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Abstract

We analyze the determinants of R&D cooperation for SMEs in Italy. We introduce in the literature human capital as one of the main determinants of R&D cooperation, concentrating on its moderating role, and specifically focusing on the high-tech sector. Using an extremely rich dataset, we improve the literature, building robust explanatory variables, and disaggregating the cooperation by partner. We find that human capital facilitates cooperation, but its moderating role depends on the type of disaggregation and/or the partner.

JEL classification code: C23, C25, H32, O32

Keywords: R&D cooperation; subsidy; firm behavior; human capital; moderating effect

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1 Introduction

Last decades have been characterized by a radical change in the economic structure of developed economies, and by the success of digital technology as the main way to produce and exchange most of the knowledge. If, on the one hand, the growing simplicity in communications has allowed an unpredictable development in many sectors of the modern society, on the other hand, this shifting has reduced the technological advantage of traditional countries, especially in the manufacturing. Moreover, technological life cycles have become shorter, requiring increasing investment in risky activities. In this modified context, R&D investments become central for firms strategy, and sharing the risk with allies has increased the relevance of collaborative research, being furthermore an important mechanism to obtain external knowledge (Shilling, 2009). Consequently, in the years the number of cooperating firms has increased (Hagedoorn, 2002): according to the Community Innovation Survey (CIS), in 2016 in Europe the percentage of cooperative innovative firms has exceeded the 30 percent.

In Italy, SMEs have always been crucial in enhancing economic growth and development, despite their resource constraints with respect to bigger players in the market. On the one hand, these constraints force firms to invest on internal resources; on the other hand, they boost SMEs to search for external knowledge and competencies. Indeed, external knowledge is an essential input to the innovation activity of SMEs, Chun and Mun (2012) state: "One viable way for SMEs to enhance the inflow of knowledge from outside of the firm is through R&D cooperation with sources of external knowledge, such as other firms, research institutions, and universities". At the same time, SMEs must efficiently and effectively use the knowledge and the skills of managers and employees they already have, to continue competing in the knowledge economy.

In this modified environment, the role of human capital has to be carefully analysed, since it is one of the most important internal resources of the firms. Human capital may affect the ability of firms to innovate, to generate profits, and to compete in the market.

A growing literature has analyzed the determinants of cooperation;[1] however, papers focusing on SMEs are relatively scarce,[2] and, despite its impor-

[1] Next section of the paper introduces the literature; more extended surveys in, inter alia, Marinucci (2012) and Silipo (2008).

[2] A relevant exception is Chun and Mun (2012), who study the determinant of R&D

tance as input, the literature on the determinants of cooperation in R&D has basically ignored firm's human capital, as a possible explicatory variable. A branch of this literature (Colombo et al., 2006; Okamuro et al., 2011) has studied the role of founders' human capital in firm's R&D cooperation choices. This approach, that is easily implementable, may be relevant for technological start-ups, but may not reflect the R&D ability of most of the firms. In this paper, we extend the literature, testing the role of the human capital as one of the direct determinants of R&D cooperation. Furthermore, human capital influences the abilities of the firms not only directly, but indirectly as well, affecting their skills. In recent years some literature has concentrated on its moderating role,[3] in particular with respect to investments and innovation.[4] We extend these models, arguing that human capital may influence the ability of SMEs to exploit and to obtain external incentives, such as orders (both public and private), and subsidies. To disentangle this aspect, we analyze its role as moderator with the variables orders and subsidies, that are some of the main determinants of R&D cooperation. Thus, the current paper sought not only to provide evidence of the relationship between incentives and R&D cooperation, but also to explore the boundary conditions influencing this effect, i.e. the moderating role of human capital. To the best of our knowledge, this is the first paper to analyze this aspect of human capital.

Furthermore, we analyze in-deep the determinants of R&D cooperation for high-tech SMEs. In this sector, firms, independently of the size, have to invest a huge amount of resources in R&D activity; thus, their motivations to cooperate in R&D may differ from the motivations of SMEs in different sectors. For example, high-tech SMEs may cooperate with private partners to rapidly enter the market a new product, whereas other SMEs cooperate to share risks and costs of the R&D activity.

Moreover, it is important to underline that most of the papers on the determinants of cooperation build explanatory variables using qualitative

cooperation in a sample of Korean firms, concentrating on the role of spillovers.

[3]According to Little et al.(2007), there is *moderation* when the presence of a variable W (moderator) influences the impact of a variable X (moderated) on the outcome Y; this influence can be modeled by creating a new variable that is the product of the moderated variable and the moderating one (XW). When the effect of XW is significant, the effect of X on Y is dependent upon the level of W.

[4]See, inter alia, Park, 2012; Bornay-Barrachina et.al, 2012; Kwon and Rupp, 2013.

indexes,[5] that may lack of objectivity. On the contrary, following the same approach we used in Cantabene and Grassi (2018),[6] we build robust explanatory variables, basing our analysis on an original dataset, containing firm level information about R&D activity and balance sheets; in other words, we use variables based on objective measures and verifiable data. Using a control function approach, which is consistent in non-linear models (Rivers and Vuong, 1988; Wooldridge,2002), we take into account the possible endogeneity of pubic subsidies, incoming spillovers and R&D intensity due to reverse causality or simultaneity in the decision to cooperate in R&D, and then we correct if necessary.

Finally, we study the Italian case that, despite its peculiarity,[7] has been little investigated in the literature on R&D.[8]

We find that human capital facilitates cooperation, and it has a crucial role in the cooperation with the public, and in the high-tech sector; however, its moderating role depends on the type of disaggregation and/or the partner. We obtain analogous results analyzing the effect of public and private incentives, that, confirming previous literature, boost R&D cooperation in most of the disaggregations we study.

The paper is organized as follows: section 2 locates the paper with respect to the literature and introduces the hypotheses; section 3 describes the data and econometric strategy; section 4 illustrates the results, with section 4.2 focusing on the high-tech sector; section 5 concludes.

[5]For example, in Europe scholars often measure spillovers, risk, etc., summing the score (from 0 to 4) expressed by the firms involved in the Community Innovation Survey.

[6]The availability of more accurate data allows us to extend the analysis of Cantabene and Grassi (2018). Here, we study the case of different partners (public and private firms), and add two explanatory variables: patents and human capital. The first, a proxy of the outgoing spillovers, is a dummy taking value 1 if the firm reports patents costs in her balance sheet; the second one is given by the share of graduated people over R&D employees.

[7]For example, with respect to the productive structure of other industrialized countries, in Italy there is a relative low number of large multinational firms, a relative low number of high-tech firms, a relative high number of SMEs, a substantial divide between North and South of the country.

[8]Papers studying the effect of R&D subsidies on R&D cooperation in Italy are Colombo et al. (2006), Carboni (2013), and Cantabene and Grassi (2018). Other papers investigating, from different prospectives, the profitability of R&D investment in Italy are Fantino and Cannone (2011), Ardovino and Pennacchio (2014), Magri (2014), Cerulli et al. (2016), Bellucci et al. (2018).

2 Related literature and hypotheses

2.1 Human capital and its moderating role

Human capital has long been considered a critical resource for the firms (Pfeffer, 1994). Spender (1996) argued that firm's knowledge is the core of the theory of the firm. Grant (1996) states that knowledge is the most important asset. Lepak and Snell (1999) argue that firms create value developing human capital. In the knowledge based economies, the human element has increased in centrality and importance, to react and adapt to markets changes, and one answer to the question why similar firms differ in performance, is that they differ in human capital (Hitt et al., 2001).

Skilled employees contribute to absorb knowledge from inside and outside firms' boundaries, and a well educated human capital should be important, particularly in SMEs 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, will be more likely to cooperate compared with firms with lower level of human capital, in order to exploit their competitive advantage, and develop innovations. Indeed, it is well-known in the economic and in the management literature that innovation plays a central role in firm competitiveness (Macher and Mowery, 2009; Wolfe, 1994). Its importance underscores the necessity of finding the key factors associated with it (Damanpour and Schneider, 2006; Subramaniam and Youndt, 2005), and R&D cooperation is one of these factors.

Many studies analyze the effect of human capital on the innovational skills of the firms (Bornay Barrachina et al., 2012; Mc Guirk et al., 2015, Bosma et al., 2004); however, there are surprisingly few studies that empirically investigate the relationship between R&D cooperation and human capital. Although a theoretical perspective suggests a positive relationship between these variables, we need concrete empirical evidence to support this proposition. Classic human capital theory argues that specific ability and skills of its workforce affect firm's productivity (Becker, 1962; Strober, 1990); in a broader way, we can extend this argument to the ability to collaborate in R&D, which is crucial for the innovational skills of SMEs, in the knowledge based economy. While some papers have concentrated on the level of skills and human capital of the founder of the firms (Colombo et al., 2006; Okamuro et al., 2011; Honjo, et al. 2014; Cao and Im, 2018), we focus on the human capital level of the firms R&D sector. This approach is closer to

the management literature's intuition to analyze the level of human capital that an organization has as a whole (e.g., Hitt et al., 2001; Pennings et al., 1998). By definition, an organization with more human capital holds many employees with high levels of knowledge, skill, and ability. In other words, firm performance is influenced not only by the key managers but also by the quality of the total pool of human capital within the organization (Wright et al., 1995). We argue that this argument is valid for the R&D cooperation as well, i.e. the level of human capital in the R&D department influences R&D cooperation. The literature has not investigated this link. In this paper, we fill this gap, including in the analysis the variable *Human Capital*, defined as the share of graduated people over R&D employees, expecting that human capital contributes to facilitate R&D cooperation:

- H1: Human capital facilitates R&D cooperation.

Previous studies have investigated the relationship between innovation and human capital in deep (Nahapiet and Ghoshal, 1998; Subramaniam and Youndt, 2005), suggesting a positive relation between these variables; other studies have tried to determine the direct effect of human capital on innovation (Alegre et al., 2006; McKelvie and Davidsson, 2006; Galunic and Rodan, 1998; Teece et al., 1997); however, despite the role that human capital is assumed to have on innovation, few studies have considered human capital as a variable that mediates and/or moderates the effects of other variables,[9] no one has analyzed the moderating role of human capital for R&D cooperation.

Human capital is an essential resource in implementing organizational strategy, providing an organization with a unique competitive advantage (Barney, 1991), and giving to employees an opportunity to earn more (Wright et al., 1995; Becker, 1962). It is a strategic element that allows firms to better perform and that should facilitate R&D cooperation. However, there is not only a *direct effect* of human capital on the firms propensity to cooperate in R&D; indeed, firms with high skilled employee should be able to exploit the opportunity given by external incentives, such as subsides and orders; i.e., we aspect firm's human capital and incentives to interact, in order to *indirectly* boost R&D cooperation. It is a well-known evidence that firms with less human capital are likely to expect lower rewards and performance (Becker, 1962); we extend this argument to the ability to exploit external incentives, such as subsidies and orders. In other words, we expect companies

[9]Kwon and Rupp, 2013; Park, 2012; Bornay-Barrachina et.al, 2012.

with human capital to be more effective in exploit external spillovers, and obtain subsidies and orders, than companies without human capital.

Our focus in this paper is on the interaction between human capital and incentives, and our aim is to understand how human capital moderates the relationship between R&D cooperation and public and private incentives; i.e., we argue that the human capital is the moderator and the variables subsidy and orders (both public and private) are the moderated: the presence of human capital may modify the impact of these incentives on the probability of a firm to cooperate in R&D.

These arguments leads to the following hypothesis:

- H2: Human capital moderates the impact of incentives on R&D cooperation

2.2 Incentives

Public and private incentives affect the probability that firms cooperate in R&D.[10] Subsidies should have a positive effect on R&D cooperation; however, a review of the empirical literature suggests that the effects of R&D subsidies on the R&D cooperation are mixed; furthermore, public subsidies may crowd-out private investment, boosting projects that firms would have financed even without incentives.[11] Spillovers refer to the exchange of ideas, know-how and experiences between firms engaged in R&D cooperation activities.

Theoretical literature has studied the role that knowledge spillovers have on the incentives to cooperate in R&D, showing that, in general, spillovers high enough facilitate R&D cooperation.[12] Empirical efforts have tried to confirm these results, and evidences suggests that firms characterized by

[10] See Cantabene and Grassi (2018).

[11] Belderbos et al. (2004) find that the impact of subsides on cooperation is not significantly different from zero; Colombo et al. (2006) find a similar result in a sample of Italian high-tech firms; on the contrary, 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 subsides on cooperation in R&D.

[12] 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. Kamien et al. (1992) introduce in the analysis product differentiation. Other contributions in Choi (1993), Leahy and Neary (1997), Goyal and Moraga-Gonzalez (2001), Capuano and Grassi (2018), under slightly different model setting, confirm these results.

higher incoming spillovers and better appropriation have, a higher probability to cooperate, with some limitations depending on partners, firm size, sector etc.[13] In the literature, surveys and investigations try to measure the importance of spillovers; i.e., qualitative indexes measure some central variables, such as spillovers and risk sharing: for example, in the CIS firms have to declare the grade of relevance they give to knowledge spillovers (or to cost and risk sharing), using a four-point scale. On the contrary, we concentrate on the measurable variable *Orders* as source of incoming spillovers: we argue that, whatever the partner, firms realizing research orders are more likely to cooperate, because the innovation activity increases the incoming spillovers, since it is realized on behalf of a third party which is outside the boundaries of the firm.

In order to obtain insight on the interaction between firms and other players outside the border of the firm, our first investigation question is about the role of incentives, both public (subsidies and public orders) and private (private orders):

- H3: Incentives (both public and private) facilitate R&D cooperation.

In the analysis we distinguish orders according to the source: we can have public orders (from universities or other public institutions), and private orders (from other firms).

Figure 1 describes the conceptual framework, showing the interaction between the hypotheses.

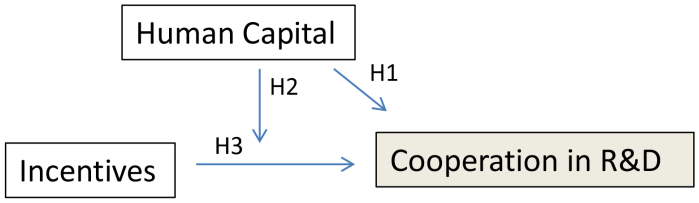

Figure 1: Conceptual framework and hypotheses

[13] Contributions include Cassiman and Veugelers (2002), Belderbos et al. (2004), Veugelers and Cassiman (2005), Lopez (2008).

3 Data Set and Econometric Model

3.1 Data

The empirical analysis is based on an original dataset including 6505 firms participating to the RS survey on R&D intra-muros in Italy. According to the Italian National Statistical Office (ISTAT) the RS survey 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.[14] The dataset includes only the firms reporting a positive amount of intramural R&D expenditure in at least one year of the time span analyzed, that is 1998-2004.

Variables in the RS survey relate to different aspects of the R&D activity of a firm, such as expenditure, personnel, financing, cooperation, research order, and public subsidies; other informations about the economic and financial activity of the firm, come from the firms' balance sheets, provided by ISTAT. Table (1) reports the descriptive statistics of the variables employed in the empirical analysis.

3.2 Dependent variables

The dependent variable $Coop$, is a dichotomous variable showing value one if, in year t, firm i realizes at least one R&D project in cooperation with someone else. In tables (3) and (5) we have distinguished cooperation according to the partners of the innovative activity. In particular, the dependent variables are two dummies equal to one if the firm was engaged in an active R&D partnership with universities and public agencies ($Coop_{pub}$), or with private firms ($Coop_{priv}$).

3.3 Independent variables

All the explanatory variables are largely used in the literature.[15]

Some firms may not have resources to invest in R&D activities, compensating this lack with more educated workers, able to appropriate the results of the innovative activity. Indeed, skilled employees contribute to absorb

[14] Information about the survey are included in the report ISTAT on RS, available at http://www3.istat.it/salastampa/comunicati/non_calendario/20041201_00/testointegrale.pdf

[15] For a discussion of the explanatory variable in the literature see Gussoni (2009).

Table 1: Descriptive statistics.

	SME				
	Obs.	Mean	Std.Dev.	Min	Max
$Coop$	9981	.33	.47	0	1
$Coop_{pub}$	9981	.16	.36	0	1
$Coop_{priv}$	9981	.25	.43	0	1
Human K.	9951	.34	.32	0	1
$Subsidy$	9981	.34	.47	0	1
$Orders_{pub}$	9981	.08	.27	0	1
$Orders_{priv}$	9981	.18	.38	0	1
$HK * Subsidy$	9951	.14	.27	0	1
$HK * Ord._{pub}$	9951	.05	.18	0	1
$HK * Ord._{priv}$	9951	.07	.21	0	1
R&D Int.	9981	.16	1.40	7.53^{-8}	47.9
Patents	8035	.60	.49	0	1
Size	9794	3.81	1.14	-2.52	5.52
Size2	9794	15.8	7.74	0	30.43
Group	6339	.39	.49	0	1
Location	9981	.03	.18	0	1
Cash-flow	9002	-2.75	.91	-5.99	4.18
Risk	9981	.12	.48	0	11.5

knowledge from inside and outside firms' boundaries. Thus, we use the variable *Human K* (defined as the share of graduated R&D employees over total R&D employees) to measure this effect.

In order to test H3, we consider a dummy variable (*Subsidy*) identifying firm that has received a public incentive to realize her R&D activity.

We investigate whether firms with skilled employees are more effective in exploit external spillovers, and obtain subsidies and orders with respect to firms with lower human capital, considering interaction between Human K and the moderated variables, namely Subsidy, Public Orders and Private Orders. These interaction variables capture how the presence of skilled employees in the R&D department modify the impact of public subsidies and spillovers on the propensity to cooperate.

We measure incoming spillovers through research orders, a dummy variable identifying firms realizing the R&D activity on behalf of someone which is outside the boundaries of the firm. We can identify the source of spillovers according to the partner of the order: universities and public institutions, private firms.

It may be the case that firms attempt to appropriate the benefits of their innovations, controlling information that flows out of the company. Cassiman and Veugelers (2002) find that a greater appropriability of the innovation process (lower outgoing spillovers) increases the probability to cooperate. Thus, we include in the analysis two measures of appropriability: *Patents* (dummy variable identifying firms reporting costs for patents' protection) and *R&D Intensity* (defined as the intramural R&D investment relative to turnover). Patents limit external spillovers, ensuring patenting firms to appropriate the results of their efforts. We have not a strong a priori on the intensity of this variable, however, we aspect its effect to be stronger in case of collaboration with private firms, rather than with public ones. Since in-house technological knowledge is crucial to absorb external knowledge, the propensity to be engaged in a cooperative agreement increases with the intensity of R&D activities (Tether, 2002).

3.4 Control variables

The relationship between firm size and R&D cooperation is not clearly assessed in the literature. Cooperation may be beneficial for small companies, since it allows them to share fixed research costs. On the other hand, large firms having the absorptive capacity required to exploit the benefits of R&D

cooperation, may be more likely to be engaged in cooperative R&D.[16] We argue that this arguments hold also for SMEs, since the behaviour and strategic motivations of micro firms may differ from that of medium firms. Thus, we control the size effect, including in the model the variable $Size$ (defined as the logarithm of total employee) and its squared ($Size^2$), to allow for possible non linearities.

Group firms may be informed about the capabilities and the attitude to innovate of internal partners, and may use their position in the group to attract internal partners for innovation. The dummy variable $Group$ captures the membership of a firm to a wider company group.

We focus on SMEs, that are likely to realize their R&D activity using only one plant. Nevertheless there are firms having more plants, in more regions. $Location$ is a dummy variable indicating the number of regions where firm realizes her own R&D activity; it takes the value 0 if it is concentrated in one region, 1 if it is realized in two or more. We expect that when the number of locations increases the propensity to cooperate increases, too.

Financial constraints and the incompleteness of financial markets may explain under-investment in R&D. Firms with higher internal liquidity might have higher R&D expenditure and this could affect the amount of cooperative R&D. Thus, we control for firms financial availability with the $Cash - flow$ variable.

Finally, the variable $Risk$ considers the possibility that firm's cooperate to share the risk of investment. It is given by the ratio between shareholders capital and total debt. We argue that the risk increases when the shareholders capital decreases, or the total debt increases. Thus, we expect a negative correlation between our measure of risk and firms propensity to cooperate in R&D.

Table (2) summarizes the variables definition and their expected signs, according to the literature.

3.5 Econometric strategy

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. Given our testing hypotheses, we assume that

[16] On the relation between size and R&D see, inter alia, Sakakibara (1997), Veugelers (1997), Fritsch and Lukas (2001), Miotti and Sachwald (2003), Franco and Gussoni (2014).

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.	
Human K.	share of graduated people over R&D employees.	(+)
Subsidy	dummy taking value 1 if the firm has received a subsidy.	(+)
$HK * Subsidy$	interaction between Human Capital and Subsidy	(?)
$Orders_{pub}$	dummy taking value 1 if the firm realizes her R&D activity on behalf of universities or other public research agencies.	(+)
$Orders_{priv}$	dummy taking value 1 if the firm realizes her R&D activity on behalf of other private entities.	(+)
$HK * Ord._{pub}$	interaction between Human K and $Orders_{pub}$.	(?)
$HK * Ord._{priv}$	interaction between Human K and $Orders_{priv}$.	(?)
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.	(+)
Cash-flow	logarithm of cash-flow relative to turnover.	(+)
Risk	shareholders capital over total debt.	(−)

Monetary variables are in thousands of euro at 2000 prices.

$$Coop_{it} = f(HumanK_{it}, Subsidy_{it}, HK * Subs_{it}, Orders_{pub/it}, \\ Orders_{priv/it}, HK * Orders_{pub/it}, HK * Orders_{priv/it}, X_{it}) \quad (1)$$

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 the cooperation decision over time using a panel data probit model with robust standard errors in order to correct for eventual heteroskedasticity.

The empirical literature has introduced arguments for the possible endogeneity of some determinants of R&D cooperation, mainly pubic 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, 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 [17]; the predicted residuals are used in the second stage as additional regressors in the structural equation without excluding the potential endogenous variables.[18]

4 Results

With the aim to analyze the determinants of cooperation in Italy, we estimate a model including all the SMEs; then, we distinguish cooperation with public institutions and private firms. Finally, we concentrate on the determinants for the high-tech sector, given the centrality of human capital in such a sector.

[17] 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, iii) dummies for the geographic macroareas, iv) technology-intensive propensity.

[18] Results available on request.

4.1 The determinants for SMEs

Table 3 shows the general results of the analysis. Column (a) illustrates the model overall; however, firms may have different motivations to cooperate with public entities (university and other public research centers), and with other private firms (both belonging to the same group or other firms). Thus, in column (b) and (c) we analyze the determinants distinguishing respectively cooperation with public and with private firms.

In column (a) the variable human capital positively affects the propensity to cooperate, while subsidies seems to be not significant. On the contrary, orders (both public and private) are highly significant; hence, we argue that external spillovers are an important determinants of cooperation for SMEs. Confirming the results of previous empirical research (and thus the robustness of our approach), we find the expected effect for the variables R&D intensity, location, cash flow and risk sharing. Summing up, in the general model we do not reject H1 and H2, and we partially reject H3.

Distinguishing cooperation by partner, results slightly change. While orders (both public and private) continue to increase the probability to cooperate in R&D, independently from the partner, human capital and subsidies affect cooperation with public partner only. This may be due to different skills, as well as resources, needed to cooperate with the public and the private sector. While research joint ventures (RJV) between private firms are usually market-oriented,[19] i.e. try to obtain marketable goods (product innovations), or to decrease the production costs (process innovations), cooperation with public involves basic R&D projects, whose results may not be immediately direct to the market: this kind of projects needs specialized skills, human capital, and huge financial resources.

The impact of the variable Human Capital, as moderator, is particularly

[19]There are numerous examples of companies that create an RJV, and then compete in the market. Among them, since 1978 Fiat, Citroën and Peugeot have been involved in an RJV to jointly develop and assemble different models of cars. In 2005, BMW and Mercedes decided to collaborate on developing hybrid engines. In 2007, a similar deal involved Fiat and Tata. Analogously BMW and Toyota collaborated on developing lithium-ion battery and diesel technology for sports cars. in 2011 Panasonic, Samsung, Sony and XPAND 3D collaborated for the development of a new technology standard for consumer 3D active glasses. In 2001 Sony, Toshiba and IBM started an R&D collaboration to develop semiconductors (system LSI). In 2005, Sony, Konica and Minolta signed a joint product development agreement for digital cameras (SLR) as a reaction to the Matsushita and Olympus collaboration signed in the same year.

relevant in the case of cooperation with public sector (column b). The interaction term is significant both for the public and for the private incentives, confirming the hypothesis H2. However, we have an interesting result: while both orders and human capital positively affect the propensity to cooperate with public partners, their interaction has a negative sign. This may mean that the impact of external spillover on the SMEs' propensity to cooperate is decreasing in human capital. In general SMEs have financial constraint and limited availability of resources, thus incentives are a crucial determinant of the propensity to cooperate. However, when human capital increases, firms skills increase as well, making the constraints less binding, thus the impact of the incentives on R&D cooperation decreases. We obtain a similar result for the variables *Subsidy* and *HK*Subsidy*. We argue that the availability of skilled employees increases both the absorptive capacity and the appropriability of firms: according to our results, as human capital increases, the importance of incentives in determining the firm's cooperation with public partners decreases.

Cooperation with private partners (column c) shows different results. Subsidies and human capital do not directly affect R&D cooperation. Indeed, we expect cooperation with private partner to have different motivations, with respect to cooperation with public institutions. In the case of cooperation with private, the appropriability of the results plays a central role: obtaining subsidies does not ensure appropriability, while the human capital alone may not be enough; however, subsidies and human capital together increase the probability to cooperate in R&D. This is exactly the moderating effect we expect human capital to have, in case of cooperation in R&D, and it should lead to an increasing number of RJV in the private sector, i.e. private companies that coordinate their R&D efforts in the research stage, and then compete in the market.[20] External spillovers continue to be an important determinant of cooperation. The impact of public orders on cooperation with private is decreasing in human capital, but we do not estimate any effect of human capital on public orders. Thus, in case of cooperation with private partners we partially reject H2. Stressing the idea that firms need mainly external incentives to cooperate with public, while they rely more on internal resources to cooperate with private firms, we note that cash-flow, location and risk sharing are strongly significant only for SMEs'

[20]See previous note for examples of RJV in the private sector, and Capuano and Grassi (2018) for a more in-depth analysis.

propensity to cooperate with private partners.

4.2 The determinants for high-tech SMEs

In this subsection, we focus our analysis on the determinants of R&D cooperation for high-tech SMEs. Because of the high level of competition in such a sector, high-tech SMEs engage high levels of R&D activity; thus, their motivations to cooperate in R&D may differ from the motivations of SMEs in different sectors. For example, high-tech SMEs may cooperate with private partners to rapidly enter the market a new product, whereas other SMEs cooperate to share risks and costs of the R&D activity. We argue that the behaviour of these firms may be different, because of the peculiar characteristics of their activity.

Table 5 shows the results in this sector. The first column (column d) does not distinguishes the partners. In this case we do not reject H1 and H3, but do reject H2.

With respect to the results obtained using the complete dataset (Table 3), the differences between the determinants of cooperation with public and private partners are more evident. In the case of public institutions (column e), public incentives (both subsidies and public orders) positively affect firms propensity to cooperate. This result confirms the one obtained in the general model, reinforcing the idea that, given the nature of the R&D project realized with the public institutions, firms need huge resources and stimuli to cooperate with public.

On the contrary, nor public subsidies neither public orders are significant in the case of cooperation with private partners (column f). However, in the case of orders, a sort of *'self reenforcing'* effect emerges: public orders increases the propensity to cooperate with public partners, private orders increases the propensity to cooperate with private partners. It may be the sign of locking-in: realizing research activity with a partner, a firm develops skills useful for cooperating with that partner.

Independently from the partner, in the high-tech sector human capital is always a relevant determinant of R&D cooperation, confirming H1. However, we do not estimate any impact of human capital as moderator nor with public subsidies, neither with private orders, whatever the partner, and the variable $HC * Ord_{pub}$ is not significant as well, in the case of coopeation with private, and has a low level of signficant in the case of cooperation with public. Thus, for high-tech SMEs the moderating effect of human capital partially

Table 3: Determinants of cooperation, SMEs

	(a)	(b)	(c)
Human K.	0.250***	0.238***	0.067
	(3.89)	(3.98)	(1.45)
Subsidy	-0.010	0.270***	-0.036
	(-0.24)	(2.66)	(-1.28)
$HK * Subsidy$	0.337***	-0.357**	0.244***
	(4.04)	(-2.22)	(4.17)
$Orders_{pub}$	2.220***	0.668***	1.303***
	(3.76)	(3.81)	(3.43)
$Orders_{priv}$	0.714**	0.155*	0.417**
	(2.46)	(1.75)	(1.99)
$HK * Ord._{pub}$	-2.872***	-0.820***	-1.791***
	(-3.30)	(-3.21)	(-3.24)
$HK * Ord._{priv}$	-0.924**	-0.236*	-0.416
	(-2.08)	(-1.72)	(-1.30)
R&D Int.	0.524***	0.224***	0.125***
	(3.80)	(5.07)	(2.92)
Patents	0.004	0.006	-0.000
	(0.21)	(0.92)	(-0.02)
Size	-0.075	0.012	-0.046
	(-1.60)	(0.87)	(-1.57)
Size2	0.016**	0.001	0.008*
	(2.51)	(0.31)	(1.92)
Group	0.005	0.006	0.012
	(0.28)	(1.03)	(0.89)
Location	0.092**	0.012	0.076***
	(2.29)	(1.01)	(2.91)
Cash-flow	0.031***	0.003	0.016**
	(2.88)	(0.97)	(2.18)
Risk	-0.086**	-0.011	-0.051**
	(-2.39)	(-1.25)	(-2.23)
N	4666	4666	4666
Wald	313.95***	274.78***	241.26***

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

disappears.

This interesting result may show that, using human capital as a moderator, in general we capture the impact of the interaction between constrained skills (human capital) and limited resources (public and private incentives) on SMEs' propensity to cooperate. However, such an interaction is not significant in the high-tech sectors, since high tech SMEs have to invest in R&D, and consequently have to cooperate in R&D, in order to survive in the market.

Coherently with previous studies, we find a positive impact of R&D intensity, Location and Size.

Table 4 summarizes the results, with respect to our starting hypotheses.

Table 4: The results on the hypotheses, according to the disaggregation

	(a)	(b)	(c)	(d)	(e)	(f)
H1	N	N	R	N	N	N
H2	N	N	P	R	P	R
H3	P	N	P	N	P	P

R = Rejected; N = Not Rejected; P = Partially Rejected

Table 5: Determinants of cooperation, high-tech SMEs

	(d)	(e)	(f)
Human K.	0.351***	0.224**	0.230*
	(2.68)	(2.15)	(1.81)
Subsidy	0.227***	0.214***	0.111
	(2.65)	(3.07)	(1.26)
$HK * Subsidy$	-0.005	-0.055	-0.042
	(-0.03)	(-0.46)	(-0.25)
$Orders_{pub}$	0.407**	0.329***	0.075
	(2.11)	(2.94)	(0.59)
$Orders_{priv}$	0.286**	0.005	0.342***
	(2.27)	(0.05)	(2.91)
$HK * Ord._{pub}$	-0.367	-0.351*	-0.006
	(-1.14)	(-1.83)	(-0.03)
$HK * Ord._{priv}$	-0.319	0.024	-0.349
	(-1.28)	(0.13)	(-1.57)
R&D Int.	0.249	1.551***	0.286*
	(1.40)	(2.68)	(1.75)
Patents	-0.033	0.006	-0.062
	(-0.57)	(0.15)	(-1.18)
Size	0.096	0.275***	0.152**
	(0.91)	(3.03)	(1.97)
Size2	-0.001	-0.023***	-0.010
	(-0.09)	(-2.63)	(-1.35)
Group	0.024	-0.022	0.042
	(0.40)	(-0.46)	(0.81)
Location	0.227***	0.070	0.136*
	(2.77)	(1.37)	(1.79)
Cash-flow	0.044	0.005	0.022
	(1.48)	(0.24)	(0.84)
Risk	-0.036	0.043	0.006
	(-0.83)	(1.50)	(0.16)
N	568	568	568
Wald	57.37***	55.97***	47.41***

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

5 Conclusion

In this paper, we have studied the determinants of R&D cooperation for SMEs in Italy, distinguishing the cooperation by partner, and concentrating on the high-tech sector. In particular, we have introduced in the literature human capital as one of determinants, studied its moderating role, and focused our analysis on subsidies and orders as determinant of cooperation.

Our paper underlines the crucial role of human capital: the results suggest that it affects the propensity of firms to cooperate in R&D, and that its effects are both direct and indirect. Directly, we show that human capital boosts cooperation in R&D (we do not reject H1 in all the cases, but one). Indirectly, i.e. concentrating on its moderating role, the effect of human capital on R&D cooperation appears to be more complex than originally assumed. We argue that it captures the impact of resources and/or skills constraints on the SMEs' propensity to cooperate. In the cases where these constraints may seriously affect the propensity to cooperate, we find that the more human capital, the less the importance of incentives as factors determining the firm's cooperation with other partners. Coherently, the moderating effect of human capital disappears for high-tech SMEs, whose propensity to cooperate may depend on the nature of the competition (and the research) in the sector. These results have important implications, since underlines the centrality of human capital even in this aspect of the business management of the SMEs. Firms wishing to invest in R&D need a well-educated workforce, to collaborate with external partners, in particular the institutional ones.

Furthermore, our research confirms the centrality of public and private incentives to boost cooperation, even if, in the case of SMEs, the significant and the magnitude of the results seem to depend on the partner. In particular, we note that, in the high-tech sector, public incentives boost cooperation with the public, while private incentives increase the probability to cooperate with private partners. In general, we can never completely reject H3, i.e. external incentives play a central role as stimuli for R&D cooperation.

Economic literature suggests that cooperation in R&D could enable firms to overcome some of the structural problems, creating scale economy in R&D, and sharing risks and costs between firms; the results of our study suggest that human capital may have a central role as well in stimulating such a cooperation, and that the State can boost cooperation through public orders and subsidies, consequently stimulating innovation, investment, and finally growth.

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

Table 6: Correlation Matrix

	Coop.	Coop.	Coop.	Subsidy	$Orders_{pub}$	$Orders_{priv}$	Human K	HK*Sub.
Coop.	1.000							
$Coop_{pub}$	0.6177*	1.000						
$Coop_{priv}$	0.8187*	0.2892*	1.000					
Subsidy	0.2647*	0.3146*	0.1777*	1.000				
$Orders_{pub}$	0.3027*	0.4135*	0.2034*	0.3086*	1.000			
$Orders_{priv}$	0.2028*	0.1246*	0.2389*	0.0673*	0.2473*	1.000		
H.K.	0.1999*	0.2649*	0.1141*	0.1329*	0.2376*	0.0801*	1.0000	
HK*Sub	0.3180*	0.3896*	0.2148*	0.7038*	0.4234*	0.1351*	0.5175*	1.000
HK*Pub	0.2777*	0.3873*	0.1946*	0.2900*	0.8832*	0.2351*	0.3357*	0.5094*
HK*Priv	0.2224*	0.2199*	0.2353*	0.1452*	0.3505*	0.7391*	0.3483*	0.3245*
R&D Int.	0.0609*	0.0864*	0.0412*	0.0521*	0.0755*	0.0308*	0.0303*	0.0561*
Pat.	-0.0042	0.0145	-0.0106	0.0085	-0.0349*	-0.0293*	0.0009	0.0063
Size	-0.0082	-0.0023	-0.0177	-0.0328*	-0.1169*	-0.1044*	-0.1454*	-0.1249*
$Size^2$	0.0127	0.0145	-0.0033	-0.0201*	-0.0927*	-0.0948*	-0.1187*	-0.1043*
Group	0.1134*	0.0820*	0.1065*	-0.0099	0.0376*	0.0594*	0.0561*	0.0095
Location	0.1123*	0.1256*	0.1041*	0.0896*	0.1394*	0.0840*	0.0993*	0.1413*
Cash-Flow	0.0877*	0.1078*	0.0636*	0.0394*	0.0579*	0.0217*	0.0902*	0.0669*
Risk	-0.0012	0.0333*	0.0065	-0.0060	0.0525*	0.0229*	0.0248*	0.0138

	HK*Pub.	HK*Priv.	R&D size	Patents	Size	$Size^2$	Group	Location
HK*Pub.	1.000							
HK*Priv	0.4094*	1.000						
R&D Int.	0.0643*	0.0490*	1.000					
Patents	-0.0277*	-0.0211	-0.0434*	1.0000				
Size	-0.1464*	-0.1452*	-0.1319*	0.2154*	1.000			
$Size^2$	-0.1209*	-0.1259*	-0.1000*	0.2124*	0.9669*	1.000		
Group	0.0237	0.0328*	-0.0190	0.1312*	0.3541*	0.3744*	1.000	
Location	0.1508*	0.1199*	0.0195	0.0009	0.0227*	0.0324*	0.0872*	1.000
Cash-Flow	0.0472*	0.0543*	0.1534*	0.0192	0.0025	0.0290*	0.0701*	0.0199
Risk	0.0450*	0.0302*	-0.0177	-0.0331*	0.0402*	0.0410*	0.0988*	0.0278*

	Cash-Flow	Risk
Cash-Flow	1.000	
Risk	0.1211*	1.000

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