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Direct and indirect effects of R&D cooperation on the innovation of Italian firms[†]

Otello Ardovino*, Luca Pennacchio** and Giuseppe Piroli***

Abstract

Firm innovation capacity depends not only on internal capabilities, but also on external expertise and knowledge acquired through cooperation. This paper analyzes direct and indirect effect of R&D cooperation on the innovation of Italian firms. Using a multivariate probit model to account for the complementarity of four different types of innovation activity and the heterogeneity in the choice of cooperation partners, we find strong and positive direct effects of collaborations with some non-competitive partners (suppliers, clients, private research institutes and consultants). Also R&D cooperation with competitors shows a relevant direct effect on firm innovation. On the contrary, collaborations with university have weaker effects; this could perhaps be due to the short-term perspective adopted in the study. These findings suggest that it is important to look at the specific type of R&D collaborations because they have a different impact on the success of innovative activities. On the other hand, indirect effects are scant and restricted to cooperation with some non-competitive partners. Such a result suggests that absorptive capacity of firms and R&D spillovers are quite weak in Italian context. Lastly, firm size and sector-specific features also affect innovation propensity.

Keywords: R&D collaboration, absorptive capacity, moderating variable, innovation, equation probit model, community innovation survey.

JEL Classification: L13, O30, O32.

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1. Introduction

In the constantly changing and uncertain economic system, innovation is a key factor for the competitiveness and the growth of firms; especially for those operating in the markets characterized by a high level of knowledge and technology. The company[1]'s innovation capacity depends crucially on the internal R&D activities. However, as it has been demonstrated by the paradigm of *open innovation* (Chesbrough, 2003), the internal expertise alone may not be sufficient. Therefore, the firms need both internal and external ideas and resources, as the relationship with the external environment has the influence on all the phases of firm processes, including those of R&D activities and innovation. The company's capacity to make use of the external sources of knowledge and innovation becomes thus strategic; especially in a social and economic environment requiring the acquisition of new knowledge and continuous reconfiguration of expertise.

According to the evolutionary approach, the concept of absorptive capacity (Cohen & Levinthal, 1990) redefines the meaning of internal R&D as it defines the ability to recognize and make use of external knowledge for commercial purposes, thanks to its resources of previously accumulated knowledge. Firms prefer investing in internal R&D rather than buying research outputs from the outside because it increases their absorptive capacity. At the same time, a greater ability to internalize external knowledge encourages firms to establish relationships with external partners. The absorptive capacity, therefore, plays the role of a mediator between the potentially available external knowledge and internal knowledge, emphasizing the benefits resulting from their interaction. The company is thus defined as a set of expertise and clear boundaries in continuous transformation making use of knowledge, both internal and external, for developing and producing innovations in order to gain a competitive advantage. In a similar conceptual framework, cooperation represents a privileged mode, through which a direct relationship with the external knowledge is realized.

There are several reasons motivating companies to establish cooperative relationships with other partners, such as technological complexity of a project that requires extensive and differentiated skills or high costs of some research (Becker & Dietz, 2004). In fact, the cooperation is beneficial in terms of exchange of resources, learning at the organizational level and technology transfer (Mäkinen & Seppänen, 2007). In some cases, a collaborative relationship is an almost inevitable solution to overcome the limited R&D capacity of some firms, such as those of small size (Lin, 2003). Moreover, collaborative relationships allow the

[1] Throughout this work "company" is used as a synonym of "firm".

company to increase their knowledge by having access, at least partially, to the partner's expertise (Hamel, 1991). Precisely for this reason, however, when partners are in the position where they need to defend their interests, some obstacles to the exchange and sharing of knowledge[2] may arise. Parkhe (1991) demonstrates how a firm, which is able to appropriate more quickly the new knowledge produced during the collaboration, for example the results of a joint research project, turns out to be the winning party in the relationship, becoming a formidable commercial competitor for the other firm[3]. For this reason, it triggers a real 'race' between the partners trying to ensure the joint use of the R&D results, which may hinder the effectiveness of collaboration and even affect the final outcome of the project (Tsang, 1999). This dynamics is certainly influenced by the nature of the partners involved in the cooperation. The companies competing in the same market will behave in a different way than, for example, those located on different stages of the production chain or active on different markets. Still a different case is the collaboration between companies and universities, which typically is driven by a purely scientific interest. Tsang (1999) makes a distinction between the non-competitive and competitive partnerships, where the partners compete in a race of learning and appropriation. In this situation, the first firm capable of internalizing and applying the knowledge produced by the collaboration acquires a competitive advantage over the other firm. In such a case, only one firm will get the benefits arising from collaboration, as there will be a *win-loss* situation. The creation of patent for a new product that takes advantage of the activities and results of a research carried out by multiple partners can serve here as an example. Instead, when partners do not compete in the same market, a *win-win* situation is possible as the collaboration is of non-competitive character. An example can be a new production process that will be applied in separate markets or in different stages of the same production chain. Therefore, the first aspect crucial for studying the nature and the benefits of cooperation is to consider the various forms of collaboration, in terms of partners involved, and to analyze the effects in relation to different types of innovation introduced by companies.

The above mentioned evolutionary theory suggests that it is not sufficient to consider the direct benefits only, but it is necessary to take into account the indirect benefits as well. In fact, collaboration is established for the realization of a given project that aims to achieve certain results, such as a new product. Simultaneously to the activities carried out in the

[2] Such knowledge flows are often referred to in the economic literature as incoming and outgoing spillovers (Cassiman & Veugelers, 2002).
[3] Parkhe (1991) writes explicitly about a 'dominator of the relationship'.

implementation of given research, through the interaction between the partners a process of learning and strengthening of firm expertise is activated, which is reflected on all levels of company operations. In other words, cooperation can be a factor strengthening the firm's internal capacities. This process is more intense and effective when the company's absorption capacity is greater, usually measured by its R&D capability. In this sense, the collaboration with partners affects the relationship between company's internal expertise and the innovation performance (Huang & Yu, 2011). In other words, cooperation has a positive moderating effect in the relationship between in-house R&D and innovation[4].

This interaction between the R&D within the company and external collaboration may represent, therefore, the real strategic drive for innovation. In addition, cooperation can transform a situation that potentially foresees a 'loser', for example a company that lost the bid for the patent ownership, in a situation in which all the partners get the benefits of a different nature. We cannot forget, however, that the partners of competitive type can implement actions that limit the process of knowledge transfer, weakening the indirect positive effect just described. Therefore, in theory, two opposite effects act simultaneously.

Our work is part of the empirical literature on companies' strategies for R&D collaboration. In particular, the object of our study covers both the direct effect exerted by different types of cooperation on the innovative capacity of firms and the effectiveness of cooperation in moderating the relationship between in-house R&D and innovative capacity. Compared to previous empirical contributions, the paper has the advantage of dealing adequately, from the econometric point of view, with the interdependence between various types of innovation implemented by companies. In addition, to our knowledge, it is the first work that analyzes, with reference to the Italian situation, the indirect effects of cooperation in R&D.

The paper is organized in the following way: Part 2 identifies, on the basis of academic literature, the theoretical hypotheses that are subsequently tested; Part 3 describes the data and the econometric model applied to test the hypotheses; Part 4 analyzes the results of the estimated models and, finally, Part 5 presents the conclusions and the most relevant implications.

[4] A variable is called moderator if it affects the direction and/or the intensity of the relationship between an exogenous variable (independent) and an endogenous variable (dependent). In the present work we want to verify if the cooperation has a moderating effect on the relationship between in-house R&D and the innovation performance of firms. The characteristics and properties of a moderating variable, also called interaction, are well illustrated in the work of Subhash et al. (2003).

2. Literature overview and development of hypotheses

The economic literature has extensively investigated the phenomenon of R&D cooperation. The collaboration between firms and other actors in the economic environment has intensified at a growing rate since the 1970s (Hagendoorn, 2002). The main factors mentioned in the literature explaining this trend refer to the huge industrial and technological changes, which in terms of results, made companies' R&D more complex, expensive and uncertain (Contractor & Lorange, 1988; Dussauge & Garette, 1999; Hagedoorn, 1993; Nooteboom, 1999). Moreover, it is interesting to note that the collaboration growth over time is not linked to the increase in public funds devoted to R&D cooperation. This appears to be true both in case of the US and the European Union. The work by Hagedoorn and Schakenraad (1993) and Peters et al (1993) demonstrates that public funding had a marginal effect on the propensity to collaborate, even in sectors with high technological content[5]. In an evolutionary context characterized by shortened innovation cycles and by the need for continuous innovation to maintain its competitiveness, several studies have pointed out that different companies enter into collaborative relationships according to their specific needs (Teece, 1992; Belderbos et al, 2004a). The collaboration with customers is useful both for obtaining new information and new ideas as well as for reducing the uncertainty related to the introduction of new products to the market. In addition, this type of cooperation can promote the growth of the market share when new products are complex and not easy to use for final consumers (von Hippel, 1988; Tether, 2002). The collaboration along the supply chain upstream, that is with suppliers, seems to be more closely linked to the need of reducing production costs and the possibility of improving the internal organizational processes (Hagedoorn, 1993). The collaboration with competitors, as it has been shown in the Introduction, is characterized by a strong trade-off between cooperation costs and benefits that makes the analysis complex. In fact, the benefits arising from the allocation of costs and risks, as well as those permitted by the sharing of resources (Das & Teng, 2000), can be canceled by problems of appropriability of the R&D results (Hamel, 1991; Parkhe, 1991; Tsang, 1999) or by the tightening of competition in final markets (Katz, 1986). The relationships with universities are privileged in sectors characterized by rapid technological

[5] In Italy, several public actions have been implemented to promote cooperation between companies in R&D. One of the most recent ones is the establishment of some technological districts, that is, high-tech science parks located in certain geographical areas of the country, which are intended to stimulate research and innovation, and therefore growth, of local production systems (Ardovino & Pennacchio, 2012).

change and in case of partnerships searching for new production processes (Rahm et al, 2000; Hall et al, 2003; Belderbos et al, 2004a).

The analysis of the effects of R&D cooperation can be addressed by applying two different perspectives, depending on whether the focus is to be on the inputs or the outputs of the enterprise (Aschhoff & Schmidt, 2008). The inputs perspective highlights the benefits relating to the acquisition and the creation of new information (Caloghirou et al., 2003), the access to complementary resources (Hagedoorn, 1993), the internalization of spillovers (De Bondt, 1997; Cassiman & Veugelers, 2002) and the sharing of costs and risks (Sakakibara, 1997). These studies tend to consider only the direct effects of cooperation on the inputs used by a firm for innovative processes, and to neglect the indirect effects that cooperation has on company's economic and technological performance. Regarding the outputs perspective, the main problem lies in identifying the correct performance measures. Belderbos et al (2004b) found out, on a sample of Dutch firms, that cooperation with suppliers and competitors promotes the growth of added value per employee, whereas cooperation with universities and competitors has a positive impact on sales growth that can be attributed to the introduction of new products into the market. The work by Lööf and Broström (2008) shows that the cooperation between universities and enterprises improves the firms' performance both in terms of a higher probability of applying for a patent and sales growth per employee due to the introduction of innovative products. It should be noted, however, that not all studies provide empirical evidence of a positive link between the activities of cooperation and innovative performance of companies. There are some studies showing a negative relationship; Janz et al (2004), for example, demonstrate that cooperation with competitors reduces the growth of sales share due to innovative products. A similar result was shown in previous works, such as Berg et al (1982) and Siebert (1996).

It is also important to stress that different forms of collaboration (with consultants, corporate group to which companies belong, universities, suppliers, competitors and customers) do not have to be mutually exclusive, and indeed, various types of cooperation can be seen as part of an overall strategy of a company that finds it convenient to engage in multiple collaborations. This type of strategy could be justified considering the synergic/ complementary effects of different types of cooperation (Belderbos et al, 2004a). For example, a new strategic alliance could increase the effectiveness of those, which are already well advanced. In the model by Milgrom and Roberts (1990) it is confirmed that such complementarity exists if the activation of a new cooperation increases, at the margin, the economic return derived from other collaborations.

This paper aims at analyzing the effects of different forms of collaboration on companies' innovative performance, the latter assessed as willingness to implement product, process, organization and marketing innovations. First, we will analyze the direct effects and, later, through the interaction of external cooperation with one of the basic input of innovation, internal R&D, we seek to verify the existence of indirect effects. A series of hypotheses will be tested regarding the direct and mediated effect of five different forms of co-operation on innovative performance of the company. The first hypothesis refers to the direct effect:

H1a: The R&D cooperation has a positive effect on the companies' innovative performance.

This hypothesis primarily concerns the existence of a general positive effect of cooperation on companies' innovative performance. The next hypothesis, instead, aims to verify the existence of interdependence between the different types of innovation pursued by the same company.

H1b: Different types of innovation are interdependent and, thus, constitute the overall company's strategy for innovation.

Depending on the type of innovative performance considered, we can obtain, both in terms of significance and intensity of the coefficient, different results in relation to various forms of cooperation. Belderbos et al (2004b), for example, find that cooperation with competitors has a positive effect only on process innovations, focussed mainly on cost reduction, while Tether (2002) demonstrates how the collaboration with customers is more oriented towards product innovation. In other words, the introduction by an enterprise of a particular type of innovation should be supported by cooperation with specific types of partners, highlighting specific strategies in collaborative choices.

H2: Not all forms of collaboration have the same direct (positive) effect on the innovative performance of companies. The activity carried out by the firm for a particular type of innovation draws different benefits depending on the partner chosen for cooperation.

In the light of empirical and theoretical models stressing the trade-off between costs and benefits of cooperation, particularly relevant in the collaboration of competitive type, it is important to verify if the benefits of cooperation with competitors are systematically lower than those relating to other types of cooperation[6]. As highlighted by the work of Katz (1986), Parkhe (1991) and Tsang (1999), the opportunistic behavior adopted by partners in competition mitigates the beneficial effects of cooperation, limiting the exchange of knowledge. On the contrary, in cooperation with partners led by non-conflicting interests, such as suppliers, consultants and universities, there should be a greater propensity to exchange/sharing of information and knowledge.

H3: Collaborations activated with uncompetitive partners bring benefits greater than those achieved with competitive partners (competitors).

The previous discussion on the absorptive capacity showed the close link between company's internal R&D and external collaborations. Therefore, it seems reasonable to assume that they would strengthen the efforts of in-house R&D and make them more effective, allowing for the best results in terms of innovative performance. In other words, we expect the cooperation to act as a moderator variable in the relationship between in-house R&D and innovative performance of companies. We expect, however, that these interaction effects would be more significant in the presence of non-competitive collaborations, compared to those between competitive partners. Our fourth hypothesis may thus be formulated in the following way:

H4: Collaborations also produce indirect benefits, ie the positive effects of moderation in the relationship between in-house R&D and innovative performance. The moderating effect of the non-competitive collaborations between partners is greater than that of the collaborations between competitive partners.

An important aspect in the analyses assessing the impact of cooperation on the performance of companies regards the duration of the time lag between the time of the collaboration and its impact in terms of performance. Belderbos et al (2004b) in fact point out that the different results reported in empirical literature may be partly attributed to the different time horizons used in the studies. For example, it is plausible to assume that the effects of cooperation pre-competitive in nature occur only in the long run. Empirical studies do not clearly indicate what the optimal duration of the time lag would be; it is thus necessary

[6] The trade-off between the costs and benefits of R&D cooperation is also used to evaluate, from the theoretical point of view, the chance for public support for the formation of innovative networks (Del Monte, 2013).

to emphasize that in this work, the analysis of the impact of cooperation on firm performance is based on a short-term perspective.

3. The data and econometric model description

The theoretical hypotheses formulated in the previous section are tested through econometric analysis using the anonymised micro-data of the Community Innovation Survey (CIS) 2008. For Italy, the observation period covered by the survey is 2006-2008 and the sample includes 19904 enterprises that, according to the NACE Rev. 2 classification, belong to the sections B-M.[7]

Since we are interested in studying cooperation in research and development, we prefer to focus our interest only on manufacturing and service firms, excluding from the sample companies operating in other sectors, which generally show a lower propensity to innovate. We also exclude firms that had no product or process innovations or innovation activity, as defined in questions 2.1, 3.1 and 4.1 of the CIS questionnaire. The final sample used for the econometric estimates is composed of 6074 firms.

The CIS provides information on the various types of innovation implemented by companies during the reference period. This information is used to construct the dependent variables for the econometric model. In particular, we have four dichotomous variables that take the value 1 or 0 depending on whether the firm has introduced or not, respectively, product innovation (*Product* variable), process innovation (*Process*), organizational innovation (*Organization*) or marketing innovation (*Marketing*).

The econometric model applied is then formed of four equations, in each of which the dependent variable is binary and represents the performance of companies in the realization of a specific type of innovation. The equations are estimated jointly by the Multivariate Probit Model (MPM), a methodology that extends the Probit Regression Model, suitable for individual equations with binary dependent variable, in case of K equations with binary dependent and among them interdependent variables. This model allows taking into account the heterogeneity between the different types of innovations and, at the same time, the possible correlation between them.

[7] The industries included are: manufacturing, mining and quarrying and other industries; construction; wholesale and retail trade, transport and storage, accommodation and food service activities; information and communication; financial and insurance activities; real estate activities; professional, scientific, technical, administration and support service activities. The following industries are excluded from the survey: agriculture, forestry and fishing; public administration, defense, education, human health and social work activities; other services.

In our analysis, in fact, the dependent variables are probably correlated because innovative companies often implement at the same time more than one type of innovation. For example, a firm introducing a new product on the market can also use a new manufacturing process or a new form of marketing to promote it to the public. In such cases the choice of a type of innovation to be introduced is closely related to the choice of other types of innovations. In addition, it is likely that firms prone and accustomed to innovation would adopt this attitude in different areas and aspects of business.

The MPM starts with a probit specification, which assumes the existence of latent variables and explanatory variables related to K through structural equations:

$$y_{i,k}^{*} = x_{i,k}^{'}\beta_k + \epsilon_{i,k}$$

with $i = 1, \dots, N$ that indicates companies, $k = 1, \dots, 4$ system equations, x the explanatory variables and β the coefficients vector.

The dependent binary observable variables are related to latent variables by the relation:

$$y_{i,k} = \begin{cases} 1 \text{ if } y_{i,k}^{*} > 0 \\ 0 \text{ otherwise} \end{cases}$$

where it is assumed that $\varepsilon_{i,k} \sim N(0, \ V)$ with V covariance matrix of the error terms of K equations that have non-zero correlation.

The maximum simulated likelihood method is used to estimate the model parameters. The MSL involves multivariate normal probabilities but for high-order integrals satisfactory direct approximations in terms of speed and accuracy do not exist, therefore, simulation methods have been proposed. Following a large body of empirical literature, we rely on smooth recursive method proposed by Getewe-Hajivassiliou-Keane, the most accurate simulation method for evaluating multivariate normal distribution functions.[8]

The regressors of interest in the model, which are also calculated using data from the CIS, refer to the expenditure for the in-house research carried out by companies and their choices of cooperation in innovative activities. The variable *R&D* measures the amount of expenditure on research and development in domestic business and is expressed in terms of logarithms. The variable *Cooperation* is a dummy equal to 1 for the firms that have

[8] Hajivassiliou et al (1996) show that under regularity conditions this estimator is consistent when both the number of draws and observations tend to infinity. See Geweke (1989), Hajivassiliou (1998) and Keane (1994) for a more comprehensive discussion on the estimation method. Our estimates are based on 100 random draws.

established at least a collaborative relationship and is useful for testing the hypothesis H1a concerning the direct positive effect of cooperation on innovative performance of companies. The variables *c_group*, *c_suppliers*, *c_customers*, *c_competitors*, *c_universities*, *c_private* measure the direct effect that the cooperation has on the innovative capacity of firms. They are dichotomous variables equal to 1 for firms that declare to have collaborated with the following subjects:

- *c_group*: companies belonging to the same industrial group;
- *c_suppliers*: suppliers;
- *c_customers:* customers;
- *c_competitors*: competitors or other companies from the same industrial sector;
- *c_universities:* universities and other public research istitutes;
- *c_private:* external consultants and private research institutes.

On the basis of these dummies, we can make a precise distinction between competitive and non-competitive collaborations: in the first one we include collaborations with competitors, that is, with companies operating in the same market, while in the second one we include all others.

As mentioned previously, due to the nature of innovative activities, companies tend to achieve several types of innovations and collaborations simultaneously. Table 1 shows the distribution of firms by number of types of partners and innovations. In fact, the scores ranged from a minimum of 1 to a maximum of 6; these values refer to the fact that a company may establish (at least) a collaboration with 1, 2, 3, 4, 5 or 6 types of partners. The rows instead refer to the fact that a firm can perform (at least) an innovation of 1, 2, 3 or 4 different types. For example, among the companies that have cooperated with all kinds of partners, 43 have implemented all kinds of innovations. Excluding the cases of absence of cooperation and innovation, the table shows that most of the firms in our sample have made at least two different types of innovation and formed relations of cooperation with more than one type of partner.

Tab 1 – Distribution of companies according to the number of different types of innovations and cooperations.

		Types of cooperation (*number of*)							
		0	**1**	**2**	**3**	**4**	**5**	**6**	***Tot***
Types of innovation (*number of*)	**0**	131	11	5	7	1	1	0	***307***
	1	890	68	33	16	6	5	1	***1194***
	2	1311	120	66	33	14	17	5	***1575***
	3	1327	142	104	76	47	21	23	***1634***
	4	1002	132	148	125	90	53	43	***1364***
	Tot	***4661***	***473***	***356***	***257***	***158***	***97***	***72***	***6074***

To analyze the indirect role of R&D cooperation and its moderating effect on the relationship between in-house R&D and companies' innovative capacity, we follow the econometric strategy used by Huang and Yu (2011). That is, we introduce the econometric model of the interaction between the regressor variables on the cost of internal research and development and the regressors related to various types of collaboration: *R&S_group*, *R&D_suppliers*, *R&D_customers*, *R&D_competitors*, *R&D_universities* and *R&S_private*.

In the model there have been added some control variables related to companies and industries, in which they operate. *Turnover* is a proxy for the firm's size and is expressed in terms of the logarithm of sales in 2006. As a number of empirical studies have found evidence of a positive link between the size and innovative capacity, such a control is particularly important.

The propensity for innovation also varies between different business sectors, in which firms operate. To take into account sectoral specificities, we include two other regressors in the model: HH, Herfhindel-Hirschman index at 2-digit level of NACE Rev. 2 and IPP, an index of intellectual property protection also calculated at level 2-digit NACE Rev. 2. The first index measures the concentration in various sectors and is calculated by reference to the turnover recorded by the companies in 2006. Several reports indicate that a high competitive intensity within an economic sector can stimulate companies' innovation (Aghion et al., 2006; Aschhoff & Schmidt, 2008). However, this relationship does not seem to be standard, and some empirical studies, such as Huang and Yu (2011), found an opposite relation. The second regressor, IPP, is an indicator of the degree of intellectual property protection in each sector and is calculated using the information for four different forms of legal protection for patents, industrial designs, trademarks and copyrights. These data, combined into a normalized index value between 0 and 1, are obtained from the CIS database and refer to the 2004 survey. From the theoretical point of view, one might expect a positive sign of the coefficient: an increase in the protection of intellectual property provides more incentives to companies to invest in research and development. However, this assumption is challenged by a part of economic literature (e.g. Moser, 2005) and it seems more plausible to limit the importance of intellectual protection exclusively to areas characterized by lower costs of imitation than those of innovation.

In addition, to take into account non-observable sectoral differences, we introduce dichotomous variables that, according to the classification adopted by Eurostat and the OECD, regroup the services and manufacturing sectors according to their technological intensity. In particular, for the manufacturing sector, *htc* identifies areas with high technological content, *m_htc* sectors with medium-high technological content, *m_ltc* sectors with medium-low technological content and *ltc* sectors with low technological content. For services, instead, *kis* refers to the sectors with high content of knowledge and *lkis* to sectors with low content of knowledge.

Table 2 shows the descriptive statistics of the variables used in the econometric analysis regarding the companies included in the sample.

Tab 2 – Descriptive statistics

	Mean	Std. Dev.	Min.	Max.
Product	0,70	0,45	0	1
Process	0,76	0,49	0	1
Organization	0,59	0,49	0	1
Marketing	0,52	0,49	0	1
Turnover*	9,18	1,91	3,85	16,35
HH	0,04	0,03	0,01	0,32
IPP	0,41	0,25	0	1
R&D*	2,30	2,89	0	13,24
c_group	0,08	0,27	0	1
c_suppliers	0,13	0,33	0	1
c_customers	0,08	0,27	0	1
c_competitors	0,07	0,25	0	1
c_universities	0,10	0,30	0	1
c_private	0,11	0,31	0	1

Note. * Natural logarithm of thousands of euro.

4. Analysis of results

The results of the basic model are reported in Table 3.

Column (1) refers to the specification with the controls as the only explanatory variables and is useful for assessing the contribution of the variables of interest that will subsequently be included in the model. In columns (2) and (3) the regressors have been added respectively for the internal R&D and cooperation and, finally, in column (4), instead of the variable *Cooperation*, there are dummies inserted for the different forms of collaboration.

Regarding the control variables, the estimates indicate that increasing the size of the companies their innovative performance grows. The *Turnover* variable has, in fact, a positive sign and is statistically significant. This result is not in line with the work of Belderbos at al. (2004b) that, on a sample of Dutch firms, does not detect a significant impact of size on innovation performance, as measured by growth in labor productivity. For the Italian case, however, there still prevails a paradigm saying that it is especially big companies that make innovations.

The degree of competitiveness of a sector, measured by the index of Herfhindel-Hirschman, shows a negative sign and is significant for process, organizational and marketing innovations: with the increase of concentration of the industry companies have less incentive to implement these types of innovation. A similar result could be interpreted by the presence of quasi-monopoly rents that characterize industries with a low degree of competition. Such rents would not push companies to pursue cost savings or increased internal efficiency objectives typically associated with process and organizational innovations. For product innovations instead the variable has alternating signs and is not statistically significant.

The index of intellectual property protection is statistically significant when we consider product innovations, showing a positive correlation between the appropriability of research results and the propensity of firms to innovate, while for other types of innovation it has no statistical significance. These results suggest that Italian firms, probably due to the small size, are reluctant to use formal methods and legal protection of intellectual property.

Carrying on the analysis of the main variables of interest, columns (2-4) indicate the positive role that the internal research and development plays in all types of innovation. In the various specifications of the base model, R&D always has a positive sign and is statistically significant, with a greater impact on product innovation than on marketing. The companies can then improve their innovative capacities by investing primarily on internal research and development resources.

Column (3) shows for all types of innovation considered, a positive sign and is statistically significant, even the dummy *Cooperation*. This confirms the hypothesis H1a on the general positive direct effect of R&D cooperation on the propensity of business innovation.

Column (4) finally shows the estimation of the specification with the individual dummies of collaboration in place of the variable *Cooperation*. The signs of coefficients are all positive, but the statistical significance provides mixed results. Cooperation with suppliers, competitors and private consultants is always statistically significant, but this is not true for collaborations with companies in the group and with customers, whose significance depends on the type of innovation considered; in case of collaborations with universities, they are never statistically significant. These results, however, may be due to the high correlation between the various dummies[9] relating to cooperative activities.

[9] In the appendix there is a correlation matrix for the variables of interest of the model, which shows a strong correlation between the dummies and also cooperation with the R&D variable.

Tab. 3 – Estimates of the basic model

Y = Product	(1)	(2)	(3)	(4)
Turnover	0,07***	0,02***	0,01*	0,02**
HH	0,26	-0,44	-0,42	-0,38
IPP	0,30***	0,38***	0,39***	0,39***
R&D		0,11***	0,10***	0,10***
Cooperation			0,36***	
c_group				0,11
c_suppliers				0,28***
c_customers				0,32***
c_competitors				0,06*
c_universities				0,13
c_private				0,16*
Y = Process				
Turnover	0,06***	0,04***	0,04***	0,04***
HH	-1,13**	-1,48***	-1,49***	-1,42***
IPP	-0,07	-0,05	-0,05	-0,04
R&D		0,05***	0,04***	0,01**
Cooperation			0,17***	
c_group				0,12
c_suppliers				0,17**
c_customers				0,07
c_competitors				0,14*
c_universities				0,12
c_private				0,15**
Y = Organization				
Turnover	0,07***	0,05***	0,04***	0,04***
HH	-1,69***	-1,95***	-1,99***	-1,94***
IPP	-0,05	-0,02	-0,02	-0,01
R&D		0,04*	0,03***	0,03***
Cooperation			0,37***	
c_group				0,21***
c_suppliers				0,27***
c_customers				0,12
c_competitors				0,25***
c_universities				0,02
c_private				0,16**
Y = Marketing				
Turnover	0,03***	0,02***	0,01**	0,01***
HH	-2,79**	-2,95***	-2,98***	-2,91***
IPP	-0,07	-0,05	-0,05	-0,04
R&D		0,02***	0,02**	0,01**
Cooperation			0,24***	
c_group				0,10
c_suppliers				0,22***
c_customers				0,02
c_competitors				0,17**
c_universities				0,13
c_private				0,22***
Pse.ll	-15312	-15183	-15106	-15044

Wald	2221	2230	2267	2328
N	6074	6074	6074	6074

*, **, *** *Coefficient statistically significant at 10%, 5%, 1%.*

Table 1 has shown that companies do not limit their cooperation strategies to one type of partners but, on the contrary, establish more types of bonds simultaneously. This consideration suggests the presence of a strong interdependence between various forms of cooperation, which from the econometric point of view, results in a strong positive correlation between the dummies for collaboration. The specification (4) of the basic model that considers jointly all the dummies then, although more consistent with the theoretical discussion presented in section 2, suffers from a significant problem of multicollinearity. In order to purify the results obtained so far, there are six constrained models estimated, which consider separately the different forms of partnership. The estimates given in Tables 5a and 5b provide more robust results in terms of statistical significance with respect to the joint estimate.

Regarding the econometric methodology, in Table 4, with reference to the specifications of the basic model, there are correlation coefficients (ρ) between the error terms of the equations that the MPM estimate simultaneously. All parameters are positive and statistically significant, confirming the hypothesis H1b and, therefore, the choice of the MPM as an estimation strategy. A similar result supports the idea that different types of innovation implemented by enterprises are interdependent and complementary; innovative activity is not limited to a single type of innovation but it is rather more structured and systematic.

Tab. 4 – Correlation between the equations of the multivariate probit

	(1)	(2)	(3)	(4)
ρ_{21}	0,08*** (0,02)	0,07*** (0,02)	0,06*** (0,02)	0,06*** (0,02)
ρ_{31}	0,07*** (0,02)	0,06*** (0,02)	0,04*** (0,02)	0,04*** (0,02)
ρ_{41}	0,20*** (0,02)	0,19*** (0,02)	0,18*** (0,02)	0,18*** (0,02)
ρ_{32}	0,18*** (0,02)	0,17*** (0,02)	0,17*** (0,02)	0,16*** (0,02)
ρ_{42}	0,12*** (0,02)	0,11*** (0,02)	0,11*** (0,02)	0,10*** (0,02)
ρ_{43}	0,27*** (0,02)	0,27*** (0,02)	0,26*** (0,02)	0,25*** (0,02)
LR Test (χ^2) ρ	480,8	487,3	499,6	501,4
Pse.ll	-15312	-15183	-15106	-15044
Wald	2221	2230	2221	2328
N	6074	6074	6074	6074

*, **, *** *Coefficient statistically significant at 10%, 5%, 1%.*
Heteroskedasticity-robust standard errors in parentheses.

The estimates of the constrained model show that the direct effect of cooperation on innovative performance of companies is always positive and statistically significant. The point estimates also indicate that the impact is different depending on the type of partner chosen for cooperation, thus confirming the hypothesis H2. Cooperation with suppliers (*c_suppliers*) has a direct, very strong impact on all types of innovation considered. This result is in contrast with other studies where no positive effect is shown on collaboration upstream (Aschhoff & Schmidt, 2008) or a positive effect limited only to process innovations (Belderbos et al. 2004b). In the Italian case, instead, it seems that collaboration with suppliers brings the greatest benefits for the innovative performance of companies.

Another result that differentiates the Italian situation concerns the effects of collaboration with customers (*c_customers*). In fact, this kind of cooperation should not have a significant impact on innovative activities of firms since information about the needs of customers (downstream firms) pass through market transactions and hence, the establishment of formal relations would not be needed (Belderbos et al. 2004b). Our findings, however, suggest the opposite, namely that the cooperation with customers has a decisive impact on the propensity to innovate of Italian companies. The non-competitive collaborations of vertical type, both upstream and downstream, are then the ones that stimulate innovative activities of Italian companies most of all.

Truly relevant is also the result of the collaboration between firms and private consultants (*c_private*), especially with reference to organizational innovations. Italian companies, in order to achieve costs reduction and to increase internal efficiency, seem to be oriented towards purchasing from outside the skills they lack.

Cooperation within a corporate group (*c_group*), although statistically significant and with a positive sign, seems to bring minor benefits to the innovative performance of the company. This result can be attributed in part to the difficulty of classifying the nature of this type of cooperation between those competitive or non-competitive. Similar concerns apply to cooperation with universities: the coefficients of the variable *c_universities* are positive and statistically significant but, for all four types of innovation they are lower than the coefficients of the other cooperation dummies. Our estimates, therefore, indicate that collaborating with universities and other public research institutions provides lower benefits on the innovative performance of firms.

The collaborations of competitive type (*c_competitors*) finally have a direct positive impact on the propensity of firms to innovate, which is particularly strong in case of organizational innovations. This result, contrasting with some previous studies (Nieto & Santamaria, 2007), can be interpreted as a support for the non-tournament literature (d' Aspermont & Jacquemin, 1988, 1990; Kamien et al., 1992), according to which the cooperation with competitors can ensure significant advantages in cost reduction and thus, has a stronger effect in reference to organizational innovation. The hypothesis H3, concerning the less positive effect of competitive collaboration when compared to those of non-competitive collaboration, does not encounter clear empirical evidence. When product innovation is considered, the impact of the former is actually lower than the non-competitive collaborations of vertical type with private consultants. For other types of innovation, however, there have not been any significant differences observed between the various estimated coefficients.

The variable related to in-house R&D and control variables related to the size of the companies, the degree of sectoral competitiveness and protection of intellectual property provide results in line with the specifications of the basic model discussed above.

The next step is to verify if the R&D collaborations, in addition to the direct effect of the capacity to innovate, have also an indirect effect through the moderation exerted on internal research and development. To this end, we have extended the previous econometric model inserting, individually, various types of collaborations and their interactions with the variable *R&D*[10].

The results, presented in Tables 6a and 6b suggest that the hypothesis H4 is only partially confirmed. Only with regard to organizational innovations there have been found significant indirect effects, primarily of cooperation with suppliers and customers and, to a lesser extent, of partnerships with universities and competitors. For other types of innovation, however, the indirect effects are quite weak and limited to cooperation with suppliers in product innovations, and companies belonging to the same group in process innovations. Finally, marketing innovations are a special case in a sense that collaborations with customers, competitors, universities and private consultants have a moderating effect, which is significant, but negative.

Bearing in mind that, overall, the indirect effects are quite weak, it is interesting to note that non-competitive cooperation, with reference to collaborations with suppliers and companies of the same group, seems to bring more indirect benefits than cooperation of competitive type. The latter is, in fact, less statistically significant and provides contrasting results, in terms of sign, in different types of innovation. This result is consistent with that obtained by Huang and Yu (2011) who analyzed the collaborations of 175 technology companies in Taiwan.

Also in this model specification the *R&D* variable, the dummies related to the direct effects of various forms of collaboration and the controls retain their signs and statistical significance noted in the previous specifications, which supports the robustness of the estimates.

Table 7 summarizes main results of the empirical analysis, reporting statistical significance and sign of the direct and indirect effects for all possible combinations of forms of collaboration and types of innovation.

[10] The *R&D* variable is excluded from this specification of the model. This strategy, based on the high correlation with the interaction terms, has already been adopted by Huang & Yu (2011). However, also including in the *R&D* variable in the model, similar results are obtained in terms of sign and statistical significance, with only minor changes in the point estimates of coefficients.

Tab 5a – Direct effects of collaborations, for each type of partner, on product and process innovations.

	Y = Product						*Y = Process*					
Turnover	0,01*	0,02**	0,02***	0,02***	0,02***	0,02***	0,03***	0,04***	0,04***	0,04***	0,04***	0,04***
HH	-0,40	-0,33	-0,55	-0,43	-0,49	-0,41	-1,45***	-1,43***	-1,57***	-1,49***	-1,51***	-1,46***
IPP	0,41***	0,39***	0,37***	0,38***	0,39***	0,39***	-0,02	-0,05	-0,06	-0,05	-0,05	-0,04
R&D	0,11***	0,10***	0,10***	0,11***	0,10***	0,10***	0,04***	0,04***	0,04***	0,04**	0,04***	0,04***
c_group	0,33***						0,25***					
c_suppliers		0,48***						0,31***				
c_customers			0,57***						0,28***			
c_competitors				0,35***						0,30***		
c_universities					0,20***						0,12***	
c_private						0,42***						0,30***
Pse.ll	-15144	-15083	-15121	-15135	-15164	-15112	-15144	-15083	-15121	-15135	-15164	-15112
Wald	2224	2315	2248	2273	2227	2282	2224	2315	2248	2273	2227	2282
N	6074	6074	6074	6074	6074	6074	6074	6074	6074	6074	6074	6074

, **, * Coefficient statistically significant at 10%, 5%, 1%.*

Tab 5b – Direct effects of collaborations, for each type of partner, on organizational and marketing innovations.

	Y = Organization						*Y = Marketing*					
Turnover	0,04***	0,05***	0,05***	0,05***	0,05***	0,05***	0,01*	0,02**	0,02***	0,02***	0,02***	0,02**
HH	-1,92***	-1,90***	-2,09***	-1,97***	-2,05***	-1,95***	-2,94***	-2,92***	-3,06***	-2,99***	-3,00***	-2,95***
IPP	0,02	-0,02	-0,04	-0,03	-0,01	-0,01	-0,02	-0,05	-0,06	-0,06	-0,05	-0,04
R&D	0,04***	0,03***	0,03***	0,04***	0,03***	0,03***	0,02***	0,02**	0,02**	0,02***	0,02***	0,01**
c_group	0,44***						0,27***					
c_suppliers		0,51***						0,38***				
c_customers			0,49***						0,29**			
c_competitors				0,52***						0,35***		
c_universities					0,32***						0,15**	
c_private						0,48***						0,37***
Pse.ll	-15144	-15083	-15121	-15135	-15164	-15112	-15144	-15083	-15121	-15135	-15164	-15112
Wald	2224	2315	2248	2273	2227	2282	2224	2315	2248	2273	2227	2282
N	6074	6074	6074	6074	6074	6074	6074	6074	6074	6074	6074	6074

, **, * Coefficient statistically significant at 10%, 5%, 1%.*

Tab 6a – Indirect effects of collaborations, for each type of partner, on product and process innovations.

	Y = Product						*Y = Process*					
Turnover	0,06***	0,06***	0,06***	0,07***	0,07***	0,06***	0,05***	0,06***	0,06***	0,06***	0,06***	0,06***
HH	0,27	0,26	0,02	0,23	0,12	0,22	-1,17**	-1,17**	-1,27**	-1,18**	-1,26**	-1,19**
IPP	0,34***	0,33***	0,29***	0,30***	0,32***	0,32***	-0,05	-0,06	-0,08	-0,08	-0,07	-0,06
c_group	0,33***						0,15					
R&D_group	0,02						0,03*					
c_suppliers		0,43***						0,28***				
R&D_suppliers		0,04**						0,02				
c_customers			0,57***						0,35***			
R&S_customers			0,03						0,00			
c_competitors				0,42***						0,35***		
R&D_competitors				0,01						0,00		
c_universities					0,53***						0,12	
R&D_universities					-0,03						0,02	
c_private						0,50***						0,31***
R&D_private						0,01						0,01
Pse.ll	-15260	-15184	-15223	-15246	-15266	-15210	-15260	-15184	-15223	-15246	-15266	-15210
Wald	2227	2305	2251	2283	2247	2319	2227	2305	2251	2283	2247	2319
N	6074	6074	6074	6074	6074	6074	6074	6074	6074	6074	6074	6074

*, **, *** *Coefficient statistically significant at 10%, 5%, 1%.*

Tab 6b – Indirect effects of collaborations, for each type of partner, on organizational and marketing innovations.

	Y = Organization						*Y = Marketing*					
Turnover	0,06***	0,06***	0,07***	0,07***	0,06***	0,06***	0,02***	0,02***	0,03***	0,03***	0,03***	0,03***
HH	-1,71***	-1,75***	-1,96***	-1,81***	-1,90***	-1,77***	-2,77***	-2,84***	-2,86***	-2,78***	-2,84***	-2,78***
IPP	-0,01	-0,03	-0,06	-0,05	-0,03	-0,03	-0,03	-0,05	-0,08	-0,07	-0,06	-0,05
c_group	0,35***						0,40***					
R&D_group	0,03						-0,02					
c_suppliers		0,43***						0,34***				
R&D_suppliers		0,03**						0,01				
c_csutomers			0,37***						0,48***			
R&D_customers			0,04**						-0,04**			
c_competitors				0,42***						0,51***		
R&D_competitors				0,04*						-0,04*		
c_universities					0,21*						0,36***	
R&S_universities					0,03*						-0,03*	
c_private						0,47***						0,55***
R&S_private						0,01						-0,04**
Pse.ll	-15260	-15184	-15223	-15246	-15266	-15210	-15260	-15184	-15223	-15246	-15266	-15210
Wald	2227	2305	2251	2283	2247	2319	2227	2305	2251	2283	2247	2319
N	6074	6074	6074	6074	6074	6074	6074	6074	6074	6074	6074	6074

, **, * Coefficient statistically significant at 10%, 5%, 1%.*

Tab 7 – Impact of R&D cooperation by the type of partner and innovation

		Product	**Process**	**Organization**	**Marketing**
Group	*direct effect*	Medium	Medium	Strong	Medium
	indirect effect	n.s.	Positivo	n.s.	n.s
Suppliers	*direct effect*	Strong	Medium	Strong	Medium
	indirect effect	Positive	n.s	Positive	n.s.
Customers	*direct effect*	Strong	Medium	Strong	Medium
	indirect effect	n.s.	n.s.	Positive	Negative
Competitors	*direct effect*	Medium	Medium	Strong	Medium
	indirect effect	n.s.	n.s.	Positive	Negative
Universities	*direct effect*	Weak	Weak	Medium	Weak
	indirect effect	n.s.	n.s.	Positivo	Negative
Private	*direct effect*	Strong	Medium	Strong	Medium
	indirect effect	n.s.	n.s.	n.s.	Negative

Note: the direct effects are always positive and their intensity is indicated.
n.s. = coefficient not statistically significant.

5. Conclusions

In spite of the widespread literature on the reasons for companies to establish cooperation with different partners in R&D, the empirical studies that evaluate the effects of such collaborations on innovative performance are not numerous.

This study has analyzed the impact of cooperation strategies with different types of partners (companies belonging to the same group, suppliers, customers, competitors, universities and private external consultants) on four types of interconnected innovations (product, process, organizational and marketing). The potential complementarity and heterogeneity that characterize the strategies of cooperation and innovation have been checked with a multivariate probit model. The analysis was conducted on a sample of Italian companies derived from the Community Innovation Survey (2008), distinguishing between direct and indirect impact of various forms of collaboration.

The results have demonstrated a significant direct positive effect of cooperation, articulated and specific, depending on the partner chosen and the type of innovation considered. The non-competitive collaborations of vertical type, both upstream and downstream, bring greatest benefits to the innovative performance of companies. Even collaborations with competitors seem to stimulate innovative activity, even though with a lower intensity. The cooperation with universities, by contrast, has a modest direct impact on innovative performance of companies. The business world and universities, even if a certain degree of cooperation between them is present, still seem quite far from generating a synergistic effect that all hope for and which seems to be already present in other contexts (Belderbos et al, 2004b; Aschoff & Schmidt 2008; Lööf & Broström, 2008). However, it needs to be noted that in this study the companies' performance has beens measured in the short run and this is undoubtedly its limit. In fact, it is well known that a part of the R&D results is achieved only in the long run, and this is especially true for cooperation with universities, which are more orientated towards basic research.

The indirect benefits are only present in some type of non-competitive collaborations (with suppliers and companies of the same group), while in the collaborations of competitive type, conflicting results come out. Only in the case of non-competitive cooperation companies are able to fully take advantage of the benefits coming from external collaborations, assimilating the knowledge generated thanks to their partnerships and thereby increasing their absorptive capacity.

Nevertheless, it should be noted that overall, the indirect effects are very weak. The R&D cooperation has thus little moderating effect on the relationship between in-house R&D and innovative capacity of Italian companies. This means that through cooperation Italian firms obtain the advantages specific to the particular object of partnership, but do not manage to increase their overall innovative capacity. In other words, R&D cooperation does not seem to generate significant knowledge spillovers. Such a finding is open for a twofold interpretation. On the one hand, Italian companies have inherent difficulties to internalize the skills and knowledge generated by collaborative relationships with external parties, perhaps due to the widespread attitude of mistrust that characterizes the country's economic and social environment. In this respect, indeed, it is widely recognized that the level of social capital in the country is quite low. On the other hand, the level of in-house R&D spending in private sector is rather limited in Italy as it is one of the lowest among the EU countries. This leads to a lack of interaction with external sources of knowledge and research, which, no doubt, reduces the strength of indirect effects that we have analyzed.

In addition, the controls indicate that sectoral specificities are relevant when we take into account different degrees of companies' innovation. Finally, larger firms that spend more on internal research and development have a greater propensity to innovate.

A limitation of this study is related to the cross-sectional structure of the data used. Since most of the explanatory variables are contemporaneous with the phenomenon that they intend to explain, that is, the propensity of firms to innovate, we have to be cautious in interpreting the results in terms of causal relationships between variables.

Appendix - Correlation between the variables of interest of the econometric model

Tab 1 – Correlation matrix for variables related to in-house R&D and various forms of collaboration

	R&D	c_group	c_suppliers	c_customers	c_competitors	c_universities	c_private
R&D	1						
c_group	0.23*	1					
c_suppliers	0.19*	0.40*	1				
c_customers	0.20*	0.35*	0.50*	1			
c_competitors	0.12*	0.22*	0.41*	0.41*	1		
c_universities	0.35*	0.35*	0.40*	0.41*	0.34*	1	
c_private	0.25*	0.37*	0.59*	0.47*	0.37*	0.56*	1

*N=6074; * Coefficient statistically significant at 1%.*

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