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R&D cooperation and choice of partner, in high and low-tech industries. Evidence from Italian firms.

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Abstract

R&D cooperation is central in the strategy of firms: in order to innovate, firms may need knowledge outside their own boundaries, using in their production process, acquaintances they do not have. In recent years, an increasing branch of the economic literature has focused on the determinants of cooperative behavior of the firms. In this paper we explore this issue, studying the determinants of R&D cooperation in Italy. In particular, we contribute to the literature using for the analysis an original dataset, containing firm level information about R&D activity, balance sheets, and other relevant variables. This allows us to build robust explanatory variables, based on objective measures and balance sheet indexes, improving the literature on R&D cooperation. Differently from previous literature, we consider human capital as one of the determinants of cooperation. Moreover, we disaggregate the population in high tech and low tech firms and distinguish the cooperation by partner, and by size (SMEs and Large firms).

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1. Introduction

In the last decades, R&D cooperation has emerged as one of the main strategies firms use to share costs and investment risks, being furthermore an important mechanism to obtain external knowledge. Consequently, in the years, the number of cooperating firms has increased (Hagedoorn, 2002) and in 2016 in Europe, the percentage of cooperative innovative firms has exceeded the 30 percent (source: Community Innovation Survey). Given the centrality and the interest of this argument, in recent years the economic literature has analysed the determinants of R&D cooperation, a branch of this literature analyses cooperation with different partners.

In the first half of the last century, antitrust authorities were suspicious through R&D cooperation between firms, assuming that cooperation in an early stage could have leaded to product market collusion. However, in the years, this approach through R&D cooperation has totally changed, and today cooperation in early stage is not only tolerated, but also promoted through public funding and subsidies, making R&D cooperation a central part of governments' innovative process and strategy. Given the centrality and the interest of this argument, in this article we examine the determinants of R&D cooperation.

In this note, we extend our previous paper Cantabene and Grassi (2019), distinguishing between High-Tech and Low-Tech firms, focusing on the choice of different partners, and adding human capital as determinant. A growing literature has analyzed the determinants of cooperation, but just a fraction has tried to study how the motivations may differ according to the partners with whom firms cooperate and very few papers have focused on the role of human capital. This paper contributes to such a literature.

It is important to underline that most of the papers on the determinants of cooperation build their explanatory variables using investigation surveys (such as the CIS), where firms reveal information about their cooperative behaviour. Thus, qualitative indexes measure some central variables, such as spillovers and risk sharing. On the contrary, we base our analysis on a dataset containing firm-level information about R&D activity, and balance sheets. To the best of our knowledge, our research project is the first to build robust explanatory variables from objective measures and quantitative indexes, improving the literature on the determinants of R&D cooperation.

2. Literature review and hypotheses

In his seminal work, Schumpeter (1942) argued that firms would not have sufficient incentives to invest in R&D activities, if they cannot capture the value generated by their investments for some significant period. Similarly, Arrow (1962) gave three reasons why perfect competition might fail to allocate resources optimally in case of invention: because the latter is risky, because the product can be appropriated only to a limited extent, and because of increasing returns in use. Cooperation in R&D may mitigate this market failure, allowing firms to approach the efficient level of R&D investment, and the State may intervene in the market stimulating cooperation through R&D subsidies.

Numerous authors have empirically analysed the factors that most influence the selection of an optimal external technological sourcing mode as well as the ratio between internal and external technological acquisition (Kleinknecht and Reijnen, 1992; Veugelers, 1997; Colombo and Garone, 1996; Veuglers and Cassiman, 1999; Bayona et al., 2001; Fritsch and Lukas, 2001; Kaiser, 2002; Piga, C. and Vivarelli, M., 2003); however, recent contributions concentrate on the role of public incentives, such as subsidies and spillovers.

Belderbos et al. (2004) show a positive impact of subsidies on R&D cooperation. Colombo et al. (2006) find a similar result in a sample of Italian High-Tech firms. Miotti and Sachwald (2003), Piga and Vivarelli (2004) Busom and Fernandez-Ribas (2008), Abramovsky et al. (2009), Carboni (2013) and Franco and Gussoni (2014) find some statistically significant effect of subsidies on cooperation. In order to obtain insight on the effect of public policies on R&D cooperation, our first investigation question is about the consequences of subsidies on the cooperative propensity of the firm:

H1: Subsidies facilitate R&D cooperation.

In the paper, we distinguish subsidies according to the source (European or national).

Spillovers refer to the exchange of ideas, know-how and experiences between firms engaged in R&D cooperation activities. Literature, both theoretical and empirical, has studied the role that knowledge spillovers have on the incentives to cooperate in R&D. The seminal theoretical contribution is d'Aspremont and Jacquemin (1988), where authors, comparing different scenarios find that, for substantial spillovers, cooperative R&D leads to higher profits and social welfare.[1] Empirical efforts have tried to confirm these results, and evidence suggests that firms characterized by higher incoming spillovers and better appropriation have a higher probability to cooperate, with some limitations depending on partners, firm size, sector etc. Contributions include Cassiman and Veugelers (2002), Belderbos et al. (2004), Veugelers and Cassiman (2005), Lopez (2008). This literature shows that firms which consider valuable exchange of ideas and relationship cooperate more. Following this line of thinking, we use the variable Orders as proxy of spillovers: we argue that firms realizing research orders are more likely to cooperate because receiving more orders firms get in touch with more agents; moreover, receiving orders firms accumulate knowhow, increasing their appropriability capacity.[2]

In order to obtain insight on the interaction between firms and other players outside the border of the firm, our second question is the following:

H2: Orders facilitate R&D cooperation.

In the paper, we distinguish orders according to the source: public orders are the ones from universities or other public institutions; private orders come from other firms.

Skilled employees contribute to absorb spillovers from inside and outside firms' boundaries. Thus, a well-educated human capital should be important; this is particularly true for small and

[1] Other contributions under slightly different model setting, confirm these results. See, inter alia, Choi (1993), Leahy and Neary (1997), Amir and Wooders (1999), Goyal and Moraga-Gonzalez (2001); more recently Karbowski, A. (2019), Capuano and Grassi (2019).

[2] A similar approach in Tether (2002) which uses as variable expenditures on acquired machinery.

medium enterprises, which may lack of resources to invest broadly in R&D. Human capital is central in the innovation process and we would expect that firms with higher proportion of highly skilled employees in R&D would be more likely to cooperate compared with firms with lower level of human capital, in order to exploit their competitive advantage. However, the economic literature has not investigated in deep the link between human capital and R&D cooperation. Some literature (Colombo et al., 2006; Okamuro et al. 2011) studied the role of founders' human capital in firm's R&D cooperation chooses, concentrating on start-ups. Other research (Bresnahan et al., 2002; Greenan, 2003; Leiponen, 2005) examines the complementarity between employees' skills and firms' innovation activity. Piva and Vivarelli (2009) show that firms' skill endowment influences a firm's R&D decision. In this paper, we include in the analysis the variable HumanK as one of the possible determinants, expecting that human capital boosts R&D cooperation:

H3: Human capital facilitates R&D cooperation.

Economic literature has shown that the importance of R&D may crucially depend on factors such as firms' size, firms' age and varies across different companies.[3] This is particularly relevant in Italy, where there are many SMEs with respect to advanced economies of similar dimension. To enlighten this aspect, we carry out a further disaggregation of the data set and consider SMEs vs large firms, where large firms are firms with more than 250 employees.[4] Thus, our final hypothesis is the following:

H4: Determinants of R&D cooperation change according to firms' size.

3. Data Set and Econometric Model

We conduct a firm level analysis on a group of 6505 firms included in a survey on R&D intra-muros in Italy, realized by Italian National Statistical Office (ISTAT). According to ISTAT, the dataset includes all the Italian firms with more than 100 employees, and all the firms that, irrespective of their size, are in a position to be able to carry out R&D activities during the reference year. Firms having those characteristics are included in the dataset if and only if they report a positive amount of internal R&D expenditure in at least one year of the time span (1998-2004).

The survey contains several variables concerning various aspects of the R&D activity of a firm; other economic and financial information come from firms' balance sheets, provided by ISTAT. Given the scope of our analysis, we consider of particular interest information about the cooperation in R&D projects (both with public or private partners), the partners from whom a firm has received a research order, and the source of subsidies (European or national).

The dependent variable is a dummy for firms engaged in R&D cooperation agreement. Thus, we have a binary outcome variable in a panel data context.

[3] See, inter alia, Conte and Vivarelli (2014), Expósito Sanchis-Llopis (2019), Pellegrino and Piva (2020).

[4] We thank a referee for this suggestion.

Given our testing hypotheses, we assume that:

$Coop_{it} = f\,(SUBeu_{it};\ SUBita_{it},\ ORDuniv_{it};\ ORDpub_{it};\ ORDpriv_{it},\ HK_{it},\ X_{it})$

where *i* identifies the firm, t the year and *X* is the vector of control variables.

The dependent variable, $Coop_{it}$, is a dichotomous variable showing value one if, in year t, the firm i realizes at least a R&D project in cooperation with someone else. We estimate the change in cooperation decision over time using a panel data probit model with robust standard errors in order to correct for possible heteroscedasticity. Note that most of our key regressors, such as subsidies and orders, are dummy variables. Therefore, the coefficient we estimate represent the intercept shift and not the slope of the function.

The empirical literature has introduced arguments for the possible endogeneity of some determinants of R&D cooperation, mainly public subsidies, incoming spillovers and R&D intensity, due to reverse causality or simultaneity in the decision to engage in R&D cooperation. Since there are reasons pro and cons, we first check for the endogeneity of the suspected variables, and then we correct it if necessary. We address the problem of endogeneity using a control function approach, which is consistent in non-linear models (Rivers and Vuong, 1988; Wooldridge, 2002). The approach consists in a two-stage procedure. In the first stage, the potential endogenous variables are regressed on all the assumed exogenous explanatory variables and the instruments. The instruments we use are: i) basicness of R&D, ii) industry averages for each of the potentially endogenous variables at the two-digit industry level, and iii) dummies for the geographic macro areas. In the second stage, we use the predicted residuals as additional regressors in the structural equation without excluding the potential endogenous variables.[5] All the explanatory variables are largely used in the literature. Table 1, in Appendix, summarizes their definition.

4. Results

With the aim to analyze the determinants of cooperation in Italy, we first consider a general model including all the firms, and perform the same estimation disaggregating the population between High-Tech and Low-Tech firms. Then, we consider the determinants in the two sub-population, distinguishing cooperation with three kinds of partner: universities, public institutions, and private firms.

4.1 The general model

Table 3 illustrates the results of the general model. The first column aggregates all the firms; the second and the third consider respectively High-Tech firms and Low-Tech firms.

In aggregate, subsidies (both national and European) are the main determinant of R&D cooperation (we accept H1); the private spillovers only seem to play a role as determinant of cooperation (we partially reject H2); human capital has a not central role (we accept H3 with a 5% level of significant), while the other significant variables have the expected sign.

[5] We used a similar approach in Cantabene and Grassi (2019, 2020). We refer to those papers for a more accurate analysis of the endogenity issue, which goes far beyond the objective of this note.

Distinguishing between High-Tech and Low-Tech firms, results slightly change. Subsidies remain one of the main determinants of R&D cooperation, independently from the source and the sector. For High-Tech firms, receiving an order from university seems not be significant; on the contrary, orders from other institutions and private orders are highly significant. A counterintuitive result, which we will re-analyze in the following section, is the negative sign of orders from universities, in the Low-Tech sector: according to this disaggregation, receiving orders from universities reduces the probability to cooperate; on the contrary, orders from other institutions have the expected sign, and private orders are not significant.

It is interesting to note that human capital is highly significant for high tech firms only, that R&D intensity is always significant, while the variable patents is not. Finally, sharing the risk of investment plays a central role as determinants for Low-Tech firms only, and the other variables do not seem to be very important as determinants of cooperation.

Summing up, disaggregating our data set according to the technological sector, we continue not rejecting H1, while we cannot accept H2 and H3 for both the populations.

4.2 Cooperation with different partners

In this disaggregation, we distinguish cooperation with universities, public institutions, and private firms. First, we note that subsidies are always significant, independently from the type of technological sector, and from the partner. However, the impact of subsidies differs according to the sector and the partner: for example, in the High-Tech population, the Italian subsidies increase the probability to cooperate with university of 48%; in the Low-Tech population, they increase the probability to cooperate with institution of around 2%.

The disaggregation with different partners allows focusing on the counterintuitive result we obtained in the previous section, i.e., the negative sign that the variable orders may have on the probability to cooperate. Consider first the High-Tech sector: in Table 3, we saw that the sign of the variable Public Order was positive. However, disaggregating by partner, in Table 4, we see that a negative effect does exist for the cooperation with university. In other words, orders from an institution discourage the cooperation with other partners, boosting the cooperation with the institution itself. In the High-Tech sector, this discouraging effect does exist for orders from university as well, that reduce the probability to cooperate with private partners. In the Low- Tech sector, a similar effect comes from the orders from university, which discourage the cooperation with private firms. Moreover, in both the sectors public orders stimulate cooperation with other public institutions, and private orders stimulate cooperation with private firms. Note that, according to our results, the discouraging effect does not exist for private orders.

Independently from the partner, human capital seems to be a relevant determinant of cooperation for the High-Tech firms, even if the effect on the cooperation with university is stronger: in other words, well-educated employees facilitate cooperation with university. Coherently with this result, human capital has a positive effect on the cooperation with university for the Low-Tech firms as well, while it is not significant for other cooperation in the Low-Tech sector. However, the disaggregation for partner underlines a central role of the human capital as a determinant of cooperation, central role that neither the basic model, nor previous literature highlight. We obtain a similar result for R&D intensity. Interestingly, patents have the expected positive sign for cooperation with private firms in the Low-Tech sector only, while have a negative effect in case of collaboration with university or other public institutions for High-Tech firm. We argue that this result is due to the nature of research: collaborating with privates, firms can be imitated and have to protect their effort; on the contrary collaborating with universities, they do not run this risk and, since research to universities and public institution tends to be aimed to basic research, patents may discourage this effort. Finally, coherently with part of the empirical literature, the variable size has a significant and positive sign, sometimes with possible non-linearities, while sharing the risk is significant in the High-Tech sector, in case of cooperation with private firms. Moreover, High Tech firms and Low-Tech firms have different pattern in investment decision, thus we would expect a huge difference in the determinants of cooperation. Some differences exist (e.g., the variable Size is significant for High-Tech firms only, the different role of human capital and R&D intensity) however, the replies to the exogenous stimulus (subsidies and orders) go in the same direction for both the type of firms.

Summing up, distinguishing the cooperation by partner, we continue not rejecting H1, we partially not reject H3, while we cannot always accept H2, since the effect of orders on the probability to cooperate seems to be manifold.

4.3 Disaggregation by size

The Italian productive structure differs from that of other European economies of similar dimension; indeed, in Italy there is a relatively low number of large multinational firms and a high number of SMEs involved in R&D, most of them grouped in industrial districts distributed throughout the country, particularly in the North. Thus, it is interesting investigating to what extent determinants of cooperation change according to firms' size.

Table 6 (in Appendix) illustrates the results when we consider SMEs and large firms, distinguishing High and Low-Tech sectors. Analysing the results, we note that for our population there is not a great difference in the determinants of cooperation when we include the size. The main ones are the not significance of human capital and R&D intensity for Low-Tech SMEs, and the not significance of Public Orders and risk for High-Tech Large firms. However, these differences are not sufficient to make us accept H4.

5. Conclusion

In recent years, an increasing branch of the empirical literature has focused on the determinants of cooperative behaviour of the firms. Some literature dealing with R&D cooperation has emphasized the role that collaboration in R&D may have on the the creation of additivity; according to this literature cooperative R&D may increase the investment in R&D and the incentive to innovate (Silipo, 2008; Pippel, 2014; Pippel and Seefeld, 2016), thus, facilitating collaboration may stimulate additivity in the investment. Understanding the reasons that lead firms to cooperate in R&D investment, in order to promote it, becomes a central issue, that may address the choices of firms wishing to compete in dynamic markets (and the choices of governments wishing to stimulate innovation).

This paper is aimed at exploring the determinants for R&D cooperation between the Italian firms, distinguishing High-Tech and Low-Tech sector, and the kind of partner. In particular, we have concentrated our analysis on subsidies and orders as a determinant of cooperation and highlighted the role of the human capital. We started analyzing a general model, aggregating all the firms in our data set independently from the sector, and without distinguishing the partner. In this case subsidies emerge as the main determinant of R&D cooperation, private orders facilitate collaboration; human capital seems not to play a central role. Nevertheless, disaggregating the population the results change. In particular, subsidies preserve their centrality, but the impact has a huge variance between sectors and partners, the role of orders is somehow ambiguous: generally, orders boost cooperation with the source of the order, but may discourage cooperation with other partners. On the contrary, human capital is central in the High-Tech sector and has an impact in the cooperation with universities for Low-Tech firms as well.

This result, that to the best of our knowledge has been neglected by previous literature, has important implications, since underlines the centrality of human capital even in this aspect of the business management, in particular for High-Tech firms. Firms wishing to invest in R&D need a well-educated workforce, if they want to collaborate with partners, both private and institutional. Economic literature suggests that cooperation in R&D could enable firms to overcome some of the structural problems. Cooperation creates scale economy in R&D, allowing firms to share risks and costs; the results of our study suggest that human capital may have a central role in stimulating such a cooperation as well. Finally, we confirm the role of the State in boosting cooperation and, consequently, innovation, investment (and finally growth).

In general, we can see that the determinants of R&D cooperation differ among different type of cooperation partners, and between sectors. This finding suggests studying separately the different types of cooperation, since a result based on a general model may not capture all the details.

Despite its insights, our study has some limitations. First, the data set we use is not very recent; moreover, it does not allow us to distinguish between vertical and horizontal cooperation: thus, we had to aggregate the collaboration with private firms in a single regression. Furthermore, both the dependent variable and most of the key regressors are dummies, in this way variability is compressed and continuous measures should have been preferable. Finally, we approached our analysis from the position of Italian companies; however, the Italian productive structure differs from that of other industrialized countries, as in Italy there is a relative low number of large multinational firms and a high number of SMEs involved in R&D. The analytical process we used should be applied to capture the reality of other countries, such as extend the data set including years that are more recent. This correspondingly stands as one future line of research.

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Appendix

Table 1: Descriptive statistics: High and Low-Tech firms

	High-Tech					**Low-Tech**				
	Obs.	Mean	Std.Dev.	Min	Max	Obs.	Mean	Std.Dev.	Min	Max
$Coop_{univ}$	6890	.17	.38	0	1	3605	.11	.32	0	1
$Coop_{pub}$	6890	.81	.27	0	1	3605	.05	.21	0	1
$Coop_{priv}$	6890	.28	.45	0	1	3605	.24	.43	0	1
Sub_{EU}	6890	.87	.28	0	1	3605	.06	.24	0	1
Sub_{It}	6890	.21	.41	0	1	3605	.17	.38	0	1
$Orders_{univ}$	6890	.15	.21	0	1	3605	.01	.10	0	1
$Orders_{pub}$	6890	.06	.25	0	1	3605	.03	.19	0	1
$Orders_{priv}$	6890	.18	.39	0	1	3605	.10	.30	0	1
Human K	6877	.32	.27	0	1	3595	.25	.29	0	1
R&D Intensity	6890	.10	1.20	7.53^{-8}	46.5	3605	.42	.52	5.47^{-8}	19.7
Patents	5873	.66	.47	0	1	3307	.62	.48	0	1
Size	6837	4.45	14.4	-2.52	10.4	3586	4.66	1.25	-1.4	9.7
Size2	6837	22.3	.49	0	107.8	3586	23.3	12.2	0	1
Group	4704	.54	.50	0	1	2225	.47	.50	0	1
Location	6890	.71	.26	0	1	3605	.04	.20	0	1
Asset	6890	.18	.14	0	.99	3605	.25	.14	0	1
Cash-flow	6199	-2.73	.86	0	4.18	3334	-2.7	.81	-6	1.7
Risk	6890	.15	.49	0	10.6	3605	.11	.42	2.31^{-7}	9.1

Table 2: Variables definition and expected sign according to the literature

Variable	Definition	Exp. sign
Coop	dummy taking value 1 if the firm realizes her R&D activity in cooperation with other public or private entities	
Sub_{EU}	dummy taking value 1 if the firm has received a European subsidy to finance her R&D activity.	(+)
Sub_{Ita}	dummy taking value 1 if the firm has received a national subsidy to finance her R&D activity.	(+)
Ord_{univ}	dummy taking value 1 if the firm realizes her R&D activity on behalf of a University	(+)
Ord_{pub}	dummy taking value 1 if the firm realizes her R&D activity on behalf of CNR, other public research agencies	(+)
Ord_{priv}	dummy taking value 1 if the firm realizes her R&D activity on behalf of other private entities, as firms belonging to the same group, other firms or private research center	(+)
Hum. K.	share of graduated people over R&D employees	(+)
R&D Int.	ratio between intramural R&D expenditure and turnover	(+)
Patents	dummy taking value 1 if the firm reports patents costs in her balance sheet	(+)
Size	logarithm of employee	(?)
*Size*2	the square of *Size*	(?)
Group	dummy taking value 1 if the firm belongs to a wider company group	(?)
Location	dummy taking value 1 if the firm realizes her R&D activity in two or more regions, 0 otherwise	(+)
Asset	capital assets relative to total asset	(+)
Cash-flow	logarithm of cash-flow relative to turnover	(+)
Risk	shareholders capital over total debt	(−)

Table 3: Determinants of cooperation, the basic model

	Overall	High-tech	Low-tech
Sub_{EU}	0.461*	0.283***	0.188**
	(1.94)	(6.75)	(2.11)
Sub_{Ita}	0.773***	0.149***	0.157***
	(4.23)	(5.38)	(3.93)
$Orders_{univ}$	-0.144	-0.029	-0.360**
	(-1.58)	(-0.30)	(-2.49)
$Orders_{pub}$	-0.049	0.165**	0.894**
	(-0.46)	(2.54)	(2.09)
$Orders_{priv}$	0.162***	0.166***	0.084
	(5.93)	(5.32)	(1.50)
Human K	0.083**	0.185***	0.048
	(2.36)	(4.40)	(1.03)
R&D Intensity	0.420*	2.361***	1.296**
	(1.75)	(4.05)	(2.36)
Patents	0.001	0.006	0.286
	(0.08)	(0.23)	(1.52)
Size	-0.003	0.104*	-0.021
	(-0.06)	(1.66)	(-0.24)
Size2	0.006	0.002	0.004
	(1.14)	(0.29)	(0.44)
Group	0.045**	0.024	0.043
	(2.36)	(0.99)	(1.42)
Location	0.018	0.060	0.087*
	(0.44)	(1.28)	(1.72)
Asset	-0.097	-0.105	-0.006
	(-1.35)	(-1.12)	(-0.05)
Cash-flow	0.038***	0.026*	0.039**
	(3.57)	(1.93)	(2.08)
Risk	-0.107***	-0.066	-0.107**
	(-3.12)	(-1.53)	(-2.28)
Wald $\chi 2$	443.25***	303.28***	130.84***
N	5640	3701	1939

Note: random effects panel probit model with robust standard errors. The left-hand variable is a dummy for the cooperation in R&D projects. The estimated coefficients are the marginal effect of the independent variable on the probability of cooperation, ceteris paribus. All regressions contain calendar year dummies (results not reported). Standardized normal z-test values are in parentheses. The time span is 1998-2004.

*significant at 0.1 level; **significant at 0.05; ***significant at 0.01.

Table 4: Determinants of cooperation, with different partners. High-Tech firms.

	University	Other Public	Private Firms
Sub_{EU}	0.094***	0.041***	0.128***
	(3.29)	(5.04)	(4.65)
Sub_{Ita}	0.483***	0.025***	0.086***
	(2.98)	(3.70)	(3.93)
$Orders_{univ}$	0.050	-0.003	-0.117**
	(1.02)	(-0.23)	(-2.14)
$Orders_{pub}$	-0.146***	0.039***	0.016
	(-2.75)	(3.39)	(0.44)
$Orders_{priv}$	-0.233	0.000	0.189***
	(-1.60)	(0.04)	(7.71)
Human K	0.103***	0.041***	0.067*
	(3.97)	(4.10)	(1.94)
R&D Intensity	0.717***	0.421***	0.324**
	(2.71)	(3.27)	(1.96)
Patents	-0.383**	-0.158**	-0.013
	(-2.15)	(-1.97)	(-0.67)
Size	0.118***	0.051***	-0.043
	(2.63)	(2.90)	(-1.04)
Size2	-0.006	-0.003**	0.011***
	(-1.52)	(-2.21)	(2.69)
Group	0.042***	0.009	0.029
	(2.61)	(1.13)	(1.46)
Location	-0.009	0.010	0.079**
	(-0.41)	(1.08)	(2.31)
Asset	-0.064	0.007	-0.073
	(-1.29)	(0.31)	(-0.95)
Cash-flow	0.017**	-0.000	0.014
	(2.37)	(-0.01)	(1.23)
Risk	-0.015	-0.002	-0.076**
	(-0.93)	(-0.17)	(-2.49)
Wald $\chi 2$	266.75***	204.56***	263.99***
N	3701	3701	3701

Note: random effects panel probit model with robust standard errors. The left-hand variable is a dummy for the cooperation in R&D projects. The estimated coefficients are the marginal effect of the independent variable on the probability of cooperation, ceteris paribus. All regressions contain calendar year dummies (results not reported). Standardized normal z-test values are in parentheses. The time span is 1998-2004.

*significant at 0.1 level; **significant at 0.05; ***significant at 0.01.

Table 5: Determinants of cooperation, with different partners. Low-Tech firms.

	University	Other Public	Private Firms
Sub_{EU}	0.077***	0.034***	0.153***
	(3.28)	(3.78)	(3.08)
Sub_{Ita}	0.049***	0.022***	0.097***
	(3.39)	(3.13)	(3.42)
$Orders_{univ}$	-0.062	-	-0.286***
	(-1.43)	-	(-3.39)
$Orders_{pub}$	0.066	0.024***	0.044
	(0.50)	(2.60)	(0.82)
$Orders_{priv}$	-0.016	-0.006	0.126***
	(-0.88)	(-0.65)	(3.58)
Human K	0.057***	0.013	-0.010
	(3.19)	(1.58)	(-0.29)
R&D Intensity	1.123**	-0.037	0.352
	(2.29)	(-0.40)	(1.41)
Patents	-0.001	0.002	0.261*
	(-0.09)	(0.44)	(1.77)
Size	0.030	0.002	-0.056
	(1.02)	(0.24)	(-0.91)
Size2	-0.001	-0.000	0.007
	(-0.54)	(-0.12)	(1.26)
Group	0.034***	0.003	0.013
	(2.88)	(0.61)	(0.56)
Location	0.037***	0.006	0.096**
	(2.67)	(0.83)	(2.24)
Asset	0.028	-0.019	-0.036
	(0.83)	(-1.17)	(-0.40)
Cash-flow	0.009*	0.004	0.020
	(1.71)	(1.06)	(1.34)
Risk	-0.017	-0.000	-0.040
	(-1.31)	(-0.12)	(-1.43)
Wald $\chi 2$	105.93***	60.98***	101.65***
N	1939	1939	1939

Note: random effects panel probit model with robust standard errors. The left-hand variable is a dummy for the cooperation in R&D projects. The estimated coefficients are the marginal effect of the independent variable on the probability of cooperation, ceteris paribus. All regressions contain calendar year dummies (results not reported). Standardized normal z-test values are in parentheses. The time span is 1998-2004.

*significant at 0.1 level; **significant at 0.05; ***significant at 0.01.

Table 6: Determinants of cooperation by size. High and Low-Tech firms.

	High-Tech		Low-Tech	
	SME	Large	SME	Large
Sub_{EU}	0.18***	0.23***	0.23***	0.40***
	(4.50)	(4.84)	(3.78)	(5.33)
Sub_{Ita}	0.12***	0.09***	0.14***	0.21***
	(5.07)	(2.57)	(4.66)	(4.46)
$Orders_{Univ}$	0.03	-0.03	0.08	-0.12
	(0.25)	(-0.26)	(0.77)	(-0.62)
$Orders_{Pub}$	0.15***	0.10	0.23***	0.22***
	(2.71)	(1.19)	(3.88)	(2.78)
$Orders_{Priv}$	0.13***	0.14***	0.08**	0.17**
	(4.88)	(3.05)	(2.49)	(2.32)
Human K	0.12***	0.20**	0.04	0.17***
	(4.02)	(2.56)	(0.96)	(2.57)
R&D Intensity	0.21**	2.88***	0.12	4.90***
	(2.36)	(3.30)	(0.71)	(3.36)
Patents	0.02	N.A.	0.02	N.A.
	(0.50)		(0.40)	
Size	-0.01	0.39	-0.16**	0.09
	(-0.10)	(1.27)	(-2.00)	(0.31)
$Size^2$	0.01	-0.02	0.02**	-0.00
	(1.00)	(-0.95)	(2.09)	(-0.14)
Group	0.02	0.04	0.05**	0.02
	(0.82)	(0.97)	(2.01)	(0.40)
Location	0.13***	0.03	0.06	0.04
	(2.89)	(0.70)	(1.14)	(0.75)
Asset	-0.09	-0.14	0.02	-0.01
	(-1.20)	(-0.98)	(0.22)	(-0.06)
Cash-flow	0.02	0.00	0.03*	0.07***
	(1.56)	(0.26)	(1.81)	(3.31)
Risk	-0.21***	0.01	-0.15**	-0.06***
	(-5.99)	(0.40)	(-2.29)	(-2.60)
Wald χ^2	158.33***	73.51***	88.47***	76.31***
N	2775	926	1403	536

Note: random effects panel probit model with robust standard errors. The left-hand variable is a dummy for the cooperation in R&D projects. The estimated coefficients are the marginal effect of the independent variable on the probability of cooperation, ceteris paribus. All regressions contain calendar year dummies (results not reported). Standardized normal z-test values are in parentheses. The time span is 1998-2004.

*significant at 0.1 level; **significant at 0.05; ***significant at 0.01.