if the firm is involved in the production of knowledge and the second is much broader, since it measures the relative weight of the expenditures on innovation-related activities (human resources, R&D, and marketing activities, amongst others). The confirmation that these variables measure different aspects of the innovation process is presented in the correlation matrix (Table 2): the correlation between the variables is negative and close to 10%.

The variables related to management of spillovers have a positive impact on the importance of cooperation. Nevertheless, the weight attributed to the protection of own knowledge is more important than the search of knowledge from public available sources. This result concerning outgoing spillovers contradicts common-intuition prediction that a firm assigning a high value to protection methods might be less open to

[12] The descriptive statistics from the part of a group variable (only 23% of cooperative firms cooperate on innovation activities with own-group firms and of these, only 14% indicated that they had cooperated exclusively with this kind of partner) show that the positive effect of belonging to a formal network on the importance of cooperation partners is not solely explained by the advantage of finding partners within the group and may also be explained by the increased network capacities that a firm has to develop to be part of a group.

cooperate and unwilling to expose its valuable assets to third parties. Our explanation for this apparent surprise is that firms that value protection methods are more prepared to be involved in cooperation activities and can give more value to cooperation partners. Concerning incoming spillovers, firms assigning a great importance to external knowledge have an incentive to cooperate in order to internalize spillovers.

Table 4 and Table 5 present the results obtained when running the model for manufacturing and service firms separately. Analysing these tables, significant differences can be identified. The coefficients of the variables employees with university-level education and engagement in R&D activities show that absorptive capacity is a more significant feature to manufacturing firms than to service firms when attributing importance to cooperation partners. This result can be explained by the fact that service firms are more homogenous concerning absorptive capacity.

(Insert Table 4 and Table 5)

The exports variable also presents different results for the two groups of firms. Higher exports intensity is a significant correlate of the importance of cooperation partners to manufacturing firms but not to service firms. A possible explanation for this finding could be that manufacturing firms are more exposed to foreign markets and Portuguese service firms, by nature, are more focussed on the internal market.

With regard to being part of a group, innovation intensity, and outgoing knowledge spillovers, manufacturing and service firms have similar profiles with respect to the importance attributed to cooperation partners. The variable incoming knowledge spillovers is positive and significant in the manufacturing specification but not for the services specification.

The analysis of the ordered probit model requires further development, namely to ascertain the magnitudes of the partial effects. The sign of the estimated coefficients does not unambiguously determine the direction of the effect for the intermediary outcome "at least one partner had low or medium importance in the innovation activities". The effect of each regressor on the importance level attributed by firms to cooperation partners is totally exposed by the coefficients of the ordinal model and the marginal effects are difficult to interpret and may be misleading concerning the middle categories. Therefore, and complementing the analysis based on the coefficients of the ordered probit model, we calculated predicted probabilities (and respective confidence intervals) for some specific firm types using the last specification of Table 3. Table 6 reports these results. The first row presents the predicted probabilities for a hypothetical firm with average characteristics, in the context of the Portuguese CIS III database.[13] This result will be the reference scenario. The firm with average characteristics has a probability of not attributing importance to cooperation in innovation activities of 0.77 and the values of the probability of attributing low or medium and high importance are less than 0.12 in both cases. This result indicates that the average firm does not attribute importance to this kind of cooperation.

(Insert Table 6)

[13] A firm that is not part of a group, engaged in R&D activities, and with average dimension and exports and innovation intensity.

The difference between firms that are part of a group and those that are not is considerable. The probability of “not important” changes from 0.68 to 0.81 and the other two categories change in the opposite direction, “medium important” from 0.13 to 0.09 and “highly important” from 0.19 to 0.10. The variable that proxies absorptive capacity (engagement in R&D activities) shows a similar evolution. A firm engaged in R&D activities presents the following predicted probabilities: “not important” - 0.72; “medium importance” – 0.12; and “highly important” - 0.16. These values are very dissimilar from those of the average firm without R&D activities, confirming that absorptive capacity plays an important role in the success of cooperation activities. The effect of these variables on the predicted probabilities of the different categories of the dependent variable influences more deeply the category “high importance”, stressing the importance of being part of a group and of absorptive capacity to cooperation in innovation activities.

After using predicted probabilities to investigate the effect of being part of a group and engagement in R&D variables on the success of cooperation in innovation activities, we calculated predicted probabilities for firms that combine these two characteristics and for firms without these features. The results are completely dissimilar; the probability of “not important” decreases from 0.88 to 0.63 and the other two categories change in the opposite trend, “medium importance” from 0.06 to 0.14 and “highly important” from 0.06 to 0.23. On one hand, if a firm is not part of a group and is not engaged in R&D activities, it is almost certain that it is not engaged in successful cooperation activities. On the other hand, if a firm has these characteristics it is more probable that it is part of cooperation agreements where at least one partner was highly important for the development of innovations.

To analyse the effect of firm size, employee qualification, innovation intensity, incoming spillovers and outgoing spillovers on the probability of being engaged in successful cooperation activities we construct five graphs (Figure 1) presenting the evolution of the probability of each category of the dependent variable with the log of the firm number of employees without university-level education, the log of the firm number of employees with university-level education, the total expenditure on innovation activities as a percentage of total turnover, the importance attributed to freely available knowledge, and the importance of strategic and formal protection methods. The vertical line in each graph represents the average of each variable.

(Insert Figure 1)

The graphs show a clear positive correlation between the five variables and the probabilities of “medium importance” and “highly important” and a clear negative correlation between the same variables and “not important”. As expected, the number of employees with university-level education has a more considerable impact than the number of employees without university-level education, since it is a measure not only of the size of the firm but also of absorptive capacity. The graphs that describe the relationship between the variables that proxy spillovers management and the predicted probabilities have a similar structure but, nonetheless, they show that valuing intellectual protection methods has a greater effect on the importance attributed to innovation cooperation partners than does the importance attributed to free available knowledge.

The graph that shows a more profound evolution is that for innovation intensity. A clear inversion of the weight of the different categories is visible, especially between the two extreme categories. This result shows that the relative level of innovation investment influences the evaluation of the importance of cooperation partners; firms investing more intensely in innovation are also those that have more perception of the advantage of cooperation on innovating activities.

In conclusion, these results confirm the perception observed in the coefficient table that the success of innovation is influenced by the size of the firms, the education of the employees, innovation intensity, incoming spillovers and outgoing spillovers.

5. Conclusion

Following the literature on cooperation on innovation activities that seeks to identify the characteristics that differentiate cooperative firms from non-cooperative firms, and the studies that focus on the effect that cooperation produces on innovation activities, the current study proposes a different approach. Taking advantage of the fact that the Portuguese CIS data allow distinguishing firms according to the valuation of the cooperation activities for the success of innovation, this paper analyses the importance of cooperation partners, focusing on the characteristics that distinguish firms that value cooperation differently.

Our analysis shows that firms with higher levels of absorptive capacity, exports and innovation intensity, that are part of a group, and that rate spillovers management as important, give more value to cooperation. These findings were obtained using an ordered probit model. We also constructed several firm types in order to analyse the effect of explanatory variables on the predicted probabilities of each importance category.

It can also be concluded that the level of importance of cooperation is positively correlated with firm size, as supported by several authors. This result must be analysed in the light of public policies. Small firms are those with fewer resources and, thus, cooperation may assume a more important role for these firms. Nevertheless, the results show that cooperation is more associated with large firms. In this context, and in order to maximize the role of cooperation in innovation activities, public policies may have to be biased toward the support of small and medium firms. Furthermore, our results also show that firms already spending on innovation and engaged in R&D activities are those benefiting more from cooperation partners. If a public programme is designed to promote cooperation innovations activities, it must consider whether firms are already engaged in innovation activities in order to maximize the benefit of the support.

We should stress that a panel-data study would be an important complement to the findings and conclusions presented in this paper. However, since the CIS survey methodology is not based on the inquiry of a panel of firms, it is impossible achieve. To partially mitigate this drawback, we hope to test our model with the larger CIS IV sample in order to check the robustness of our results. The research on innovation related issues is only possible with this type of survey. The theory of the firm and, in particular, the analysis of firm decisions concerning innovation and cooperation and the outcome of those decisions needs to be confronted with applied microeconometric studies using firm data.

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Table 1– Cooperation activity amongst firms engaged in innovation activities (descriptive statistics)

Variable	All innovative firms		Firms where cooperation was unimportant to innovation		Firms where cooperation had low or medium importance to innovation		Firms where cooperation was highly important to innovation	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Employees with university-level education (log)	1.706	1.544	1.404	1.384	2.458	1.664	2.518	1.660
Employees without university-level education (log)	4.240	1.385	4.017	1.250	4.950	1.380	4.758	1.625
Exports share	0.224	0.320	0.204	0.309	0.303	0.339	0.267	0.344
Part of a group dummy	0.414	0.493	0.334	0.472	0.571	0.498	0.649	0.479
Engagement R&D dummy	0.636	0.481	0.568	0.496	0.785	0.414	0.828	0.379
Innovation intensity	0.580	1.023	0.598	1.103	0.510	0.835	0.544	0.761
Innovation intensity (square)	1.380	5.456	1.573	6.184	0.949	3.639	0.871	2.400
Incoming knowledge spillovers	0.411	0.305	0.388	0.300	0.441	0.308	0.486	0.313
Outgoing knowledge spillovers	0.161	0.212	0.134	0.194	0.220	0.252	0.240	0.236
Low-tech firm dummy	0.333	0.472	0.354	0.479	0.354	0.481	0.238	0.428
Medium-tech firm dummy	0.288	0.453	0.281	0.450	0.304	0.463	0.311	0.465
High-tech firm dummy	0.050	0.219	0.043	0.203	0.025	0.158	0.093	0.291
Non-knowledge intensive service firm dummy	0.131	0.338	0.145	0.352	0.114	0.320	0.086	0.281
Knowledge intensive service firm dummy	0.179	0.384	0.161	0.368	0.152	0.361	0.265	0.443
Number of Observations	858		621		81		156	

Table 2– Cooperation activity amongst firms engaged in innovation activities (correlation matrix)

	Cooperation in innovation activities (level of importance)	Employees with university-level education (log)	Employees without university-level education (log)	Exports share	Part of a group dummy	Engagement R&D dummy	Innovation intensity	Innovation intensity (square)	Incoming knowledge spillovers	Outgoing knowledge spillovers	Low-Tech firm dummy	Medium-Tech firm dummy	High-Tech firm dummy	Non-Knowledge intensive service firm dummy	Knowledge intensive service firm dummy
Cooperation in innovation activities (level of importance)	1.000														
Employees with university level-education	0.306	1.000													
Employees without university-level education	0.222	0.570	1.000												
Exports share	0.095	0.068	0.338	1.000											
Part of a group dummy	0.262	0.530	0.334	0.028	1.000										
Engagement R&D dummy	0.217	0.250	0.188	0.084	0.161	1.000									
Innovation intensity	-0.013	-0.121	-0.156	-0.043	-0.079	-0.101	1.000								
Innovation intensity (square)	-0.047	-0.112	-0.112	-0.024	-0.055	-0.091	0.910	1.000							
Incoming knowledge spillovers	0.125	0.122	0.151	0.113	-0.032	0.139	0.071	0.037	1.000						
Outgoing knowledge spillovers	0.202	0.333	0.243	0.100	0.181	0.218	-0.047	-0.069	0.137	1.000					
Low-Tech firm dummy	-0.076	-0.189	0.141	0.163	-0.121	-0.086	0.040	0.008	0.084	0.002	1.000				
Médium-Tech firm dummy	0.031	-0.050	0.070	0.128	-0.050	0.053	-0.043	-0.046	0.085	0.008	-0.448	1.000			
High-Tech firm dummy	0.065	0.110	0.040	0.074	0.094	0.086	0.011	-0.013	0.071	0.099	-0.167	-0.151	1.000		
Non-Knowledge intensive service firm dummy	-0.068	-0.097	-0.098	-0.190	-0.082	-0.112	0.028	0.116	-0.102	-0.137	-0.273	-0.246	-0.092	1.000	
Knowledge intensive service firm dummy	0.084	0.329	-0.185	-0.250	0.261	0.076	-0.013	-0.038	-0.154	0.055	-0.327	-0.295	-0.110	-0.180	1.000

Table 3 - Cooperation Success (1998-2000): ordered probit model for the importance of cooperation partners

Ordered Probit Estimation	1	2	3	4
Coefficients	Cooperation in Innovation Activities (level of importance)			
Employees with university-level education (log)	0.135***	0.140***	0.117**	0.119**
	(0.044)	(0.051)	(0.049)	(0.055)
Employees without university-level education (log)	0.089*	0.083	0.051	0.042
	(0.048)	(0.058)	(0.051)	(0.063)
Exports share	0.270*	0.321*	0.335**	0.331*
	(0.143)	(0.176)	(0.154)	(0.183)
Part of a group dummy	0.376***	0.366***	0.408***	0.425***
	(0.111)	(0.113)	(0.115)	(0.124)
Engagement R&D dummy			0.482***	0.410***
			(0.122)	(0.124)
Innovation intensity			0.454***	0.547***
			(0.143)	(0.162)
Innovation intensity (square)			-0.092**	-0.111***
			(0.037)	(0.040)
Incoming knowledge spillovers			0.273*	0.354**
			(0.157)	(0.181)
Outgoing knowledge spillovers			0.413*	0.559**
			(0.228)	(0.251)
Médium-Tech firm dummy (1)	0.175		0.159	
	(0.121)		(0.129)	
High-Tech firm dummy (1)	0.315		0.086	
	(0.287)		(0.303)	
Non-Knowledge intensive service firm dummy (2)	0.020		0.238	
	(0.170)		(0.181)	
Knowledge intensive service firm dummy (2)	0.221		0.176	
	(0.187)		(0.202)	
Industry Fixed effects	No	Yes	No	Yes
Observations	821	821	768	768
Cut Point [1]	1.588***	1.133***	2.084***	1.635***
	(0.204)	(0.284)	(0.259)	(0.304)
Cut Point [2]	1.934***	1.501***	2.462***	2.038***
	(0.208)	(0.288)	(0.263)	(0.310)
Wald chi2	102.70	357.90	143.59	348.16
Pseudo R2	0.081	0.122	0.110	0.153

Robust standard errors are in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%
All dummy variables: dF/dx is for discrete change of dummy variable from 0 to 1
(1) Only for manufacturing firms and following the OECD's Standard Industry Agreggation by Technology Level
(2) Only for service firms and following the OECD's Standard Industry Agreggation by Technology Level

Table 4 - Cooperation Success (1998-2000): ordered probit model for the importance of cooperation partners (manufacturing firms)

Ordered Probit Estimation	1	2	3	4
	Manufacturing			
Coefficients	Cooperation in Innovation Activities (level of importance)			
Employees with university-level education (log)	0.213*** (0.063)	0.192*** (0.065)	0.202*** (0.069)	0.198*** (0.070)
Employees without university-level education (log)	0.039 (0.067)	0.080 (0.079)	0.010 (0.077)	0.047 (0.089)
Exports share	0.364** (0.159)	0.350* (0.194)	0.426** (0.172)	0.362* (0.206)
Part of a group dummy	0.376*** (0.140)	0.333** (0.137)	0.367*** (0.141)	0.340** (0.142)
Engagement R&D dummy			0.571*** (0.152)	0.462*** (0.157)
Innovation intensity			0.495*** (0.184)	0.618*** (0.212)
Innovation intensity (square)			-0.121** (0.051)	-0.144** (0.058)
Incoming knowledge spillovers			0.413** (0.189)	0.500** (0.217)
Outgoing knowledge spillovers			0.301 (0.274)	0.488 (0.296)
Médium-Tech firm dummy	0.154 (0.125)		0.139 (0.135)	
High-Tech firm dummy	0.242 (0.300)		0.010 (0.329)	
Industry Fixed effects	No	Yes	No	Yes
Observations	566	566	532	532
Cut Point [1]	1.495*** (0.267)	0.255 (0.873)	2.144*** (0.341)	1.477*** (0.349)
Cut Point [2]	1.882*** (0.270)	0.660 (0.873)	2.564*** (0.340)	1.922*** (0.360)
Wald chi2	79.37	243.89	102.13	236.66
Pseudo R2	0.097	0.130	0.133	0.175

Robust standard errors are in parentheses

* significant at 10%; ** significant at 5%; *** significant at 1%

All dummy variables: dF/dx is for discrete change of dummy variable from 0 to 1

Table 5 - Cooperation Success (1998-2000): ordered probit model for the importance of cooperation partners (service firms)

Ordered Probit Estimation	1	2	3	4
	Services			
Coefficients	Cooperation in Innovation Activities (level of importance)			
Employees with university-level education (log)	0.060	0.077	0.054	0.039
	(0.058)	(0.077)	(0.070)	(0.083)
Employees without university-level education (log)	0.105	0.067	0.042	0.009
	(0.077)	(0.086)	(0.080)	(0.091)
Exports share	-0.689	-0.759	-0.780	-1.025
	(0.722)	(0.771)	(0.758)	(0.698)
Part of a group dummy	0.303	0.377*	0.389*	0.510**
	(0.198)	(0.210)	(0.198)	(0.222)
Engagement R&D dummy			0.358*	0.388*
			(0.198)	(0.204)
Innovation intensity			0.528**	0.641**
			(0.209)	(0.249)
Innovation intensity (square)			-0.092**	-0.113**
			(0.042)	(0.050)
Incoming knowledge spillovers			0.071	0.125
			(0.317)	(0.337)
Outgoing knowledge spillovers			0.553	0.698
			(0.427)	(0.480)
Knowledge intensive service firm dummy	0.294		0.009	
	(0.185)		(0.232)	
Industry Fixed effects	No	Yes	No	Yes
Observations	255	255	236	236
Cut Point [1]	1.439***	0.915**	1.565***	1.301***
	(0.296)	(0.331)	(0.357)	(0.360)
Cut Point [2]	1.711***	1.211***	1.870***	1.630***
	(0.304)	(0.335)	(0.368)	(0.365)
Wald chi2	30.02	47.87	57.01	49.15
Pseudo R2	0.062	0.116	0.089	0.136

Robust standard errors are in parentheses

* significant at 10%; ** significant at 5%; *** significant at 1%

All dummy variables: dF/dx is for discrete change of dummy variable from 0 to 1

Table 6 – Predicted probabilities for several firms with a particular set of characteristics

Firms' Characteristics (all innovative firms)	Probability for outcome category					
	No partner was important for the development of innovation activities		At least one partner had low or medium importance for the development of innovations		At least one partner was highly important for the development of innovations	
Average firm	0.77	[0.72, 0.82]	0.10	[0.08, 0.12]	0.12	[0.09, 0.16]
Firms part of a group	0.68	[0.62, 0.74]	0.13	[0.11, 0.15]	0.19	[0.15, 0.24]
Firms not part of a group	0.81	[0.77, 0.85]	0.09	[0.07, 0.10}	0.10	[0.07, 0.13]
Firms engaged in R&D activities	0.72	[0.67, 0.76]	0.12	[0.10, 0.14]	0.16	[0.13, 0.20]
Firms not engaged in R&D activities	0.84	[0.79, 0.89]	0.08	[0.07, 0.09]	0.08	[0.05, 0.12]
Firms engaged in R&D activities and part of a group	0.63	[0.56, 0.69]	0.14	[0.11, 0.17]	0.23	[0.18, 0.29]
Firms not engaged in R&D activities and not part of a group	0.88	[0.83, 0.92]	0.06	[0.03, 0.09]	0.06	[0.03, 0.09]

Figure 1 – Predicted probabilities: employees without university-level education (log), employees with university level-education (log) and innovation intensity

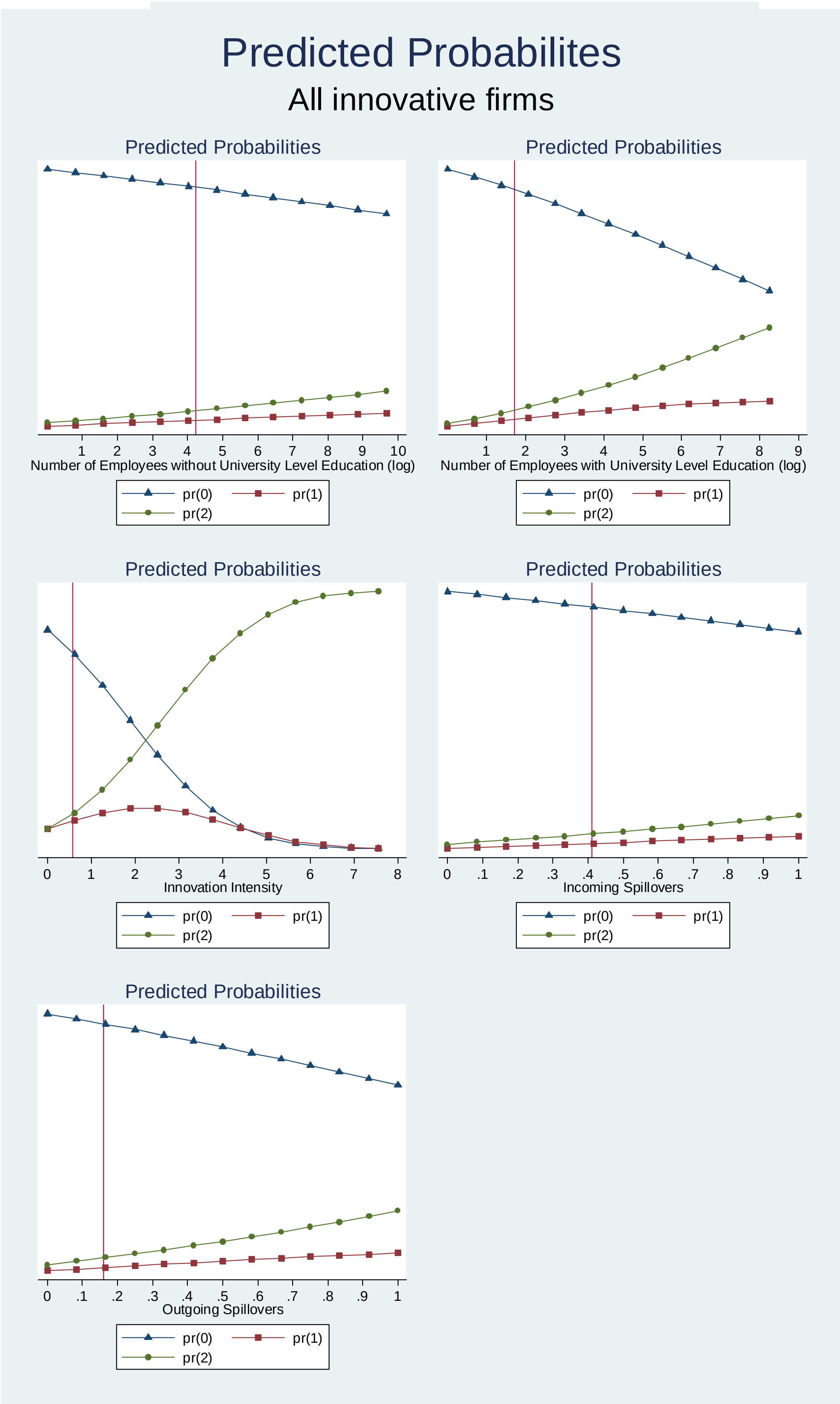

Table A-1 – Variables description

Variable	Type	Construction
Cooperation in Innovation Activities	Dummy	One, if the firm cooperated with domestic partners between 1998 and 2000.
Cooperation in Innovation Activities (level of importance)	Ordered	Categorical and ordered variable with three classes: no partner was important for the development of innovation activities (NI; “not important”); at least one partner had low or medium importance in the innovation activities (LMI; “medium importance”); and at least one partner was highly important for the development of innovations (HI; “highly important”)
Employees with university-level education	Log	Logarithm of the number of employees with university-level education
Employees without university-level education	Log	Logarithm of the number of employees without university-level education
Exports share	Share	Total exports as a percentage of total turnover
Part of a group dummy	Dummy	One, if the firm belongs to a domestic group of firms.
Engagement R&D dummy	Dummy	One, if the firm had any R&D activities between 1998 and 2000.
Innovation intensity	Share	Total expenditure on innovation activities as a percentage of total turnover
Innovation intensity (square)	Share	Square of innovation intensity
Incoming knowledge spillovers	Categorical	Sum of importance (number between 0 (not used) and 3 (high)) of professional conferences, meetings and journals and of exhibitions and trade fairs as sources of innovation. Rescaled between 0 (no spillovers) and 1 (maximum spillovers).
Outgoing knowledge spillovers	Categorical	Sum of the number of strategic and formal protection methods for innovations (secrecy, complexity of design, lead-time advantage, patents, copyrights, trademarks, registered designs). Rescaled between 0 and 1
Medium-Tech firm dummy	Dummy	One, if firm is from NACE 24(excl.244), 25-29, 31, 34, 35(excl.353)
High-Tech firm dummy	Dummy	One, if firm is from NACE 244, 30, 32, 33, 353
Non-Knowledge intensive service firm dummy	Dummy	One, if firm is from NACE 51, 60, 63
Knowledge intensive service firm dummy	Dummy	One, if firm is from NACE 61, 62, 64, 65, 66, 67, 72, 73, 74.2, 74.3