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Measuring the effects of University-Firm cooperation on the firm's innovative performance: evidence from Spain

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Measuring the effects of University-Firm cooperation on the firm's innovative performance: evidence from Spain

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Abstract

In this paper we empirically analyze the effects of cooperation in innovation with universities on the firm's innovative performance. With a database of 8535 innovative firms in Spain, we estimate the effect of different patterns of cooperation with universities on the firm's capacity to introduce innovations and on its resulting effects. The main conclusion to be drawn is that cooperation with universities by itself does not have any effect on the firm's innovative performance; to obtain positive effects on the firm's innovative performance is necessary the creation of innovation networks including other economic agents, specially public and private research centers. The estimation results show that firms belonging to a cooperation network including universities, experiment a higher rate of success in introducing innovations. These effects are especially higher in firms developing innovation in services and in support activities. Finally, the econometric results indicate that the simultaneous cooperation between private firms, public or private research centers and universities raise the production quality and increases the firm's market share.

Keywords: Cooperation with universities; innovative performance; Selection models

JEL classification: O31; O32; I23

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1. INTRODUCTION

In the past four decades, basically since the implementation of the Bayh-Dole act in the U.S., the analysis of the University-Industry (U-I here after) links have gained importance. At the macroeconomic level, several authors have pointed out the relevance of scientific research on the innovation spillovers (Jaffe, 1989; Adams, 1990; Rosenberg and Nelson, 1994; Mansfield, 1995; Griliches, 1998; Cohen et al., 2002; among others). On the other hand, from a firm level approach, cooperation in R&D has been widely studied in the literature, identifying the firm's characteristics that affect the interaction in R&D with other institutions (Hagedoorn and Schakenraad, 1990; Hagedoorn, 1993; Veugelers, 1997; Hagedoorn et al., 2000; Negassi, 2004; Belderbos et al., 2004a; Aschhoff and Schmidt, 2008; among other). Notwithstanding the widespread evidence on the importance of U-I cooperation, the analysis of the effects resulting from this type of cooperation still is scarce (Löf and Broström, 2008).

Innovative firms are constantly searching for new ways to internalize external knowledge into their production function. With this aim, firms have found that the cooperation in innovation activities is a valuable mechanism to access to new technological resources, which can contribute to faster development of innovation, improved market access, economies of scale and scope, and cost sharing and risk spreading (Ahuja, 2000; Cassiman and Veugelers, 2002; Hagedoorn, 2002; López, 2008; and Faria et al, 2010). In this context, universities have been recognized as a capable research partner for solving R&D problems and as advisers on technology strategies and by supporting the technology generation and/or the adoption of a new technology (Spyros and Woerter, 2009). Moreover, the cooperation in innovation with universities has been characterized by the timely appropriation of very-new technological opportunities (Mohonen and Hoareau, 2003) and by the increment on the innovation sales, as well as the increase in the propensity to apply for patents (Löf and Broström, 2008).

Several empirical studies have attempted to identify the factors determining the U-I cooperation in innovation activities, concluding that this type of cooperation is based on the complementarity on the innovation processes, and on the uncertainty level of the innovation results (Veugelers and Cassiman, 2005). On the other hand, and based on a firm level analysis, Adams et al. (2001), Mohonen and Hoareau (2003) and

Veugelers and Cassiman (2005) concluded that U-I cooperation depends on the firm's absorptive capacity, on its innovative capacity, on its proximity to fundamental research, and in some firm-specific characteristics, like size and industrial affiliation. Nevertheless, the analysis and identification of the effects of the U-I cooperation in innovation have been less studied.

Universities are invited to cooperate with industry in projects involving new science and unknown technological arena (Hall et al., 2001). Various studies have addressed the role of universities in the production of R&D spillovers (Adams, 1990), the effects of the geographical proximity to universities on firms' patenting behavior and in the introduction of very new products to the market (Jaffe, 1989; Acs et al., 1992; Kafmann and Tödtling, 2001; Belderbos et al., 2004). Nevertheless, the effects of the U-I cooperation in innovation have not been always studied adequately. According to Mohnen and Hoareau (2003) the outcomes of this type of cooperation are usually analyzed in the same context as cooperation with suppliers, competitors or costumers. Nonetheless, cooperation in innovation with universities tends to be predominant in the early stages of the innovation process, increasing the firms' abilities to perform more radical innovations, rather than the generation of incremental innovations.

The objective of this paper is to analyze the effects resulting from the cooperation in innovation activities with universities on the firm's performance. From the Technological Innovation Panel (PITEC for its acronym in Spanish) we were able to construct a dataset of 11,377 Spanish firms. This database collects information about the firm's capacity to innovate, the cooperative agreements with universities and other institutions, the firm's specific characteristics (size, economic sector, ownership structure, etc.) and the R&D strategy (R&D intensity, share of employees in R&D activities, percentage of R&D in applied and basic research, among others.).

In order to estimate the effects of the U-I cooperation in innovation on the firm's innovative performance we have run a set of regression models differentiating between innovation in products (goods and services) and innovation in processes (manufacturing methods, logistic systems and support activities). We also controlled for possible problems of simultaneity and self-selection bias. Moreover, we have tested the impact of U-I cooperation in innovation on the effects resulting from the firm's innovative activity, such as changes in the range of products, increase in the products quality and

flexibility, and increments in the production capacity. Finally, with the aim of identify the specific effect of the U-I cooperation we analyze the different patterns of cooperating with universities, including exclusive and simultaneous cooperation with universities and market partners, simultaneous cooperation with universities and other research institutions and simultaneous cooperation between universities, market partners and research institutions.

The rest of the paper is organized as follows. Section 2 briefly reviews the literature on cooperation in innovation with universities. Section 3, delineates the methodological approach and describes the data used. Section 4 presents the econometric model. Section 5 discusses the empirical results. Finally, in section 6, we summarize our findings with some concluding remarks.

2. UNIVERSITY-INDUSTRY COOPERATION IN INNOVATION

The literature that analyzes cooperation in innovation has been mainly focused on the causes, rather than on the effects. According to Robertson and Gatignon (1998) cooperative agreements are made when there is a benefit obtained from the externalization of technological sources. Generally, prior studies have demonstrated that cooperation in technological activities can be explained by reasons of cost reduction, risk sharing, access to financial capital, complementary assets, improved capacity for rapid learning, and knowledge transfer (Eisenhardt and Schoonhoven, 1996). Moreover, Baum and Oliver (1992) and Saxton (1997), have shown that cooperation may allow firms to combine loyalty programs, enhance legitimacy, establish trust, and improve reputation. On the other hand, cooperation in innovation positively depends on the level of uncertainty of technological processes in terms of results and time, ie, firms are more likely to cooperate with research centers and universities as the R&D outcomes become less tangible (Hagedoorn et al., 2000; Bayona et al., 2002; Tether, 2002; Miotti and Sachwald, 2003).

According to Hagedoorn et al. (2000) firms cooperate with a research institution (including universities) in order to reduce the cost of the R&D internalization; to broaden the effective scope of innovation activities; to promote organizational learning and enhance competitiveness; to increase the efficiency in the networks creation by the internalization of knowledge spillovers; to reduce the risk on the R&D results creating new investments options in high-opportunity and high-risk activities. In other words, the

U-I cooperation in innovation mainly depends on the complementarity between both institutions, in terms of cost reduction and accessibility to a broader scope of innovation activities; and secondly, on the reduction of the information asymmetries on the uncertainty in the innovation results.

The identification and the analysis of the determinants of the U-I cooperation in innovation has been deeply studied in the literature (see Hagedoorn et al., 2000; Kaufman and Tödtling, 2001; Mohenen and Hoareao, 2003; Laursen and Salter, 2004; Veugelers and Cassiman, 2005; Fontana et al., 2006; among others). Essentially, the vast majority of these studies conclude that U-I cooperation can be explain by four groups of firm's characteristics. First, the firm's propensity to cooperate with universities increases with its own absorptive capacity, measured as the share of R&D expenditures (Kleinkench and VanReijnen, 1992; Colombo and Gerrone, 1996; Röller et al., 1997; and Dutta and Weiss, 1997) and the number of employees in R&D activities (Schartinger et al., 2001). The second factor that explains U-I cooperation in innovation is the firm's proximity to basic research in this case, the firm's likelihood to cooperate in R&D activities with universities increases with the level of uncertainty of the expected results of the research project being conducted. This uncertainty level is closely related to the degree of basic research performed by the firm (Veugelers and Cassiman, 2005). Finally, the firm's basic characteristics such as size and industrial affiliation also explains the U-I cooperation in innovation.

Despite that the identification of the determinants of the U-I cooperation have been deeply studied, the analysis of the effects of this type of cooperation on the firm's innovative capacity remind unclear (Lööf and Broström, 2008). The literature that analyzes the effects of U-I cooperation in innovation on the firm's innovative performance has mainly focused on the firm's innovation outputs, rather than on the innovation process. However, according to Hagedoorn et al. (2000), the firm's main motivations to cooperate with universities are based on the possibility to access new knowledge and to increase their internal capacity of that. Moreover, Spyros and Woerter (2009), Laursen and Salter (2004) and Mohnen and Hoareau (2003) suggest that firms are more prone to cooperate in innovation with universities when they want to increase their technological capability and to facilitate the adoption of new technologies. Therefore, the effects resulting from the U-I cooperation should be analyzed on the firm's innovation process rather than on the innovation outputs.

Different authors have analyzed the effect of U-I cooperation in innovation, finding a positive impact on the sales growth and on the percentage of the total sales coming from new products. One of the pioneering works in this area was conducted by Adams et al. (2001). These authors, based on a survey of industrial laboratory technologies, they have analyzed the effect of U-I Cooperative Research Centers (IUCRCs) on industrial R&D laboratories, in terms of the number of patents granted. Their results are not conclusive in terms of the estimated effect of the cooperation with universities over the number of patents granted, ie, the U-I cooperation do not affect firm's performance. In a later paper, Belderbos et al. (2001), based on a dataset of 2353 from the German Community Innovation Survey (CIS) during the period 1996-1998, analyzed the effects of U-I cooperation on the growth in the value added per employee and on the growth of the new products to the market sales per employee, finding a positive effect of the U-I cooperation on the latter, but they did not find any relationship between the U-I cooperation and the former.

In a more recent paper Lööf and Broström (2008), using a sample of 2071 firms belonging to the Swedish CIS in the period 1998-2000, analyzed the effects of U-I cooperation in innovation on the firm's innovation sales and on the firm's propensity to apply for patents. The main results from this analysis indicate that the U-I cooperation increases innovation sales. However, this effect does not hold for a sub sample of firms with more than a 100 employees. On the other hand, the authors found that the U-I cooperation have a positive effect on the firm's propensity to patent, except for service firms. Nevertheless, Spyros and Woerter (2009) using data of 2428 Swiss firms in the period 2002-2004, analyzed the same two output variables finding no significant effect resulting from the cooperation in innovation with universities.

Until now, the analysis of the effects resulting from the U-I cooperation in innovation on the firm's innovative performance have been conducted by measuring changes in innovation outputs. However, previous studies regarding the firm's motivations to cooperate with universities have shown that firms are willing to establish partnering agreements with universities in order to solve or improve the innovation process rather than to increase the outputs of innovation, which is the main objective of this paper.

3. EMPIRICAL APPROACH

Unlike the studies mentioned in the previous section, which analyzed the effect of U-I cooperation on the economic impact of innovations, we focus our attention on studying the effect of the U-I cooperation on the improvement of the firm's innovative capacity. For this purpose, it is necessary to study the impact of cooperation from the beginning of the innovation process, ie from introducing innovations into the market, until to observe the resulting effect of this innovation over the firm's innovative capacity. The empirical analysis is divided in two stages. First, we analyze the impact of the U-I cooperation in the firm's capacity to introduce innovations, distinguishing between different types of innovations. Secondly, we estimate the impact resulting from the introduction of these innovations on the enhancement of the firm's innovative process.

Cooperation in innovation is a component of a firm's strategy that affects the whole innovation process. The literature about cooperation in innovation has distinguished between different partners, such as competitors, clients, suppliers, public and private research institutions, technological centers and universities, analyzing the determinants or the effects of each type of cooperation individually. Nonetheless, cooperation in innovation is not always made exclusively between two types of partners. In a high percentage of cases, cooperation in innovation takes place through innovation networks which include three or more partners. The analysis of the individual effect of each type of cooperation separately might lead to an erroneous estimation of the determinants of this cooperation or a mistaken evaluation of the effects resulting from this cooperation.

In order to capture a more accurate impact of partnering in innovation with universities, we distinguish between four types of partnering agreements with universities: first, exclusive cooperation between firms and universities; secondly, cooperation agreements between firms, universities and market partners (competitors, clients or suppliers); third, cooperation between firms, universities and research institutions (private or public research centers, and technological centers); and finally, cooperation agreements including all possible partners in innovation, (firm, universities, market partners and research institutions). Accordingly, in the first step of this analysis we evaluate the effect of the different types of partnering agreements with universities on the firm's capacity to introduce innovations, and in the second stage, we estimate the

impact of the different types of cooperation on the enhancement of the firm's innovative capacity

3.1. DATA

The information used in this paper can be grouped in three categories. First, we describe the variables of analysis, including the firm's capacity to introduce innovations and the resulting effects on the innovation process. Secondly, we explain the different patterns of cooperation in innovation with universities. Finally, we discuss a set of control variables that, according to the literature, may explain the firm's propensity to introduce innovations and the possible resulting effects from the innovative activity.

The data used in the empirical analysis comes from the Technological Innovation Panel dataset (PITEC for its acronym in Spanish). The PITEC database is a statistical instrument for monitoring the technological innovation activity of Spanish firms. This database is constructed by the Spanish National Institute of Statistics (INE), with the advice of a group of university researchers and under the financial support of the COTEC foundation. The group of firms that make up this database belongs to the Spanish CIS and follows a balanced panel-data structure, allowing us to analyze the firm's behavior during different periods of time, and therefore, permitting us to establish causality relations and to control for possible endogeneity problems in the econometric analysis. According to our objective of analyzing the effects of the U-I cooperation on the firms' innovation process we have used two waves of the PITEC database, corresponding to the years 2005 and 2007. The PITEC database gathers information in 2007 for a total of 12,124 firms, 5.9% of the total firms have to be removed from the original sample due to temporary or permanent closures, mergers or absorptions, or for reasons of confidentiality. Finally, we used only the firms that were present in during the whole period of analysis, ending with a final sample of 8,535 firms (74.87% of the total sample available).

3.1.1. Variables of analysis

As we mentioned before, the PITEC follows the same structure of the Community Innovation Survey. In this sense, it is possible to identify the type of innovation performed by the firms. This survey differentiates between two types of innovations; products and processes innovations. The first refers to is the introduction of

goods or services into the market, or the significant improvement over basic features, technical specifications, incorporated software or other intangible components, desired goals and benefits of existing products. On the other hand, the innovation in processes consists on the implementation of new (or improved) manufacturing methods, logistic systems and support activities. Innovation in products or processes (new or improved) must be for the firm, and not necessarily for the economic sector or market. The information about the introduction of innovations refers to the period T and T₂.

According to the sample of firms used in the empirical analysis for 2007, the 78.83% of the total firms has introduced at least one innovation during the period 2005-2007, 60.82% of which have introduced innovations in products and 58.47% have introduced innovation in processes. According to this information a large percentage of firms (40.46%) perform innovations in products and processes simultaneously, whereas the percentage of firms performing innovations only in products (20.36%) or process (18.01%) is lower.

The innovation in products can be of two types; in goods or in services. The 51.66% of the total firms have introduced innovation in goods and the 42.68% have developed innovations in services. On the other hand, the innovation in processes can be of three types; manufacturing methods, logistic systems and support activities. In this case, 43.13% of firms have introduced innovations in manufacturing methods, whereas the 32.81% introduced innovation in support activities and 12.27% introduced innovations in logistic systems. As can be seen, a large percentage of firms introduced more than one type of innovation. In the case of innovation in products, the percentage of firms that have introduced innovations in goods and services simultaneously reaches 16.80%, whereas the percentage of firms that have entered two or more types of innovations in processes reaches 22.26%. Table 1 shows the number of firms performing each type of innovations.

<TABLE 1 HERE>

The PITEC survey also allows us to observe the results the innovative activity may have had on the firm's innovative performance. Specifically, the survey identifies some effects of the introduction of an innovation on the increment of the firm's range of products, on the augment of the firm's production quality and flexibility, and on the rise of the firm's production capacity, during the period between T and T₂. The survey also

collects information about the degree of importance of these effects, distinguishing between the following four categories: null, low, medium and high.

In order to describe the effects resulting from the innovation activity we have constructed a frequency table crossing the type of innovation introduced by the firm with the level of importance of each of the effects. On average, about half of the innovative firms have experienced high levels of increments in their range of products and in their production quality, whereas about a third of the innovative firms have experienced this level of increments in their production flexibility and in their production capacity. In aggregate, it appears that firms engaged in product innovation experience greater impact on the product range and on the quality of production, while firms performing product innovations have greater increases in flexibility in the production process and more production capacity.

<TABLE 2 HERE>

3.1.2. Cooperation in innovation with universities

The PITEC survey asks about the cooperation agreements made by the firms in the period between T and T₋₂. According to the survey definition, cooperation in innovation refers to the active participation in innovation activities with other firms or nonprofit entities, excluding the pure outsourcing of R&D activities. The survey identifies the following eight types of cooperation partners: firms belonging to the same group, suppliers, clients, competitors, private institutions of R&D, universities and other centers of higher education, public research institutions and technological centers. These different types of partners can be classified in three groups; i) Market partners, including firms from the same group, competitors, clients and suppliers; ii) research institutions, including public and private research institutions and technological centers; and iii) universities and higher education institutions. According to the objective of this paper we focus on the cooperation in innovation with universities, taking into account all possible partnering agreements, ie exclusive cooperation with universities, cooperation with universities and market partners, cooperation with universities and research institutions and cooperation with universities, market partners and research institutions simultaneously.

The 15.48% of the total firms have cooperated in innovation activities with universities, where the 81% of these firms (12.54% out of total firms) have cooperated simultaneously with other institutions, and the remaining 19% (2.94% out of total firms) cooperated exclusively with universities. The 54% (8.37% of the total firms) of the firms that cooperated with universities established partnering agreements with market partners and research institutions simultaneously, being the most common patterns of cooperation with universities. Around 13.9% (2.16% of total firms) of the firms that cooperated with universities and market partners, and 13% (2.02% of total firms) cooperated with universities and research institutions.

<TABLE 3 HERE>

If we compare the firms' innovative behavior based on the establishment (or not) of cooperation agreements with universities we found that firms that have cooperated with universities show a higher capacity to introduce innovations and a better ability to improve their innovation processes. In general, firms that have cooperated with universities show a greater capacity to introduce innovations. However, this capacity differs depending on the pattern of cooperation undertaken. In average, firms that have cooperated with universities, market partners and research institutions show a greater capacity to introduce innovations and a better ability to improve their innovation process. Firms that have cooperated exclusively with universities, on the other hand, do not show differences in their capacity to introduce innovations, and show a lower capacity to improve their production capacity and their flexibility in the production process.

<TABLE 4 HERE>

3.1.3. Control variables

In order to estimate a more accurate impact of the U-I cooperation, we have introduced in the empirical analysis a set of variables representing the firm's characteristics, the firm's R&D strategy and the main factors hampering the innovation process.

The firm's basic characteristics are approached by the following five variables:
i) the size of the firms measured as the natural logarithm of the number of employees;
ii) a dummy variable equal to one if the firm belongs to a group of firms; iii) ownership

structure differentiating between public firms, private firms and research centers; iv) export activity, approximated with a dummy variable equal to one if the firm has had sales outside the national territory; and finally, we included sectoral dummies to control for specific sector characteristics. On the other hand, the firm's R&D strategy is approximated through the following four variables: i) a dummy variable equal to one if the firm performs R&D systematically; ii) the share of R&D expenditures in basic research; iii) the share of R&D expenditures in applied research; and iv) a dummy variable equal to one if the firm has received public subsidies for R&D. Finally, we control for the different factors that have prevented or hindered the decision to innovate. In this case we have created three categorical variables measuring the importance of factors. The first variable is related to the cost of innovation and access to financial support, such as, lack of funds, lack of funding from external sources, and high cost of innovation; the second variable refers to knowledge factors, for instance, lack of qualified personnel, lack of technological information and difficulties to find cooperation partners; finally, the third variable approximates market factors hindering innovation, such as, entry barriers, uncertainty in the demand for innovations and lack of market information.

Table 5 shows the descriptive statistics of the whole set of variables used in the empirical analysis, including the type of innovation performed by the firm, the effects resulting from the innovation activity, the different patterns of cooperation with universities, and control variables.

<TABLE 5 HERE>

3.2. ECONOMETRIC STRATEGY

The econometric analysis is divided in two stages. In the first stage we estimate the effect of U-I cooperation on the firm's capacity to introduce innovations, whereas in the second stage we estimate the effect of the U-I cooperation in the improvements in the firm's innovation processes resulting from the innovation activity.

In the first stage we estimate the effect of the cooperation in innovation with universities on the firm's capacity to introduce innovations. As explained above, the survey allows us to identify five types of innovations, two of them related to product innovations (goods and services), and the remaining three related to process innovations

(manufacturing methods, logistic systems and support activities). According to the survey structure, we have information on whether the firm has introduced an innovation of each type; consequently, our variables of analysis are discrete; being equal to one if a firm has introduced an innovation of each type and zero otherwise. This stage is divided in two parts. In the first part we analyze the effect of the U-I cooperation on the firm's capacity to introduce innovations in products and processes, without differentiating the specific type of innovation. In the second part we estimate the effect of U-I cooperation on the introduction of innovation in goods and services, as well as in manufacturing methods, logistic systems and support activities.

As we mentioned in the section 3.1.1, firms usually introduce more than one type of innovation simultaneously. Therefore, we have used multivariate probit models (MVP) to estimate the effects of U-I cooperation on the firm's capacity to introduce innovations. The MVP, proposed by Ashford and Snowden (1970), is an accepted class of models mainly used for the analysis of correlated binary data. In this type of models, the response is multivariate, correlated and discrete. Generally speaking, the MVP model assumes that given a set of explanatory variables the multivariate response is an indicator of the event that some unobserved latent variable falls within a certain interval. The latent variable is assumed to arise from a multivariate normal distribution. The MVP test and corrects for the possible correlation in the error terms in the equations explaining the decision to introduce more than one type of innovation. Consequently, at this stage we estimate the following system of simultaneous equations.

$$\begin{cases} \text{Inn. Products}_i = F_i(X_{U-I}; Z; \varepsilon_{prod}) \\ \text{Inn. Processes}_i = F_i(X_{U-I}; Z; \varepsilon_{proc}) \end{cases}$$

Where X_{U-I} represents the different patterns of cooperation with universities, Z is a vector of control variables and ε_{prod} and ε_{proc} are the errors including the common term.

On the other hand, we estimate the effects generated by the cooperation in innovation with universities on the firm's capacity to introduce specific types of innovations in products or process. In this case we use a multivariate probit, estimating simultaneously the firm's propensity to introduce one or more types of innovations. In this case the system of equations is as follows:

$$\left\{ \begin{array}{l} \text{Inn. Goods}_i = F_i(X_{U-I}; Z; \varepsilon_{good}) \\ \text{Inn. Services}_i = F_i(X_{U-I}; Z; \varepsilon_{serv}) \\ \text{Inn. Manufacturing methods}_i = F_i(X_{U-I}; Z; \varepsilon_{man}) \\ \text{Inn. Logistic systems}_i = F_i(X_{U-I}; Z; \varepsilon_{logis}) \\ \text{Inn. Support activities}_i = F_i(X_{U-I}; Z; \varepsilon_{supp}) \end{array} \right.$$

In this system of equations the error terms could be correlated in several possible ways, according to the different binary combinations between the five types of innovations (goods and services, goods and manufacturing methods, and so on).

Finally, in the second part we estimate the resulting effect of the cooperation in innovation with universities on the firm's innovative performance. With this aim, we analyze the determinants of the increment on the firm's range of products, on the augment of the firm's production quality and/or flexibility, and on the rise of the firm's production capacity. For the empirical analysis we have re-categorized the variables into a set of dummy variables that take the value of zero if the increments have been null or low and one in the other cases.

According to the survey structure, the results of the innovation activity are present only in the case that a firm has introduced, at least, one innovation. Therefore, we have to separate the sample into innovative and non-innovative firms, and analyze only the firms with innovation activity. The analysis of this subset of firms can lead to a self-selection bias. To address this problem we have employed a two stage model. Following Manning et al. (1987), in the first stage we estimate the selection model, predicting the firm's probability to innovate in each of the different types of innovation (goods, services, manufacturing methods, logistic systems and support activities) using all available observations. In the second stage, we estimate the effects of the U-I cooperation in innovation on the firm's innovative capacity, using the different types of innovation introduced as a selection variable. According to Hass and Hansen (2005) this procedure is more appropriated than the Heckman selection model, as long as the endogenous variable is observed rather than estimated, and when the dependent variable is not continuous.

Just as in the first stage, there may be a problem of simultaneity in the estimation of the effects resulting from the innovation activity. Therefore, in order to control for the correlation problems between the error terms, we have estimated a set of

simultaneous equations using multivariate probit models for each type of innovation. Using this estimation strategy we are able to identify the specific effect of each type of U-I cooperation patterns on the improvements of the firm's innovative performance for each type of innovation introduced. Therefore, we estimate the following set of simultaneous equations:

$$Effect_{hi} = F(X_{U-I}; Z; \varphi_j; \varepsilon_h) \rightarrow If Inn_j = 1$$

Where $Effect_h$ refers to the firm's increment in the range of products, flexibility, quality and production capacity, respectively, φ_j is the firm's probability to introduce the "j" type of innovation, ε_h is the error term associated to the effect "h", and $Inn_j = 1$ refers to the subset of firms that have introduced innovations of the "j" type. And Z , as before, is a set of control variables.

4. EMPIRICAL RESULTS

According to the estimation strategy, the analysis of the econometric results is divided in two parts. The first part refers to the effects of the U-I cooperation in innovation on the firm's propensity to introduce innovations, whereas the second part analyzes the effects of the U-I cooperation in the firm's innovative performance.

4.1. EFFECTS OF U-I COOPERATION ON THE FIRM'S PROPENSITY TO INTRODUCE INNOVATIONS

Table 6a presents the estimation results of the effects of U-I cooperation in innovation on the firm's probability to introduce innovations in products and/or processes. The table is composed of four columns, where the first two present the individual estimations of the effect of cooperation in innovation with universities of the firm's propensity to introduce innovation in products or processes, without taking into account the possible simultaneity issues. The columns three and four present the estimated effects of the U-I cooperation, controlling for the simultaneity in the introduction of these two types of innovations.

<TABLE 6a HERE>

The first issue concerning the results presented in table 6 is the simultaneity problem. Accordingly we have run a likelihood ratio (LR) test comparing the estimation

of the individual models versus the simultaneous estimation. The LR test for the hypothesis that the two equations are independent is equal to 126.20 and highly significant, which implies that the simultaneous estimation is more efficient than the estimation of individual probit models. Moreover, there is a sharp contrast in the estimates of the correlation between the equation error terms (ρ), which is equal to 0.198 and significant at 99%, meaning that there is a common component in both error terms.

The determinants of the firm's capacity to introduce innovations are consistent with previous literature findings. For example, the firm's size, export orientation and the systematic development of R&D activities positively explain the firm's propensity to introduce innovations in products and processes, whereas public funding and the share of employees in R&D positively affects the introduction of product innovations, and the percentage of R&D in applied research explains the introduction of process innovations.

The four types of cooperation with universities positively (and significantly) affect the introduction of innovation in products and processes. Nevertheless the not all the U-I cooperation patterns affect in the same magnitude. According to the results presented in table 6a, in the case of the innovation in products, the firms that cooperate simultaneously with universities and market partners are the ones that experiment a higher probability to introduce this type of innovation, whereas in the case of the introduction of process innovation, the pattern of cooperation that have a higher effect on the firm's propensity to introduce this type of innovation is the simultaneous cooperation between market partners, research institutions and universities.

Taking into account that the estimated coefficients of discrete choice models are not directly interpretable, and in order to extract deeper conclusions, we have predicted the firm's marginal success probability to introduce each type of innovations, then we have compared the average probability between the different types of U-I cooperation.

The table 6b shows the average marginal probability for each type of U-I cooperation agreement. The mean marginal probability to introduce product innovations is 60.9%. This probability is reduced to 57.9% when taking into account firms that have not established cooperation agreements with universities only. On the other hand, the average marginal probability to introduce process innovation of the whole sample is 58.7%, and equal to 56.2% in the case of the group of firms that do not cooperate with

universities. In relation to the firms that have cooperated with universities results indicate that firms cooperating simultaneously with universities and market partners have, on average, a probability of 82.2% to introduce product innovations, whereas in the case of process innovations, the simultaneous cooperation between research institutions, market partners and universities, is the cooperation agreement that has the highest probability of success.

<TABLE 6b HERE>

According to the estimation of the effects of U-I cooperation on the introduction of specific types of innovation, the first issue to take into account is the analysis of the simultaneity bias. The first sign stating the existence of simultaneity bias is the likelihood ratio test comparing the individual estimation of each type of innovation against the simultaneous estimation; this test is equal to 1697.17, which implies that the simultaneous model is more efficient than the estimation of individual probit models. On the other hand, results indicate that there is a common error term affecting the different combinations of innovation types. This correlation is especially high between the innovation in support activities and the innovation in logistic systems, where the correlation coefficient reaches the 0.477, and is significant at 99%.

Table 7a and 7b present the determinants of the specific types of innovations (goods, services, manufacturing methods, logistic systems and support activities) and the marginal probabilities of success, respectively. According to table 7a, firms that exclusively cooperate with universities are less prone to introduce innovations in services, manufacturing methods, logistic systems and support activities. The most important pattern of U-I cooperation in all of this type of innovations is the simultaneous cooperation with market partners, research institutions and universities. Unlike the previous types of innovation, in the case of innovations in goods the most important pattern of cooperation is one that includes market partners and universities. Nevertheless, simultaneous cooperation with market partners and research institutions is the second most important cooperation strategy.

<TABLE 7a HERE>

As in the analysis of the determinants of the introduction of innovation in products and processes, we have calculated the marginal probability of success in the

introduction of the innovation in goods, services, manufacturing methods, logistic systems and support activities. Comparing the average marginal probability of success (table 7b), depending on the partnering agreement established we found that firms that have made cooperation agreements including universities and market partners have, on average, greater probability of introducing innovations in goods, services and support activities than firms that have established other types of cooperation or do not have cooperated during the period of analysis. On the other hand, firms cooperating with universities and research institutions have, on average, higher probability to innovate in manufacturing methods and in logistic systems. However, even though firms that exclusively cooperate with universities have, on average, more probability to introduce innovations than firms that do not cooperate, this type of cooperation has the lower average of marginal probability to success, compared to the other U-I cooperation patterns.

<TABLE 7b HERE>

Till here, we can conclude that firms that cooperate with universities are more prone to introduce innovations. Nevertheless, the rate of success in innovation activities depends on the partners that participate in the innovation process. Firms oriented to product innovations show higher success rates when establishing cooperation agreements involving both universities and market partners. On the other hand, firms involved in process innovations experiment increases in their ability to innovate if they have established partnering agreements with universities and research institutions.

4.2. EFFECTS OF U-I COOPERATION ON THE FIRM'S INNOVATIVE PERFORMANCE

In this section we analyze the changes in the firm's innovative performance, which is approached by the increment in the range of products, by the improvement of the flexibility and quality, and by the augment in the production capacity. As we mention in section 3.2, in order to analyze the effects mentioned above, we have to select the firms that have introduced at least one innovation in the previous period. Accordingly, we have divided the sample according to the type of innovation introduced, shifting from a general type of innovation (product and process innovations) to more specific types, such as innovation in goods, services, manufacturing methods, logistic systems and support activities.

<TABLE 8 HERE>

The table 8 presents the estimation for firms that have introduced product and/or process innovations. According to the firms that have introduced innovation in products, the most effective strategy of cooperation, ie, increasing the firm's ability to improve their innovation performance, includes the simultaneous participation of universities, research institutions and market partners. Firms that have established this type of cooperation agreement are more prone to present increments in scale and scope, to develop more flexible innovation processes and to increase their product quality. Excluding the effect on the increments of production capacity, due to the cooperation in innovation with universities and market partners, the remaining cooperation agreements do not present improvements on the firm's innovative performance.

On the other hand, regarding to the firms that have introduced process innovations, cooperation with universities is a good strategy, especially for firms that aim to increase their range of products or their production quality. However, cooperation in innovation with universities has a reduced (or null) impact on the increment of the firm's production capacity, where only cooperation with universities and market partners has a positive effect. Finally, exclusive cooperation with universities has a negative effect on the flexibility of the firm's innovative process.

In order to have a more specific effect of the U-I cooperation in innovation we have repeated the previous analysis, separating the sample by the specific type of innovation (goods, services, manufacturing methods, logistic systems and support activities). The results are presented in table 9.

Firms that have established cooperation agreements including universities, market partners and research institutions are more likely to increase their range of products and to augment their product quality, independently of the type of innovation performed. This type of cooperation agreement also shows positive effects on the firm's production capacity in firms oriented to innovation in goods, services and manufacturing methods, and augments the flexibility in the firm's innovative process in firms that have introduced innovation in goods.

Cooperation agreements including universities and market partners, regardless of the type of innovation, present positive effects on the improvements of product quality.

This effect is especially higher in firms oriented to innovation in manufacturing methods. Moreover, the firms that have introduced innovation in goods and have established this type of U-I cooperation are more able to increase their production capacity and to augment flexibility in their innovative processes. On the other hand, firms that have cooperated simultaneously with universities and research institutions have a greater propensity to increase the quality of their products, as long as they are oriented to innovations in goods, support activities and manufacturing methods. This type of cooperation also shows positive effects on the increments on the range of products in firms that have introduced innovations in goods and support activities.

Exclusive cooperation in innovation with universities seems to be the less effective cooperation agreement to increase the firm's innovative performance. This type of cooperation only presents a positive effect on the increment of product quality in firms that have introduced innovation in manufacturing methods. However, firms that have established this type of cooperation and have introduced innovations in logistic systems, present a negative effect on the increments of the flexibility in their innovative processes and on their production capacity. This type of cooperation has no effects on firms oriented to innovations in goods, services and support activities.

<TABLE 9 HERE>

According to the results presented in this section, it is possible to establish a positive relationship between the U-I cooperation in innovation and the firms innovative performance. Nevertheless, exclusive cooperation with universities by itself is not enough to change the firms' innovative behavior. With this aim is necessary to create cooperative networks including market partners and/or research institutions.

5. CONCLUSION

In this paper we have analyzed the effects on the firm's innovative performance generated by cooperating in innovation with universities. In this study we have differentiated between the following four patterns of cooperation: i) exclusive cooperation with universities; ii) cooperation with universities and research institutions; iii) cooperation with universities and market partners; and iv) cooperation with universities, market partners and research institutions. The analysis of the different cooperation agreements allows us to identify the specific effect that each has on the

improvement of the firm's innovative performance. The analysis is divided in two stages; in the first one we estimate the effect of cooperating with universities on the introduction of product and process innovations, whereas in the second stage we estimate the effects of U-I cooperation on the enhancements of the firm's innovative capacity, in terms of increments on the firm's range of products, augments on the product quality and on the flexibility of the innovation process, and on enlargement of production capacity.

The results from the first stage indicate that the cooperation in innovation with universities has positive effects on the firm's propensity to introduce innovations. However, the magnitude of the impact depends on the type of innovations introduced and on the type of cooperation agreements established. According to the econometric analysis, the firms that have cooperated simultaneously with universities and market partners have, on average, a 40% greater probability to introduce innovations in products, than firms that have not cooperated in innovation with universities. On the other hand, simultaneous cooperation with universities and research institutions has a greater effect on the introduction of processes innovations, where firms that have established such cooperation have, on average, a 25% higher probability to succeed, than firms that have not cooperated with universities. Excluding the firms oriented to innovation in goods, where the most effective type of cooperation is the one including universities and market partners, simultaneous cooperation with universities, market partners and research institutions is the most efficient strategy for firms that aim to innovate in services, manufacturing methods, logistic systems and support activities.

In the second stage we have estimated the effects of the different types of U-I cooperation on the firms' innovative performance. The econometric analysis indicates that the U-I cooperation in innovation is more effective in firms engaged in processes innovations, than in firms oriented to innovation in products. In the case of firms engaged in processes innovation, the cooperation in innovation with universities and other partners (market partners and/or research institutions) increments the firms' range of products and augment the production quality, these effects are greater when the cooperation in innovation is carried out jointly between market partners, research institutions and universities. On the other hand, regarding to the firms engaged in product innovation the cooperation in innovation has positive effects only when it is made jointly with market partners and research institutions. The results also indicate

that the simultaneous cooperation between firms, market partners, research institutions and universities increments the firms capacity to augment their range of products and their quality. Moreover, the increments in the product quality are higher in firms oriented to innovations in manufacturing methods and on innovation in support activities, whereas the effects on the firms' range of products are greater in firms oriented to innovations in goods and services.

According to the evidence presented in this paper, we are able to conclude that the cooperation in innovation with universities is not enough to increment the firms' innovative performance. In order to maximize the effects resulting from the U-I cooperation is necessary to create cooperation networks which integrate market partners and research institutions.

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Table 1. Description of the types of innovation performed

Type of innovation	Number of firms	% of the total sample
<i>innovator</i>	6728	78.83%
<i>Products</i>	5191	60.82%
<i>Processes</i>	4990	58.47%
<i>Only products</i>	1738	20.36%
<i>Only processes</i>	1537	18.01%
<i>Product & process</i>	3453	40.46%
Innovation in products		
<i>Goods</i>	4409	51.66%
<i>Services</i>	3643	42.68%
<i>Only in goods</i>	2975	34.86%
<i>Only in services</i>	782	9.16%
<i>Goods & services</i>	1434	16.80%
Innovation in processes		
<i>Manufacturing methods</i>	3681	43.13%
<i>Logistic systems</i>	1047	12.27%
<i>Support activities</i>	2800	32.81%
<i>Only in manufacturing methods</i>	1930	22.61%
<i>Only in logistic systems</i>	115	1.35%
<i>Only in support activities</i>	1045	12.24%
<i>Manufacturing methods & logistic systems</i>	145	1.70%
<i>Manufacturing methods & support activities</i>	968	11.34%
<i>Logistic systems & support activities</i>	149	1.75%
<i>Manufacturing methods & logistic systems & support activities</i>	638	7.48%

Note: the percentages are calculated in terms of the total sample, including 8,535 firms

Table 2. Effects of innovation activity on the firm's performance by type of innovation

		Range of products	Quality	Flexibility	Production capacity
<i>Goods</i>	<i>Null</i>	5.78%	8.89%	18.62%	20.82%
	<i>Low</i>	14.04%	9.34%	23.97%	19.53%
	<i>Medium</i>	29.55%	32.62%	34.38%	32.82%
	<i>High</i>	50.62%	49.15%	23.02%	26.83%
<i>Services</i>	<i>Null</i>	6.14%	6.14%	8.48%	14.44%
	<i>Low</i>	14.62%	14.62%	7.54%	18.95%
	<i>Medium</i>	30.42%	30.42%	30.42%	36.19%
	<i>High</i>	48.83%	48.83%	53.56%	30.42%
<i>Manufacturing methods</i>	<i>Null</i>	13.85%	12.09%	7.63%	9.89%
	<i>Low</i>	13.88%	8.34%	22.63%	16.73%

	<i>Medium</i>	26.81%	28.99%	37.00%	35.56%
	<i>High</i>	45.45%	50.58%	32.74%	37.82%
<i>Logistic Systems</i>	<i>Null</i>	10.41%	9.17%	4.78%	7.45%
	<i>Low</i>	12.61%	6.59%	17.67%	13.94%
	<i>Medium</i>	28.18%	27.79%	34.86%	35.15%
	<i>High</i>	48.81%	56.45%	42.69%	43.46%
<i>Support activities</i>	<i>Null</i>	15.11%	13.25%	6.50%	10.50%
	<i>Low</i>	14.71%	7.89%	22.04%	16.82%
	<i>Medium</i>	27.89%	29.39%	39.04%	37.25%
	<i>High</i>	42.29%	49.46%	32.43%	35.43%

Note: the percentages are calculated in terms of the total firms in each subsample: innovation in good (4409); innovation in services (2216); innovation in manufacturing methods (3681); innovation in logistic systems (1047); innovation in support activities (2800)

Table 3. Patterns of cooperation in innovation with universities

	% of total firms
<i>Cooperation with universities</i>	15.48%
<i>Exclusive cooperation with universities</i>	2.94%
<i>Cooperation with universities and other institutions</i>	12.54%
<i>Cooperation with universities and market partners</i>	2.02%
<i>Cooperation with universities and research institutions</i>	2.16%
<i>Cooperation with universities, market partners and research institutions</i>	8.37%

Table 4. Mean comparison of the type of innovation and the effects of the innovation activity by cooperating with universities

	(1)	(2)	(3)	(4)	(5)	(6)
Type of innovation						
Goods	0.159***	0.030	0.182***	0.190***	0.077*	0.191***
Services	0.198***	0.036	0.227***	0.203***	0.095**	0.247***
Manufacturing methods	0.153***	0.011	0.180***	0.046	0.136***	0.207***
Logistic systems	0.074***	-0.015	0.092***	0.041	0.046*	0.109***
Support activities	0.153***	0.015	0.179***	0.104***	0.025	0.222***
Effects of the innovation activity						
Range of products	0.291***	0.026	0.338***	0.244***	0.041	0.405***
Quality	0.392***	0.071	0.447***	0.403***	0.284***	0.452***
Flexibility	0.153***	-0.121***	0.241***	0.076	0.024	0.314***
Production capacity	0.225***	-0.156**	0.308***	0.121	0.091	0.382***

Note: (1) general cooperation with universities; (2) exclusive cooperation with universities; (3) cooperation with universities and other partners; (4) cooperation with universities and market partners; (5) cooperation with universities and research institutions; (6) cooperation with universities, market partners and research institutions. Mean comparison between firms that have cooperated with universities and

firms that have not cooperated with universities. A positive difference means that the average of the firms that cooperated with universities is higher than the average of firms that have not cooperated. The *, **, *** represent that the mean difference is statistically different from zero.

Table 5. Descriptive statistics

	Period	Mean	Std. Dev.	Min	Max
Type of innovation					
<i>Goods</i>	2005 2007	0.517	0.500	0	1
<i>Services</i>	2005 2007	0.260	0.438	0	1
<i>Manufacturing methods</i>	2005 2007	0.431	0.495	0	1
<i>Logistic systems</i>	2005 2007	0.123	0.328	0	1
<i>Support activities</i>	2005 2007	0.328	0.470	0	1
Effects of the innovation activity					
<i>Range of products</i>	2005 2007	0.697	0.460	0	1
<i>Quality</i>	2005 2007	0.754	0.431	0	1
<i>Flexibility</i>	2005 2007	0.600	0.490	0	1
<i>Production capacity</i>	2005 2007	0.618	0.486	0	1
Cooperation in innovation					
<i>Cooperation with other institutions</i>	2005 2007	0.164	0.370	0	1
<i>Exclusive cooperation with universities</i>	2005 2007	0.029	0.169	0	1
<i>Cooperation with universities and market partners</i>	2005 2007	0.020	0.141	0	1
<i>Cooperation with universities and research institutions</i>	2005 2007	0.022	0.145	0	1
<i>Cooperation with universities, market partners and research institutions</i>	2005 2007	0.084	0.277	0	1
Control variables					
<i>Ln(number of employees)</i>	2005	3.707	1.471	0.000	9.952
<i>Group</i>	2005	0.342	0.474	0	1
<i>Public firm</i>	2005	0.019	0.136	0	1
<i>Research center</i>	2005	0.017	0.129	0	1
<i>Export activity</i>	2005	0.644	0.479	0	1
<i>Share of employees in R&D</i>	2005	0.188	0.269	0.000	1.000
<i>Continuous R&D</i>	2005	0.595	0.491	0	1
<i>% of R&D in basic research</i>	2005	0.047	0.169	0	1.000
<i>% of R&D in applied research</i>	2005	0.319	0.381	0	1.000
<i>Public funding</i>	2005	0.496	0.500	0	1
<i>Cost factors hampering innovation</i>	2005 2007	0.558	0.497	0	1
<i>Knowledge factors hampering innovation</i>	2005 2007	0.222	0.416	0	1
<i>Market factors hampering innovation</i>	2005 2007	0.352	0.478	0	1

Table 6a. Effects of the U-I cooperation on the firm's propensity to introduce product and process innovations

	Probit		Multivariate probit	
	Products	Processes	Products	Processes
<i>Cooperation with other institutions</i>	0.481 (0.042)***	0.482 (0.041)***	0.478 (0.043)***	0.477 (0.041)***
<i>Exclusive cooperation with universities</i>	0.311 (0.088)***	0.309 (0.085)***	0.307 (0.093)***	0.306 (0.086)***
<i>Cooperation with universities and market partners</i>	0.683 (0.121)***	0.281 (0.102)**	0.670 (0.119)***	0.271 (0.107)**
<i>Cooperation with universities and research institutions</i>	0.429 (0.106)***	0.438 (0.103)***	0.424 (0.110)***	0.439 (0.105)***
<i>Cooperation with universities, market partners and research institutions</i>	0.513 (0.064)***	0.600 (0.062)***	0.511 (0.065)***	0.600 (0.061)***
<i>Ln(number of employees)</i>	0.094 (0.014)***	0.139 (0.013)***	0.093 (0.014)***	0.140 (0.013)***
<i>Group</i>	0.007 (0.035)	-0.049 (0.034)	0.007 (0.035)	-0.049 (0.034)
<i>Public firm</i>	-0.039 (0.112)	-0.232 (0.111)**	-0.036 (0.112)	-0.233 (0.108)**
<i>Research center</i>	-0.102 (0.132)	-0.083 (0.127)	-0.106 (0.132)	-0.085 (0.126)
<i>Export activity</i>	0.225 (0.035)***	0.109 (0.034)***	0.227 (0.034)***	0.111 (0.034)***
<i>Share of employees in R&D</i>	0.526 (0.078)***	0.071 (0.073)	0.525 (0.083)***	0.068 (0.072)
<i>Continuous R&D</i>	0.451 (0.033)***	0.203 (0.033)***	0.451 (0.033)***	0.202 (0.032)***
<i>% of R&D in basic research</i>	6.69·10 ⁻⁴ (8.83·10 ⁻⁴)	0.001 (8.63·10 ⁻⁴)	6.63·10 ⁻⁴ (8.13·10 ⁻⁴)	0.001 (8.78·10 ⁻⁴)
<i>% of R&D in applied research</i>	5.28·10 ⁻⁴ (4.11·10 ⁻⁴)	9.79·10 ⁻⁴ (4.01·10 ⁻⁴)**	5.58·10 ⁻⁴ (4.12·10 ⁻⁴)	0.001 (4.02·10 ⁻⁴)**
<i>Public funding</i>	0.121 (0.031)**	0.022 (0.031)	0.122 (0.031)**	0.024 (0.031)
<i>Log likelihood</i>	-4897.95	-5238.00	--	--
<i>Log pseudolikelihood</i>	--	--	-10072.86	--
<i>LR chi2</i>	1454.59	926.94	--	--
<i>Wald chi2</i>	--	--	3067.65	--
<i>p(Products-Processes)</i>	--	--	0.198 (0.017)***	--
<i>Likelihood ratio test of p(Products-Processes)</i>	--	--	126.201***	--

Note: The number of observations is 8413. Standard errors in parenthesis. *, **, ***, denotes level of significance at 10%, 5% and 1%, respectively. The estimations include two digit sectoral dummy variables and factors hampering the innovation activity. The estimations results presented are based on 50 pseudo-random standard uniform variates drawn when

calculating the simulated likelihood. The estimations were replicated for 100, 200 and 500 draws and the variation of both coefficients and standard errors were minimal.

Table 6b. Marginal probability of success in the introduction of product and process innovations

	Products	Processes
<i>All sample</i>	0.609	0.587
<i>Firms that do not cooperate with universities</i>	0.579	0.562
<i>Exclusive cooperation with universities</i>	0.662	0.627
<i>Cooperation with universities and market partners</i>	0.822	0.643
<i>Cooperation with universities and research institutions</i>	0.723	0.703
<i>Cooperation with universities, market partners and research institutions</i>	0.811	0.785

Table 7a. Effects of the U-I cooperation on the firm's propensity to introduce specific product and process innovations

	Goods	Services	Manufacturing methods	Logistic systems	Support activities
<i>Cooperation with other institutions</i>	0.389 (0.041)***	0.360 (0.047)***	0.339 (0.039)***	0.269 (0.048)***	0.402 (0.039)***
<i>Exclusive cooperation with universities</i>	0.274 (0.085)***	0.211 (0.090)**	0.218 (0.085)**	0.157 (0.112)	0.247 (0.084)***
<i>Cooperation with universities and market partners</i>	0.643 (0.111)***	0.440 (0.102)***	0.271 (0.101)***	0.262 (0.122)**	0.308 (0.100)***
<i>Cooperation with universities and research institutions</i>	0.256 (0.102)**	0.396 (0.101)***	0.401 (0.099)***	0.346 (0.118)***	0.231 (0.098)**
<i>Cooperation with universities, market partners and research institutions</i>	0.433 (0.060)***	0.501 (0.057)***	0.527 (0.058)***	0.443 (0.066)***	0.509 (0.056)***

Note: The number of observations is 8413. Standard errors in parenthesis. *, **, ***, denotes level of significance at 10%, 5% and 1%, respectively. The estimations include control variables, two digit sectoral dummy variables and factors hampering the innovation activity. The estimations results presented are based on 50 pseudo-random standard uniform variates drawn when calculating the simulated likelihood. The estimations were replicated for 100, 200 and 500 draws and the variation of both coefficients and standard errors were minimal.

Table 7b. Marginal probability of success in the introduction of specific product and process innovations

	Goods	Services	Manufacturing methods	Logistic systems	Support activities
<i>All sample</i>	0.518	0.260	0.434	0.123	0.330
<i>Firms that do not cooperate with universities</i>	0.493	0.230	0.410	0.111	0.306
<i>Exclusive cooperation with universities</i>	0.546	0.303	0.446	0.113	0.354
<i>Cooperation with universities and market partners</i>	0.705	0.454	0.478	0.164	0.432
<i>Cooperation with universities and research institutions</i>	0.581	0.352	0.564	0.171	0.358
<i>Cooperation with universities, market partners and research institutions</i>	0.694	0.481	0.623	0.219	0.533

Table 8. Effects of U-I cooperation on firm's innovative performance. Product and process innovations

	Products				Processes			
	Range of products	Quality	Flexibility	Production capacity	Range of products	Quality	Flexibility	Production capacity
<i>Cooperation with other institutions</i>	0.081 (0.064)	0.025 (0.065)	0.231 (0.056)***	0.257 (0.058)***	0.395 (0.070)***	0.221 (0.075)***	0.113 (0.069)	0.049 (0.071)
<i>Exclusive cooperation with universities</i>	0.134 (0.118)	0.040 (0.121)	-0.126 (0.107)	-0.108 (0.105)	0.215 (0.117)*	0.161 (0.123)	-0.214 (0.113)*	-0.091 (0.114)
<i>Cooperation with universities and market partners</i>	-0.141 (0.135)	0.112 (0.148)	0.115 (0.118)	0.316 (0.123)**	0.347 (0.135)**	0.684 (0.176)***	0.217 (0.136)	0.241 (0.140)*
<i>Cooperation with universities and research institutions</i>	0.088 (0.133)	0.141 (0.143)	0.080 (0.118)	0.126 (0.112)	0.267 (0.126)**	0.335 (0.145)**	-0.137 (0.126)	-0.099 (0.127)
<i>Cooperation with universities, market partners and research institutions</i>	0.246 (0.086)***	0.219 (0.089)**	0.162 (0.071)**	0.303 (0.073)***	0.469 (0.089)***	0.426 (0.101)***	0.053 (0.088)	0.128 (0.091)
<i>Ln(number of employees)</i>	0.004 (0.019)	0.038 (0.020)	0.135 (0.017)***	0.118 (0.017)***	0.072 (0.023)***	0.038 (0.025)	0.077 (0.023)***	0.036 (0.023)
<i>Group</i>	0.010 (0.048)	-0.056 (0.048)	0.021 (0.043)	0.025 (0.043)	-0.024 (0.045)	-0.085 (0.047)	0.045 (0.045)	0.064 (0.046)
<i>Public firm</i>	-0.453 (0.142)***	-0.226 (0.154)	-0.029 (0.138)	-0.207 (0.140)	-0.503 (0.144)***	-0.356 (0.154)**	0.011 (0.154)	-0.147 (0.147)
<i>Research center</i>	0.136 (0.167)	0.204 (0.201)	0.105 (0.139)	0.184 (0.147)	0.018 (0.159)	-0.002 (0.181)	0.112 (0.154)	0.369 (0.170)**
<i>Export activity</i>	0.043 (0.053)	0.006 (0.056)	-0.022 (0.048)	0.051 (0.050)	0.299 (0.046)***	0.212 (0.048)***	0.066 (0.046)	0.099 (0.047)
<i>Share of employees in R&D</i>	-0.123 (0.107)	-0.029 (0.108)	0.127 (0.092)	0.054 (0.097)	0.236 (0.104)**	0.157 (0.101)	0.062 (0.089)	0.032 (0.093)
<i>Continuous R&D</i>	0.080	0.032	0.083	0.196	0.522	0.410	0.080	0.124

	(0.064)	(0.064)	(0.059)	(0.059)***	(0.046)***	(0.048)***	(0.046)*	(0.046)***
<i>% of R&D in basic research</i>	0.003	0.001	0.002	0.001	0.003	6.55·10 ⁻⁴	3.89·10 ⁻⁵	-6.43·10 ⁻⁴
	(0.001)**	(0.001)	(0.001)**	(0.001)*	(0.001)***	(0.001)	(0.001)	(0.001)
<i>% of R&D in applied research</i>	2.04·10 ⁻⁴	-9.37·10 ⁻⁵	8.76·10 ⁻⁴	2.81·10 ⁻⁴	0.001	2.24·10 ⁻⁴	3.59·10 ⁻⁴	-4.01·10 ⁻⁴
	(5.41·10 ⁻⁴)	(5.57·10 ⁻⁴)	(4.82·10 ⁻⁴)*	(4.94·10 ⁻⁴)	(5.31·10 ⁻⁴)**	(5.57·10 ⁻⁴)	(5.23·10 ⁻⁴)	(5.30·10 ⁻⁴)
<i>Public funding</i>	0.137	0.105	0.005	0.015	0.026	0.038	0.060	0.051
	(0.044)***	(0.044)**	(0.039)	(0.039)	(0.040)	(0.043)	(0.040)	(0.041)
<i>Log pseudolikelihood</i>			-10005.207				-10026.964	
<i>Wald chi2</i>			566.80				672.47	
<i>Likelihood ratio test</i>			3182.09***				2734.69***	

Note: The number of observations is 8413. Standard errors in parenthesis. *, **, ***, denotes level of significance at 10%, 5% and 1%, respectively. The estimations include control variables, two digit sectoral dummy variables and factors hampering the innovation activity. The estimations results presented are based on 50 pseudo-random standard uniform variates drawn when calculating the simulated likelihood. The estimations were replicated for 100, 200 and 500 draws and the variation of both coefficients and standard errors were minimal.

Table 9. Effects of U-I cooperation on firm's innovative performance. Specific product and process innovations

		Exclusive cooperation with universities	Cooperation with universities and market partners	Cooperation with universities and research institutions	Cooperation with universities, market partners and research institutions
<i>Goods</i>	<i>Range of products</i>	0.200 (0.131)	0.096 (0.140)	0.305 (0.150)**	0.337 (0.087)***
	<i>Quality</i>	0.145 (0.133)	0.360 (0.147)**	0.401 (0.159)**	0.411 (0.090)***
	<i>Flexibility</i>	-0.141 (0.118)	0.210 (0.119)*	-0.062 (0.125)	0.186 (0.071)***
	<i>Production capacity</i>	-0.119 (0.118)	0.302 (0.122)**	-0.098 (0.129)	0.280 (0.073)***
<i>Services</i>	<i>Range of products</i>	-0.015 (0.151)	-0.008 (0.165)	0.122 (0.174)	0.370 (0.105)***
	<i>Quality</i>	0.011 (0.168)	0.501 (0.195)**	0.100 (0.182)	0.383 (0.120)***
	<i>Flexibility</i>	-0.169 (0.152)	-0.020 (0.149)	-0.023 (0.162)	0.123 (0.093)
	<i>Production capacity</i>	-0.139 (0.152)	0.158 (0.157)	0.094 (0.164)	0.239 (0.097)**
<i>Manufacturing methods</i>	<i>Range of products</i>	0.136 (0.137)	0.202 (0.163)	0.062 (0.132)	0.294 (0.085)***
	<i>Quality</i>	0.235 (0.142)*	0.598 (0.189)***	0.434 (0.168)**	0.444 (0.096)***
	<i>Flexibility</i>	-0.110 (0.128)	0.359 (0.158)*	-0.200 (0.128)	0.108 (0.081)
	<i>Production capacity</i>	0.101 (0.129)	0.231 (0.158)	-0.013 (0.137)	0.199 (0.087)**
<i>Logistic systems</i>	<i>Range of products</i>	-0.212 (0.265)	1.156 (0.455)**	0.052 (0.235)	0.324 (0.146)**
	<i>Quality</i>	-0.175 (0.287)	4.224 (0.148)***	0.030 (0.277)	0.391 (0.157)**
	<i>Flexibility</i>	-0.500 (0.285)*	0.342 (0.276)	-0.197 (0.254)	0.176 (0.141)
	<i>Production capacity</i>	-0.712 (0.273)***	0.419 (0.319)	-0.303 (0.249)	0.184 (0.150)
<i>Support activities</i>	<i>Range of products</i>	0.084 (0.156)	0.228 (0.170)	0.328 (0.189)*	0.322 (0.096)***
	<i>Quality</i>	0.192 (0.161)	0.504 (0.242)**	0.429 (0.181)**	0.428 (0.109)***

<i>Flexibility</i>	-0.250 (0.147)	0.062 (0.167)	0.143 (0.175)	0.004 (0.090)
<i>Production capacity</i>	-0.228 (0.146)	0.058 (0.168)	0.138 (0.171)	0.091 (0.096)

Note: The number of observations is 8413. Standard errors in parenthesis. *, **, ***, denotes level of significance at 10%, 5% and 1%, respectively. The estimations include control variables, two digit sectoral dummy variables and factors hampering the innovation activity. The estimations results presented are based on 50 pseudo-random standard uniform variates drawn when calculating the simulated likelihood. The estimations were replicated for 100, 200 and 500 draws and the variation of both coefficients and standard errors were minimal.