Università Cattolica del Sacro Cuore

DIPARTIMENTO DI DISCIPLINE MATEMATICHE,
FINANZA MATEMATICA ED ECONOMETRIA

Cooperative innovation

Evidence from Italian firms

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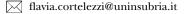Maria Grazia Zoia

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Abstract

For small and medium-sized enterprises (SMEs), R&D cooperation with sources of external knowledge is becoming increasingly essential for fostering innovation activities. This paper investigates the effects of collaboration on innovation by considering four different partner types: competitors, customers, suppliers, Universities and Government laboratories. Using firm-level data from the Community Innovation Survey for the years 2006-2008 (CIS 2008) and applying a Heckman probit model with sample selection, we analyse the determinants of cooperation and innovation probabilities for each type of partner. Results show that internal and external R&D acquisitions, public financial support, as well as belonging to a scientific sector or to a business group are significant determinants of the partners' choice for collaboration, although with different magnitude across various types of collaborations.

JEL classification: <u>O32</u>; <u>L24</u>

Keywords: cooperation; innovation; discrete choice; sample selection bias.

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1 - *Introduction*

Social capital theory has been used to analyse the internal and external networks in organizations (Nahapiet and Ghoshal, 1998; Leenders and Gabbay, 2001) and during the last decade, it has been applied to technological innovation and inter-organizational cooperation at a firm level. In fact, in the knowledge economy, when globalization processes induce firms to face strong competitive pressure, it is no longer sufficient to rely on in-house innovation. Making "permeable the borders of the firm" is becoming more and more important. Therefore, firms should acquire and exploit knowledge by both cooperating with external entities and increasing communication between internal departments in order to introduce either new or higher quality products faster and more cheaply than competitors and to gain new competitive advantage. External and internal linkages constitute what is called "corporate social capital". The role played by partners as a source of knew - knowledge is becoming more important than in the past, as entrepreneurs recognise that technological innovations are less and less the outcome of an individual firm's isolated effort (Fisher and Varga, 2002; Drejer and Jorgensen, 2005).

Starting from the seminal contribution of Mariti and Smiley (1983), a substantial empirical and theoretical effort has been devoted to an understanding of R&D collaboration (for a survey of the literature see, e.g., Ozman, 2009). In particular, a large number of cross-sectional studies have shown the positive impact of external R&D cooperation on corporate innovation performance. This result parallels the well known fact that innovations are increasingly brought in the market by networks of firms (see, e.g., Loof et al, 2002, Miotti and Schwald, 2003; Faems et al, 2005; Hoang et al., 2005; Loof et al. 2008). This can be explained through different theoretical arguments: R&D partnerships are alternatively seen as means to internalize spillover, to reduce transaction costs and/or to explore and assimilate new knowledge fields embedded in other firms' core competencies.

Even if the number of R&D partnerships has significantly increased in the last 20 years, most of the existing literature does not

distinguish cooperation by type of partners, but instead aggregates over cooperation types, with some notable exceptions (Belderbos et al., 2004; Tether, 2002).

This paper aims at investigating the determinants of cooperative behaviour of Italian innovative firms. The influence of cooperation on firms' capability to introduce new or significantly improved goods, services or production processes is analysed using firm level data from the Community Innovation Survey (CIS 2008) for Italy. In contrast with previous literature, we examine this phenomenon over three dimensions: vertical cooperation, i.e. firms that carry out cooperation with customers and suppliers; horizontal cooperation, i.e. firms' that cooperate with their competitors, consultants, research institutes or private labs, and institutional cooperation, i.e. cooperation agreements with Universities and public research centres. This paper therefore combines considerations related to the determinants of R&D cooperation with issues dealing with the impact of collaboration on innovation performance.

Our dataset includes both innovative and non-innovative firms. Since the partner for cooperation activity is only observed for those firms that innovate, we face a possible problem of sample selection. As a consequence, we apply a Heckman probit to account for this issue. The model we estimate is thus composed by two equations, the first devoted to innovative and the second to cooperative behaviour. Since we are interested in exploring the determinants of cooperation, we include each explanatory variable in all these two equations.

With reference to innovation activities, the present paper aims at investigating i) the determinants of firms' partner choice for collaboration and, ii) the factors affecting firms' capability to introduce new or significantly improved goods and/or services and/or processes. We show that forms of collaboration differ across cooperation types and vary strongly according to specific firms' attributes. In particular: (i) internal and external R&D acquisitions and belonging to the scientific sector have a significant positive impact on collaboration with Universities and other research centers; (ii) external R&D acquisition, being part of a business group and public financial support

are dominant positive determinants both for vertical and horizontal collaboration.

The paper is organized as follows. Section 2 reviews the literature on the relation between collaboration networks and innovation whilst Section 3 provides an overview of the data and some descriptive statistics. Section 4 describes the variables used by the Heckman model and Section 5 discusses empirical results. Section 6 provides the conclusions and the policy implications. A methodological appendix regarding the econometric specification used in the empirical analysis completes the paper.

2 - *Literature Review*

As cooperation has become more and more crucial in innovation processes, firms have been struggling to find external partners. In recent years several theoretical and empirical analyses have been put forward to explain R&D cooperation strategies for innovation. In particular, we focus on two main streams of research.

The first is the industrial organization literature, which focuses on the importance of both incoming and outgoing spillover as a major determinants or R&D cooperation strategies. The second regards the management literature, which applies the transaction cost theory and concludes that firms may choose to cooperate in order to reduce and share respectively the costs and the risks associated to the innovation process (see, e.g., Das and Tend, 2000).

As regard the first approach, the incoming spillovers refer to the external flow of knowledge a firm may be able to grasp, while outgoing spillovers pertain to firms' ability to control the stock of knowledge that may eventually flow out of the firm itself. In early studies on R&D collaboration, cooperation was most often captured as a homogenous object (i.e. R&D cooperation vs. internal R&D) and the emphasis was mainly on technological spillovers as factors that influence the firms' decision to cooperate (see, e.g., Kats, 1986; D'Aspermont et al., 1988; and Kamien et al., 1992). They conclude that if incoming spillovers are sufficiently high, firms are induced to collaborate in order to internalize the possible advantages. Moreover, the possibility of knowledge leakages may increase firms' willing-

ness to take advantage of R&D investment partners. These early models have been later extended, recognizing that firms attempt to minimize the outgoing spillover, and maximize the incoming spillover (Belderbos et al. 2004; Lopez, 2008).

In recent years, this relationship has been empirically tested. Cassiman and Veugelers (2002) measure the impact of publicly available information on the probability of collaboration and show that a higher probability of collaborating with research organizations is associated with a higher incoming spillover. Moreover, Veugelers and Cassiman (2005) show that the main characteristics of the R&D cooperation between industry and University are the high uncertainty, the high transaction costs and the high spillovers to other market actors, while the firms' ability to control the outgoing spillover is not crucial for this decision.

Whilst research institutions (University and Research Centre) aim at providing new scientific and technological knowledge (Drejer and Jorgenses, 2005) which are relevant in producing innovation, only a few studies consider this relationship. Ashhoff et al. (2006) conclude that collaborations with Universities improve the probability of innovative firms of developing new products, and Belderbos et al. (2004) find that it increases in the growth of sales are related to market novelties. Loof et al. (2008) show that this kind of collaboration influences innovative performance. Levy et al. (2009) find that companies in high tech sectors, or located in foreign countries are likely to activate a multi-partner collaboration with the University, while domestic and regional companies have higher propensity to activate exclusive collaboration.

The second approach aimed at explaining the determinants of R&D cooperation emphazises the firms' resources constraints, i.e. cost, risk, knowledge complementarities, appropriability as determinants of cooperation. In this sense, the innovation success is influenced by the nature of cooperation partners. Collaboration can be either vertical or horizontal.

Vertical collaboration can be established with customers or suppliers and allows a firm to gain considerable knowledge about new technologies, markets and process improvements (Whitley, 2002). It

has a more significant impact on both product and process innovation (Miotti and Schwald, 2003). Specifically, cooperation with customers aims to reduce the risk related to market uncertainty by increasing the probability that the innovation will be a commercial success while collaboration with suppliers aims to secure and increase the quality of firms' inputs and to benefit from cost reductions through innovation process. In particular, Fritsch and Lukas (2001) state that innovative efforts are associated with client collaboration finalized to achieve product innovations. Moreover, there is a strong evidence that market information from clients and a direct collaborations leads to more successful new product development (see, e.g., Amara and Landry, 2005). Tether (2002) also concludes that collaborations with clients could be beneficial when we consider innovation with high degree of novelty. Cassiman and Veugelers (2002) show that higher appropriability[1] increases the probability of cooperation with suppliers and customers but has no significant impact on cooperation with research institution. Lopez (2008) contrasts this result and shows that the effectiveness of strategic protection has a positive impact on cooperation with any other partner. Furthermore, collaboration with suppliers allows firm to reduce the risk of new product development, while contribute to improve flexibility, product quality and market adaptability (Chung and Kim, 2003). Catozzella and Vivarelli (2007) emphasize the role played by internal R&D investments in fostering the complementarity of innovative inputs. Innovation is a complex phenomenon consisting of substitutability and complementarity relationships, where the possibility of benefiting of synergies between innovative inputs depends on the amount of internal R&D. In-house R&D, besides generating an innovative output by its own, expands the effects of other innovative inputs interacting with it. Finally, cooperation with customers is positively related to the success of process innovations (Freel et al., 2006) and positively affects growth in sales of product and services new to the market (Belderbos et al., 2004). It is worth noticing that firms' interactive dynamic capabili-

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[1] We refer to appropriability as the firms' ability to control outflows of knowledge. If firms are not able to protect their knowledge, the possibility of free-riding increases, and the probability of signing collaboration agreements decreases.

ties may be positively affected by firms' interactions with clients and suppliers (Iammarino et al., 2013). Vertical cooperation is based on a complex process of "learning by interaction or using" from upstream suppliers and downstream users (Von Hippel, 1988).

Horizontal collaboration can be established with competitors. It is often motivated by concerns regarding knowledge appropriability (as, e.g. in D'Aspremont and Jacquemin, 1988), knowledge exchange or cost sharing (Miotti and Sachwald, 2003) and aims at producing some basic research and at establishing standards by sharing common problems outside the competitor's area of influence (Tether, 2002; Bayona et al., 2001). This is because collaborating with a competitor can greatly enhance the knowledge base of a firm because competitors usually have similar needs in terms of product and process development so that the knowledge base developed by a firm may be particularly relevant for its competitors. However, because partners remain competitors, it is not certain that they will be systematically very cooperative in sharing their knowledge. In fact, if from one side pre-competitive programs can provide the grounds for working with competitors, form the other side firms engaged in such agreements face the risk of stiff competition in the future. The empirical evidence is not unique. Belderbos et al. (2004), Loof et al. (2002), and Aschhoff et al (2008) seem to confirm that horizontal cooperation improve firm performance. However, Caloghirou et al. (2003) and Dyer et al. (2006) do not find a significant impact of competitors on the overall success of R&D.

Recently, the so called "open innovation model" (see, e.g., Chesbrough, 2003, Laursen and Salter 2006) reinforce the view that firms draw knowledge that may lie outside their own boundaries. More precisely, according to this paradigm, firms should use inflows and outflows of knowledge and expand the market for the external use of innovation by collaborating with partners. In this way firms would share risks and reward thus achieving advanced technological capabilities (Iammarino et al., 2013).

It is important to point out that both horizontal and vertical collaboration involve learning processes which rely on the firm's absorptive capacity (Von Tunzelmann, 2009) In fact, cooperation in

R&D and other innovation activities may positively affect the firm's competencies and capabilities only if the firm's learning and absorption processes are at work. In this framework, learning process may be either internal (that is generated by the production activity) or external (that is stemming from suppliers, users or general advances in science and technology) (Iammarino et al., 2013).

3 - *Data description*

Our empirical analysis is based on data from the Community Innovation Survey 2008 (CIS 2008). The Community Innovation Survey is a firm level survey, compiled every 4 years in all EU member states and some non-EU countries. The survey on the Italian sample is administered by the Italian National Institute of Statistics (ISTAT).

The CIS 2008 is a micro dataset specifically planned to study the innovative performance at firm-level and, as such, it has been designed to analyse the main features of firms' innovation activities. The CIS questionnaire provides both a set of general information (such as main industry of affiliation, group belonging, turnover, employment, exports, etc.) and a broad set of variables measuring the firms' level of innovation (e.g. expenditure on innovation, public funding, sources of information for innovation, innovation co-operation, innovation objectives, organisational and marketing innovation, environmental related benefits from innovation, etc.).

In particular, CIS 2008 focuses on co-operations towards the attainment of innovation insofar as it measures the active partnership of the observed enterprise with other enterprises or non-commercial institutions such as Universities or public research institutes, both at a national and an international level. Moreover, co-operation may involve more than one partner and concerns products, services and process innovations. The questionnaire collects data coming from a stratified sample of companies, which proves to be representative of the Italian firms with more than 10 employees in different sectors. The extensions of sample results to the entire population can be done

by means of a weighting procedure that relates the interviewed firms to those of the population (ISTAT, 2010). The 53 percent response rate registered for this data set has determined a sample of 19,904 firms. Given the original CIS 2008 database, we proceeded to restrict the analysis to units with observable values for the expenditure in external R&D activities. We further drop firms declaring to co-operate although not innovating. We end up with a sample of 19,890 firms. In order not to reduce the representativeness of the sample at stake we have not further restricted its size at a first stage of the analysis. The composition of the sample firms used in the analysis is shown in Figure 1. On the whole of the 19,890 firms, 38 percent (7,463) out of all firms are innovative. Specifically, the innovative firms are defined as those that accomplished technological innovations during the period 2006-2008.

With reference to cooperation with external agents, the survey asked innovative firms two sequential questions. The former aimed at knowing whether firms have signed any cooperative agreement on innovation activities with other firms or institutions during the three years 2006-2008 or not. Firms that signed a cooperative agreement were asked to indicate the type of firms and institutions they cooperated with, as well as its geographical location. Respondents could select more than one partner among these: other businesses within the business group; suppliers of equipment, materials, services, or software; clients or customers; competitors or other businesses in your industry; consultants, R&D institutes and private labs; Universities or other higher education institutions; Government or public research institutes. In the same question the information on the type partners is crossed with that of its geographical location: a) Italy, b) the EU member states, candidates and EFTA countries, c) the United States, d) China and India, and e) other countries.

Among innovative firms, a share of 22 percent (1,609) signed at least one co-operative agreement on innovation related activities during the period 2006-2008. Figure 2 lists the types of collaborations. Since the second question allowed for multiple responses, we report the number of innovators by type of partners as a share of innovative co-operators. The most selected type of partner are suppliers of

equipment, materials, services, or software, followed by consultants, commercial labs, or private R&D institutes and Universities or other higher education institutions. Figure 3 gives an overview of the geographical distributions of cooperative agreements, by reporting the number of innovators by geographical location of partners as a share of innovative co-operators.

In what follows, we focus on firms that have answered as undergoing both the horizontal and vertical "technological cooperation".

4 - *Model Specification*

The aim of the model is to reveal which firms' characteristics influence the firm's capability to collaborate on innovative activities with different partners and to introduce new or significantly improved good/services/production process.

For this purpose we use a bivariate probit model with sample selection where the R&D cooperation (y_2) can be observed if and only if the innovation activity (y_1) in the selection equation is equal to one. The model, which is discussed in detail in the methodological appendix, can be synthetically specified as follows

$$y_{1i} = \begin{cases} 1 & if \quad \mathbf{x}'_{1i}\boldsymbol{\beta}_1 + \varepsilon_{1i} > 0 \\ 0 & if \quad \mathbf{x}'_{1i}\boldsymbol{\beta}_1 + \varepsilon_{1i} \leq 0 \end{cases}$$

and

$$y_{2i} = \begin{cases} 1 & if \quad y_{1i} = 1 \quad and \quad \mathbf{x}'_{2i}\boldsymbol{\beta}_2 + \varepsilon_{2i} > 0 \\ 0 & if \quad y_{1i} = 1 \quad and \quad \mathbf{x}'_{2i}\boldsymbol{\beta}_2 + \varepsilon_{2i} \leq 0 \end{cases}$$

with

$\varepsilon_{1i}, \varepsilon_{2i}$ bivariate normal $[0,0,1,1,\rho]$.

The LR (Likelihood Ratio) test rejects the hypothesis that the correlation between the error terms is equal to zero. Therefore we estimate jointly the equations by using the maximum likelihood method (ML).-This confirms the correlation between the unobservable components in the selection and outcome equations.

In order to estimate the selection equation, we first distinguish innovative from non-innovative firms. For the purpose of this study, all firms that introduced new or significantly improved goods or services and/or the processes used to produce or supply all goods or services, are considered as innovators. These may be new to the business or new to the market. We consider both national and international partners. For the econometric analysis we are interested in factors affecting the firm's attitude both to cooperate and to innovate. Econometric estimates in this paper adopt the following firm-level indicators as explanatory variables:

1) Part of a business group: being part of a group can influence firms' propensity to be engaged in successful innovation and to cooperate with an increasing number of partner (see, for instance, Piga et al., 2004; Dachs et al., 2008). Mairesse et al. (2002) underline the expected innovative benefits due to easier access to (internal) finance and to the effect of intra-group knowledge spillovers for firms that are members of industrial groups. Similarly, Iammarino et al. (2012) point that the firm's technological status benefits from the relationships within a group. If the firm is part of a business group the binary variable takes the value 1.

2) Sales: in CIS questionnaire firms are asked to estimate the amount of sales in 2006 and 2008. We account for the amount of sales at the beginning of the 3 year period, at December 31st 2006, to avoid endogeneity, due to possible simultaneity between sales growth and the firm's innovation capabilities.

3) Scientific sectors: collaborations may differ depending on the type of industry. There are sectors where firms present a higher level of innovation and R&D practice. Thus, following Mohnen and Hoareau (2003) we aggregate all industries with

a high level of technology in a unique sector defined as the scientific sector[2]. Moreover, Pavitt sectoral dummies were added to the econometric specification in order to control for the different sectorial technological opportunity and appropriability conditions.

4) Small and medium size: firm size is defined in terms of number of employees. Respondents estimate the business's average number of employees at the end of 2008. Through this variable, we distinguish between firms with less than 250 employees to account for the firm's size. Following the Schumpeterian view, small and medium businesses are supposed to have lower ability to innovate and to cooperate (Schumpeter, 1943).

As it is well known, in order to cope with the identification issue in an Heckman model, the selection equation should have at least one variable that is not in the outcome equation in order to get rid of identification problems. However, we introduce additional variables both in the outcome and in the selection equation. Part of the observations for the additional variables in the outcome equation are censored and therefore these covariates can be used only in the first step. Additional variables which are included in the selection equation are: new organizational strategies in public relations and new pricing policies. The firm's attitude to innovate strategies of relations with other firms or public institutions, through new production or commercial agreements, is posited to affect innovation. Similarly, the firm's flexibility to introduce new pricing policies, through adequate

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[2] This includes the following industries: manufacturers of coke and refined petroleum, chemical and pharmaceutical products, computer, electronic and optical products, machinery and equipment, motor vehicles, trailers and other transport equipment, telecommunications, computer programming, consultancy and related activities, information service activities, architectural and engineering activities, technical testing and analysis, scientific research and development. The name code classification is reported in Appendix B, Table B1.

discount schemes, can increase the firm's market power and therefore attract the necessary funds to invest in innovation activities.

We do not introduce variables that might potentially arise bias due to simultaneity, that is when explanatory variables are jointly determined with the dependent variable. Firstly, we exclude dummy for internationalization, measured as the presence of the firm in foreign markets. Firms' competitiveness and technological innovation have to increase simultaneously to maintain the market share in the intentional scenario (e.g. Archibugi and Iammarino, 1999; Narula and Zanfei, 2003). Since innovation, innovative cooperation and internationalization are jointly determined, it is not possible to analyze causal relationships with a dataset without adequate instrumental variables or longitudinal data.

Similarly, we do not include dummies for other organizational or advertising innovations because these are likely to arise unobservable effects, since these are often the outcomes of managerial skills in innovating. In fact, the introduction of an innovation is often the result of both organizational innovations aimed at improving the product and services delivery, and new methods of work organization, such as the introduction of mechanisms of individual responsibilities or team-working, which improve the internal efficiency. Similarly, once the firm innovates, the channel of distribution of innovative products and services needs to be upgraded to new marketing practice and to new advertising techniques, such as, e.g., the launch of a new brand and/or the introduction of loyalty cards. These techniques reveal the firm's attitude and managerial capabilities to promote the entry into new markets.

The additional variables for the outcome equation are: public financial support, internal and external R&D, acquisition of machinery, equipment and software and training for innovative activities. These variables can be correlated also with innovation, but since they have censored observation they can only be used in the outcome equation.

Public financial support includes financial support via tax credits or deductions, grants, subsidized loans and equity investments. A Government subsidy or a fiscal incentive should increase a firm's in-

novative performance, although the empirical evidence on this is quite controversial.

As far as the internal R&D, it can be defined as that set of creative work undertaken within the business that increases knowledge for developing new and improved goods or services and processes. However, some firms may choose to purchase external R&D performed by companies, including other businesses within the group, or by public or private research organizations.

Moreover, investment in innovative activities often implies both the acquisition of advanced machinery and equipment as well as computer hardware and software, and the training for innovative activities. As argued by Cassiman and Veugelers (2002), Piga et al. (2004) and Lambertini et al. (2004), firms with high levels of absorptive capacity are better prepared to join other partners in innovative projects. We use as a measure of absorptive capacity the training for innovative activities intensity. The binary variable indicates whether firms invest in specific internal or external training for their personnel with the aim of supporting them in innovative development. The hypothesis to be tested through empirical analysis can be synthesized as:

Hypothesis 1: Firms' attitude towards innovative cooperation should be positively and significantly influenced by characteristics such as being part of a business group, sales, belonging to scientific sectors, benefiting from public funding and investments in in-house and external R&D, machinery, software and training for innovative activities.

Hypothesis 2: Firms' attitude towards innovative cooperation should be negatively and significantly influenced by being a small and medium enterprise.

Hypothesis 3: Firms' ability to innovate should be positively and significantly influenced by characteristics such as being part of a business group, sales, belonging to scientific sectors, benefiting from

public funding, new strategies in public relations and new pricing policies.

Hypothesis 4: Firms' ability to innovate should be negatively and significantly influenced by being a small and medium enterprise.

Table 1 describes the variables used in the empirical analysis and reports the variable means in percentage values. In CIS 2008 sample 28 percent of firms are part of a business group. The average amount of sales is almost 42,000 in 2006 and almost 47,000 in 2008. Interestingly, 62 percent of firms registered an increase in sales growth from 2006 to 2008. In Table 1 turnover values are transformed in natural log. Furthermore, we aggregate technological firms in a single scientific sector including a minority of the sample, representing only 9 percent of the firms. We have information on the firm's size for almost all sectors: 90 percent are small and medium sized enterprises. This percentage would be even higher considering that the CIS sample does not include firms with fewer than ten employees. A small proportion of firms, 12 percent, benefited from public financial support on innovation related activities. Amongst innovation expenditure, the more frequent is the acquisition of machinery, equipment and software (31 percent), followed by training for innovative activities (20 percent) and by internal R&D activities (15 percent). Only 7 percent of companies purchase external R&D competencies. With reference to changes in business strategies, almost a quarter of the total sample applied new organizational strategies in public relations. Firms are less prone to introducing changes in prices (12 percent).

The second part of Table 1 shows the conditional means for the set of covariates. Observing the distribution of innovative firms we note that, on average, almost 32 percent of them are part of a group. The average log of turnover for innovative firms is similar to the unconditional mean. Interestingly, among innovative firms we observe a high percentage of small and medium enterprises (82 percent) and firms purchasing machinery, equipment and software (81 percent). The proportions of firms belonging to an industrial group are relatively higher among University and Government cooperators (64

percent), compared to the other two cooperating groups (52 percent and 54 percent). In the subsample of businesses collaborating with institutions, 44 percent of the firms are in the scientific sector and 65 percent benefit from public financial support. The presence of firms investing in internal or external R&D activities, as deducted by comparing the three columns of collaborating firms, is higher among firms which engage in Universities and Government partnerships.

5 - *Results*

This section discusses the results, answering the research questions about the determinants of cooperation and innovation probabilities. We replicate the estimation process for three different types of cooperation: firms that have cooperation agreements with Universities and public research centres (institutional), firms that carry out vertical cooperation with customers and suppliers (vertical), firms that carry out horizontal cooperation with their competitors (horizontal). We do not consider collaboration with other firms within the same group to avoid endogeneity.

Table 2 shows the estimates for different types of collaborations and the set of explanatory variables.

5.1. Determinants of cooperation probability between firms and institutions or other partners, conditional on innovating

Table 2 reports Heckman probit coefficients estimates of firm-specific factors, measuring the effects of firm's characteristics on the probability of institutional, vertical and horizontal cooperation conditional on the firm's ability to innovate. In the cooperation equation, we observe that being part of a business group positively and significantly affects the probability that the firm enters cooperative agreements for all types of cooperation. Similarly, firms that belong to scientific sectors are also more likely to be involved in institutional cooperation than traditional industries. These results partially confirm Hypothesis 1 and are consistent with Mohnen and Horeau

(2003), who find a positive effect for technological sectors, although our results show that this effect is not significant for vertical and horizontal cooperation. Differently from what expected in Hypothesis 1, the estimated coefficient of natural log of sales, shows that this measure of the firm's size has a negatively effect on both vertical and horizontal cooperation.

As expected (Hypothesis 2), SMEs are less prone to cooperate with other partners and therefore less able to innovate. This reinforce findings by Frischer and Varga (2002), who find size to be an important factor for industry-public collaboration. Compared to large firms, SMEs have more difficulties in entering cooperative networks and developing new R&D linkages, due to lower financial resources and little accumulation of experience in technical knowledge (Chun and Mun, 2011). Although small firms could overcome these constraints by joining cooperative agreement, firm's size may still hamper R&D cooperation due to the lack of the necessary human resources and management skills required to engage in cooperative activities. In line with Hypothesis 1, the more the firm benefits from public financial support, the more the firm is likely to engage in cooperative agreements.

Another key factor for cooperative behavior is the investment in internal R&D. This is in line with the conclusion of other empirical studies (Fritsch and Lukas 2001, Berlderbos et al. 2004) and confirms the results of Fischer and Varga (2002), who estimate that in-house research activities increase the probability of cooperation with public institutions. In-house R&D seems to reinforce the firm's absorptive process: Catozzella and Vivarelli (2007) find that internal R&D is the most important determinant of innovative output, allowing for higher complementarity effects between diversified innovative inputs. Indeed, firms that invest in internal innovation activities, may accumulate the required ability to develop projects involving external institutions, such as Universities and Government. To gain a deeper insight into this evidence, Table 3 compares the average amount of internal and external R&D expenditure for the year 2008 by types of collaborations. The group of firms joining at least one cooperative agreements with Universities and Government laborato-

ries presents the highest average expenditure in internal R&D activities.

Results show that external R&D activities have also a positive and significant effect on all types of cooperation. Acquisitions of machinery, equipment and software have some positive influence only in terms of vertical cooperation. Expenditure in on-the-job innovative training has a stronger positive effect on vertical rather than horizontal agreements, while it results not having any influence on institutional partnerships.

For most of the variables, the statistical significance of the estimated parameters is quite similar among types of collaborations, thus revealing robust regularities in the attitude towards cooperation of innovation related activities. However, the magnitude of coefficients differs if we compare the effects for institutional, vertical or horizontal collaboration. In order to better qualify Hypothesis 1 and 2 we rank coefficients on the base of their magnitude. The dominant variables for institutional cooperative behavior are: public financial support, internal and external R&D investments. Differently, the dominant factors of vertical cooperation are: external R&D, being part of a business group and public financial support. For the probability of horizontal innovation the key factors are: external R&D, public financial support and being part of a business group. Surprisingly, a minor role is played by the acquisition of machinery, equipment and software, by sales and investments in job training.

5.2. Determinants of innovation probability

The coefficient estimates of the selection equations, compared in the second part of Table 2, indicate which firm's characteristics have a higher impact on the innovation probability. Results are very similar across models. Surprisingly, as opposed to Hypothesis 3 being part of a business group decreases the probability of innovating. The level of sales, belonging to scientific sectors and the development of new strategies in firm's public relations and pricing policies strongly supports the ability to innovate. As expected from Hypothesis 4, we obtain a negative small and medium enterprise sized effect.

The three dominant determinants in this case are: new organizational strategies in public relations, new pricing policies and belonging to a scientific sector.

6 - Concluding remarks

In this paper we have explored the determinants of R&D cooperative behavior of Italian innovative firms and analysed the impact of collaboration on innovation performance. We used firm level data from the Community Innovation Survey (CIS 2008) for Italy. Cooperation has been analysed along three dimensions, namely vertical (with customers and suppliers), horizontal (with competitors) and institutional (with Universities and public research centers). We used a bivariate Heckman probit model to control for sample selection and partial observability and we further replicated the estimates for the above mentioned three different types of cooperation. This modeling strategy allows us to distinguish the determinants of innovation from the determinants of collaborations.

As far as the latter, our analysis shows that forms of collaboration differ across cooperation types and vary strongly according to specific firms' attributes. We find that public financial support, internal and external R&D acquisitions, have a significant positive impact on collaboration with Universities and other research centres. As in Varga (2002), our analysis indicates that in-house research activity increases the cooperation probability among firms and institutional partners. We find, moreover, that there are three dominant positive determinants both for vertical and horizontal collaboration, i.e. i) external R&D acquisition; ii) being part of a business group; and, iii) public financial support. Finally, the size seems to be an important factor for industry-public collaboration. SME, for example, are less prone to cooperate with other partners (and therefore less able to innovate). In contrast with Fisher and Varga (2002) operating in an international market has a negative effect on firms' attitude to cooperate. Italian firms seems to be more linked to local rather than international partners.

As far as the determinants of innovation, we find that the development of new organizational strategies in public relations and new pricing policies strongly enhances the ability to innovate. On the contrary, being part of a group decreases the probability of innovating. The above mentioned size effect, with small firms less inclined to cooperation than large ones, also entails a smaller probability of innovation for entrepreneurial activities of limited dimension. Finally, belonging to scientific sectors and the firm's turnover, are both positive important factors for innovation fostering.

These results have clear implication in terms of innovation policy. First, policies to increase firms' size are strong innovation drivers. In this respect inter-firm aggregation and the creation of technological network seem relevant goals for industrial policy authorities. Moreover, public administrations have a key role in promoting cooperation activities by offering public funds to innovative firms.

Finally, it is important to stress that a panel-data study would be an important complement to the findings of this paper. However, this is currently difficult with Community Innovation Survey data management and we leave therefore this issue for future research.

Table 1: Descriptive statistics, unconditional and conditional means in percentage values.

	Unconditional means	Innovative firms	Conditional means		
			Collaborating firms		
			Institutional	Vertical	Horizontal
Number of firms	19,890	7,463	696	1,054	975
Dependent variables					
Innovative firms	38				
Firms with institutional collaboration	4				
Firms with vertical collaboration	5				
Firms with horizontal collaboration	5				
Explanatory variables					
Part of an enterprise group	28	32	64	52	51
Natural log of firm's turnover at December 31st, 2006[a]	15.32 (1.70)	15.90 (1.89)	17.49 (2.17)	16.79 (2.22)	16.82 (2.24)
Scientific sectors	9	16	44	29	30
Small and medium size	90	82	51	64	64
Public financial support	12	33	65	48	54
Internal R&D	15	39	79	60	63
External R&D	7	19	51	39	43
Acquisition of machinery, equipment and software	31	81	78	83	81
Training for innovative activities	20	54	69	69	69
New organizational strategies in public relations	14	27	48	49	51
New pricing policies	12	22	29	33	33

Notes: a – Mean is reported in percentages for discrete variables and standard deviation is reported in brackets for continuous values. All other variables are binary indicators.

Table 2: Heckman probit model result estimates of institutional,
vertical and horizontal cooperation probability and innovation probability.

Explanatory variables	Institutional Cooperation		Vertical Cooperation		Horizontal Cooperation	
	Coeff.	St. err.	Coeff.	St. err.	Coeff.	St. err.
Probit on collaboration conditional on innovation						
Part of an enterprise group	0.290***	0.057	0.302***	0.046	0.297***	0.045
Natural log of firm's turnover at December 31st, 2006	0.036	0.020	-0.045*	0.016	-0.032**	0.016
Scientific sectors	0.310***	0.058	0.001	0.049	0.087	0.049
Small and medium size	-0.151**	0.074	-0.131**	0.062	-0.161*	0.061
Public financial support	0.443***	0.046	0.188***	0.037	0.354***	0.036
Internal R&D	0.399***	0.053	0.151***	0.041	0.206***	0.040
External R&D	0.379***	0.051	0.309***	0.044	0.412***	0.043
Acquisition of machinery, equipment and software	0.014	0.056	0.121*	0.046	0.009	0.044
Training for innovative activities	0.071	0.049	0.166***	0.037	0.114*	0.037
Constant	-2.220***	0.399	-0.245	0.301	-0.370	0.300
Probit on innovation						
Part of an enterprise group	-0.454***	0.026	-0.456***	0.026	-0.453***	0.026
Natural log of firm's turnover at December 31st, 2006	0.206***	0.008	0.204***	0.008	0.205***	0.008
Scientific sectors	0.704***	0.034	0.698***	0.034	0.701***	0.034
Small and medium size	-0.175***	0.042	-0.175***	0.042	-0.172***	0.042
New organizational strategies in public relations	0.848***	0.029	0.856***	0.029	0.868***	0.029
New pricing policies	0.734***	0.032	0.724***	0.031	0.714***	0.031
Constant	-3.480***	0.149	-3.447***	0.148	-3.461***	0.148
[LR test of rho = 0: Chi-squared (1)] Atanh Rho	-0.442***	0.066	-0.615***	0.052	-0.623***	0.053
Number of firms	19,890		19,890		19,890	
Censored	12,427		12,427		12,427	
Uncensored	7,463		7,463		7,463	
Log likelihood	-12,904		-13,845		-13,886	

Notes: * significant at 10%, ** significant at 5%, *** significant at 1%.

Table 3: Average amount of R&D expenditure by types of collaboration for the year 2008, thousands of euro.

| R&D expenditure | Types of collaboration | | |
	Institutional	Vertical	Horizontal
External	1,633	1,053	1,005
Internal	4,669	2,947	2,903

*Figure 1: Percentage of firms that introduced new
or significantly improved goods, services
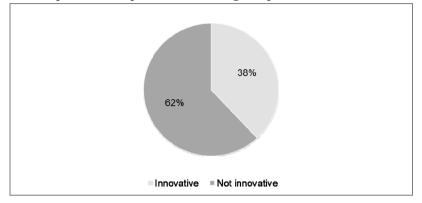or production processes during the period 2006-2008.*

*Figure 2: Number of innovators by type of partners
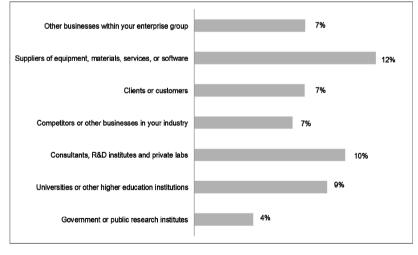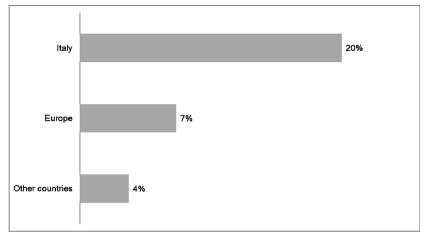as a share of innovative co-operators, CIS 2006-2008.*

Figure 3: Number of innovators by geographical location of partners as a share of innovative co-operators, CIS 2006-2008.

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Appendix A

Section A1: Methodological Appendix

This section presents the model specification and deals with related methodological issues. The Italian CIS 2008 database contains qualitative information regarding the different channels of knowledge transfer between firms and the various actors within the innovative system. In particular, it poses questions regarding collaborative agreements in a sequential way.

As a first step, firms had to declare whether they were innovative or not in the years covered by the survey (2006-2008). In that case, they were asked had they had any cooperation arrangements with any type of partner. Finally, cooperating firms were asked to specify the type of partner.

Since only innovative firms were requested about possible collaboration, the latter variable is not recorded for non-innovative enterprises and this may raise a sample selection bias in the estimation technique using CIS2008 data. Hence, estimating the cooperation equation for only innovative firms, by neglecting the underlying selection mechanism, would not take into account that missing information on non informative firms is not completely random. In fact, non innovative firms represent a self-selected sample, not a random sample, as the decision to innovate or not was made by individual firms. It is likely that firms that have a low propensity for collaboration choose not to collaborate and this would account for much of the missing data. It is therefore likely that by using the simple probit model, which considers only innovative firms, we overestimate firm's collaboration propensity. On the other hand, if in estimating a bivariate probit, which firstly considers the firm's choice in matters of innovation, and secondly the firm's cooperation propensity, the missing values on collaboration are replaced by zeros, this would result in an underestimation of this latter variable. In fact, estimating missing data with zeros would mean assuming no collaboration for non innovative firms.

The probability of a firm's involvement in cooperative agreements, conditioned on the probability that it innovates, is modelled by using a bivariate probit suitable for partial observability; namely a Heckman probit model composed of two equations. This model accounts for sample selection because all variables are completely observed in the innovation (selection) probit equation, while only a selected (censored) sample of them is present in the collaboration (outcome) probit equation.

The first equation, which describes the probability of a firm being selected (that is the probability of experiencing innovation), is specified as follows

$$y_{1i}^* = x_{1i}' \beta_1 + \varepsilon_{1i}$$

where y_{1i}^* is a latent variable that indicates whether the *i-th* firm innovates or not, x_{1i} is a set of explanatory variables accounting for the decision of firm i to innovate (see Table 2 for a full description of these covariates). β_1 is the vector of the associated coefficients and ε_{1i} is an error term. Subsequently, a binary variable y_{1i} is associated to the latent variable y_{1i}^* in such a way that a zero value for y_{1i} is associated to a negative value for y_{1i}^* whereas a unity value for y_{1i} is associated to a non-negative value for y_{1i}^*. In formulas

$$y_{1i} = 1 \quad if \quad y_{1i}^* > 0$$
$$y_{1i} = 0 \quad if \quad y_{1i}^* \le 0$$

The second equation, describing the propensity for collaboration (main event), is specified as follows:

$$y_{2i}^* = x_{2i}' \beta_2 + \varepsilon_{2i}$$

where y_{2i}^* is the latent variable that indicates whether the *i-th* firm sets up a collaboration agreement or not in order to pursue innovation. x_{2i} is a set of explanatory variables accounting for the decision of firm i to cooperate, including the determinants of the firm's behaviour, such as internationalization, group, sales growth, scientific sectors, size, public financial support and so on. β_2 is the vector of the associated coefficients and ε_{2i} is an error term. As before, a binary variable y_{2i} (whose outcomes are of main interest) is attached to the latent variable y_{2i}^* in such a way that a zero response to y_{2i} is associated to a negative value for y_{2i}^*, whereas a unity response for y_{2i} is associated to a non negative value for y_{2i}^*:

$$
\begin{aligned}
y_{2i} &= 1 \quad if \quad y_{2i}^* > 0 \\
y_{2i} &= 0 \quad if \quad y_{2i}^* \le 0
\end{aligned}
$$

Noting that y_{2i} is observed if and only if y_{1i} is equal to one.

In addition, we assume that the error terms ε_{1i} and ε_{2i} are identically distributed over time according to a bivariate normal distribution with mean 0. Since the scale of the dependant variables y_i^* is undefined, we can further assume, with no loss of generality, that both the variances of ε_{1i} and ε_{2i} are unitary, that is

$$
var(\varepsilon_{1i}) = var(\varepsilon_{2i}) = 1
$$

In addition, we assume that
$$
cov(\varepsilon_{1i}, \varepsilon_{2i}) = \rho
$$

where ρ shows the correlation between the error terms (due to un-accounted factors) in both the probability to innovate and cooperate. The log-likelihood of this model is built as the sum of three log-likelihoods, thus reflecting the true dataset structure: firms that do not innovate, firms that innovate but do not collaborate and, firms that both innovate and collaborate

$$lnL = \sum_{y_{1i}=0} lnA_1 + \sum_{y_{1i}=1, y_{2i}=0} lnA_2 + \sum_{y_{1i}=1, y_{2i}=1} lnA_3 \quad (1)$$

where

$A_1 = \mathbf{\Phi}_1(-\mathbf{x}'_{1i}\boldsymbol{\beta}_1)$ is the likelihood corresponding to firms that do not innovate, with $\mathbf{\Phi}_1$ denoting the cumulative univariate normal distribution function;

$A_2 = \mathbf{\Phi}_2(\mathbf{x}'_{1i}\boldsymbol{\beta}_1, -\mathbf{x}'_{2i}\boldsymbol{\beta}_2, \rho)$ is the likelihood corresponding to firms that innovate but do not cooperate, with $\mathbf{\Phi}_2$ denoting the distribution function of a bivariate normal density;

$A_3 = \mathbf{\Phi}_2(\mathbf{x}'_{1i}\boldsymbol{\beta}_1, \mathbf{x}'_{2i}\boldsymbol{\beta}_2, \rho)$ is the likelihood corresponding to firms that both innovate and cooperate. [3]

Should the error terms be uncorrelated, meaning that the above bivariate probit is a model based on decisions taken sequentially but

---

[3] If we denote with N the total number of firms in the sample, with M the number of the innovative firms and with N_1 the number of the firms that established a collaboration relationship, then the likelihood function can be written as follows

$$\prod_{i=1}^{N_1} \mathbf{\Phi}_2(\mathbf{x}'_{1i}\boldsymbol{\beta}_1, \mathbf{x}'_{2i}\boldsymbol{\beta}_2, \rho) \prod_{i=N_1+1}^{M} \mathbf{\Phi}_2(\mathbf{x}'_{1i}\boldsymbol{\beta}_1, -\mathbf{x}'_{2i}\boldsymbol{\beta}_2, \rho) \prod_{i=m+1}^{N} \mathbf{\Phi}_1(-\mathbf{x}'_{1i}\boldsymbol{\beta}_1)$$

independently, the above log-likelihood function would be the sum of two separate log-likelihoods. A likelihood ratio test[4] (LR) can be used to validate the hypothesis of independent equations. When ρ is significantly different from zero, the LR test rejects the hypothesis of independent equations and this entails that the estimation of the equations cannot be done separately.

The parameters $\boldsymbol{\beta}_1$, $\boldsymbol{\beta}_2$ and ρ can be estimated either by the maximum likelihood (ML), that is by maximizing the likelihood of observing 0/1 responses on y_1 and the 0/1 responses to y_2 contained in the whole sample, or the Heckman two-step method. In this latter approach, the two equations are separately estimated. As a first step, the ML probit estimation of the selection equation produces an estimate of the inverse Mills ratio for each observation. This estimate is added to the outcome equation as an additional "control" variable to accommodate the selection effect (Greene, 2012) [5],[6].

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[4] This test, whose asymptotic distribution is a chi-squared variable with one degree of freedom, compares the likelihood of the full bivariate model with the sum of the likelihoods for the univariate probit models.

[5] In this paper we apply the two methods because both the ML and the Heckman's two-step estimation present some drawbacks and there is not a dominant technique in the literature. On the one hand, the ML method, based on the strong assumption of normality in the error terms, may raise some problems of convergence. On the other hand, in a two-step method the heteroschedastic nature of the error term in the outcome equation (see the following note) should be duly taken into account when the standard errors of the estimated coefficients are computed.

[6] As Heckman showed, sample selection (or incidental truncation) causes a specification error in the outcome equation which is given by the omission of a variable, namely the inverse Mills ratio. In fact it can be proved that

$$E(y_{2i}^* \,\big|\, \boldsymbol{x}_{21} , y_{1i}^* > 0) = \boldsymbol{x}_{21}' \boldsymbol{\beta}_2 + \rho\lambda_i$$

where λ_i, called the inverse Mills ratio, is given by

Section A2: Robustness check, the Heckman two-step method

This section is concerned with examining the robustness of rankings of coefficients on cooperative behavior to variations in the method for deriving those coefficients. In fact, the bivariate model with sample selection can be estimated using the ML probit procedure, as for the previous illustrated results, and the Heckman two-step method. In this sub-section we present the results of this second procedure, which requires the estimation of a standard probit and a linear regression model.

At a first stage, we estimate a simple probit model of the innovation equation. Using the probit estimates, we calculate the inverse Mills ratio for each observation. At a second stage, we compute the ordinary least square (OLS) estimates of the cooperation equation only for the subsample of uncensored observation. In this final step we include the sample selection correction term given by the inverse Mills ratio, which is considered as an additional independent variable.

Table A shows the estimated coefficients which can be compared with Table 3. Although the OLS and the ML coefficients are not di-

$$\lambda_i = \frac{\phi_1(\mathbf{x}_{1i}'\boldsymbol{\beta}_1)}{\Phi_1(\mathbf{x}_{1i}'\boldsymbol{\beta}_1)}$$

and ϕ_1 is the normal density. Accordingly, the cooperation equation reads as follows

$$y_{2i}^* = \mathbf{x}_{2i}^*\boldsymbol{\beta}_2 + \rho\lambda_i + \upsilon_{2i}$$

where υ_{2i} is a non systematic, heteroschedastic error term, that is

$$E(\upsilon_{2i}\,|\,y_{1i}^* > 0) = 0$$

$$E(\upsilon_{2i}^2\,|\,y_{1i}^* > 0) = \tau_i^2$$

and $\tau_i^2 = [1 - \rho^2\lambda_i(\lambda_i + \mathbf{x}_{1i}'\boldsymbol{\beta}_1]$.

rectly comparable, we observe that the level of significance and the sign of the estimated coefficients are similar. The inverse Mills ratio coefficients present the same sign of the correlation terms reported in Table 3. The key t-value relates to the inverse Mills ratio coefficient, which is the relevant parameter to test whether the selection bias is significant. This confirms the negative correlation between the unobservable components in the selection and outcome equations.

Table A: Heckman two-step procedure, ordinary least square estimates for the cooperation equation

Explanatory variables	Types of collaboration					
	Institutional		Vertical		Horizontal	
	Coeff.	St. err.	Coeff.	St. err.	Coeff.	St. err.
Part of a business group	0.040***	0.009	0.077***	0.011	0.062***	0.010
Natural log of firm's turnover at December 31st, 2006	0.007**	0.003	-0.011*	0.004	-0.012***	0.003
Scientific sectors	0.093***	0.010	0.009	0.012	-0.002	0.012
Small and medium size	-0.069***	0.012	-0.050***	0.014	-0.043*	0.014
Public financial support			0.048***	0.008	0.071***	0.008
Internal R&D	0.063***	0.007	0.032***	0.009	0.029*	0.009
External R&D	0.103***	0.009	0.097***	0.011	0.123***	0.010
Acquisition of machinery, equipment and software	0.015	0.008	0.035***	0.010	0.017	0.010
Training for innovative activities	0.006	0.006	0.035***	0.008	0.024*	0.008
Sample selection correction term	-0.047***	0.011	-0.143***	0.013	-0.146***	0.013
Constant	-0.009	0.056	0.363***	0.069	0.368***	0.066
Number of firms	7,463		7,463		7,463	
Adjusted R^2	0.160		0.103		0.116	

Notes: * Significant at 10%; ** Significant at 5%; *** Significant at 1%

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Appendix B

*Table B1: NACE classification codes and definitions
of sectors included in the scientific group*

NACE Rev. 2	Sector definitions
19	Manufacture of coke and refined petroleum products
20	Manufacture of chemicals and chemical products
21	Manufacture of basic pharmaceutical products and pharmaceutical preparations
26	Manufacture of computer. electronic and optical products
28	Manufacture of machinery and equipment n.e.c.
29	Manufacture of motor vehicles. trailers and semi-trailers
30	Manufacture of other transport equipment
61	Telecommunications
62	Computer programming. consultancy and related activities
63	Information service activities
71	Architectural and engineering activities; technical testing and analysis
72	Scientific research and development