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The relation between human capital and innovation at a firm level A study on a sample of European firms.

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Abstract

In this paper we wonder if the human capital "embodied" in the workforce has in itself (being constant the effort in R&D) a relation with the innovative capabilities of the firm, and if this link is better expressed with linear or non linear expressions. Then we test the existence of an interaction, and of what sign, between the education of the workforce and the R&D effort of the firm. Finally, we verify if the relationship between human capital and innovation has different strength in different countries. The empirical test is performed on data coming from a survey (EFIGE) run in seven European countries concerning the period 2007-2009. We adopt several models of multivariate analysis, to analyze different kinds of dependent variables (dichotomous, percentage) and different statistical problems (possible sample selection and endogeneity). Our The results to show a statistically significant and positive relationship between the ratio of graduated employees and the percentage of turnover from innovative products, being constant the share of personnel employed in R&D. This relationship, besides, appears not linear as we find decreasing marginal return for human capital as well as for R&D. Then, we find a complementarity between human capital and R&D: the strength of the link between human capital and innovation is higher when firm's R&D increases. We also find some significant differences in the intensity of the human capital/innovation link across different countries.

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1. Introduction

The importance of human capital for growth has been largely emphasized. This link has its roots at the firm level, where it is easy to suppose a relationship between the education of the workforce and the innovative capacity of the firm: more educated workers may introduce more innovations and they are needed to import and manage innovations created by other firms. Indeed, the link between human capital and innovation has been largely investigated at a macroeconomic level, with a special emphasis on the externalities, but, we think not enough at the firm level. This paper aims to contribute to fill this gap.

The relationship between education and innovation is evident if we consider the employees with high education working in R&D laboratories, but the link between R&D and innovation at the firm level has received more attention: we inquiry if an higher education of workforce is important

for innovation even excluding R&D activities. Empirically, we answer to the following question: is there a relationship between the share of graduate workers with tertiary education on one side and the probability to introduce a product innovation and the percentage of turnover derived from innovative product on the other side, being constant the share of workers directly occupied in R&D activities (obviously even controlling for several other factors that may have an effect on the innovation)? If such relation exists, we ask whether it is linear or it is better approximated by a non linear function.

Out theoretical framework roots in the knowledge production function. It states that innovation at the firm level is related with the cognitive capital present in the firm itself, where this is, precisely, not only the expenses formalized in R&D but also by the level of internal human capital (Audretsch and Feldman, 2004).

Moreover, we analyse the interaction between these two components. It is possible to hypothesize both a complementarity and a substitutability relationship. We can suppose that the higher is the human capital embodied in the workforce the larger is the effect of R&D on innovation: a qualified workforce may multiply the innovative potential coming from research laboratories; this is a relationship of complementarity. Alternatively, it is possible to suppose that, if R&D expenditure is absent or low, the innovative strength particularly belongs to the qualified personnel not working in laboratories; this is a relation of substitutability: the lower is the expenditure in R&D, the higher the effect of human capital on innovation. Therefore we ask whether between human capital and R&D are complimentary or substitute at a firm level.

This paper also try to shed the lights on differences of the effect of human capital on innovation from an international prospective. We ask the following question: if human capital embodied in the workforce has an effect on the innovativeness of the firm, is this effect significantly different among different countries?

The empirical analysis is in fact conducted on data coming from a survey (EFIGE) run in seven European countries and concerning the period 2007-2009. This survey is better described in the third section.

To address such issues we performed a regression analysis, comparing several different techniques. To test for the linearity of the relationship between the elements of cognitive capital and the innovativeness of the firm a non-parametric analysis was also used.

The article is structured as follows: the second paragraph presents a review of the relevant literature on the relationship between human capital, R&D and innovation; the third paragraph describes the data (first sub-section), presents the results of the univariate and bivariate analysis

(second section) and of the multivariate analysis, followed by a synthesis of the results (third section); our conclusions end the paper.

2. Human capital, R&D and innovation: looking for a microeconomic literature

The link between human capital, R&D and innovation has been usually considered on a macroeconomic point of view. In the theory of growth the importance of human capital and R&D are almost immediately acknowledged, but in the "classical" Solow's model of growth (1956) they remain in a sort of "black box". Mankiw, Romer and Weil (1992), extending the Solow's model with the inclusion of human capital, managed to explain almost two thirds of the variability of growth rate among different national economies. The new theory of growth gives particular emphasis to the importance of human capital (Lucas, 1988) and R&D (Romer, 1990 a, b) for growth. Even if the models of these authors have a microfoundation, the context remains macroeconomic.

An important theoretical and empirical breakthrough was the introduction of the knowledge production function of Griliches (1979), because the scope of the theoretical formulation is explicitly microeconomic and because in this formulation the output is no longer production but directly innovation and knowledge is the input. Although the latter is a term with a clear economic meaning, empirically needs to be explained: as Audretsch and Feldman (2004) underline, citing Cohen and Klepper (1991 and 1992), the main source of knowledge in firm is generally considered R&D, which is therefore the term that underpins most empirical investigations; other elements in which the knowledge "translates" vary with the specific objective of the study. In the Audretsch and Feldman (2004)'s formulation the knowledge production includes, in addition to R&D, human capital as an input of innovation. In the empirical studies such formulation of the knowledge production function is rarely estimated at a firm level. It is usually extended to industry, geographic area or country, highlighting the role of spillovers and externalities; innovation output of each firm depends only partly from internal sources of knowledge. Knowledge function largely depends on the research done by other firms, in the public and private centres of research, geographically contiguous, on the human capital present in the geographic area of the firm (see, for an analysis of the Italian case, Audretsch and Vivarelli, 1996). Therefore, when it is studied the link between input and output of knowledge at the firm level, this is often weak, while, if the unit of analysis is wider, the relationship becomes clearer.

In the decades since the introduction of the theoretical model of the knowledge production function there are many and important contributions, even empirical, that substantiate this approach

(Griliches and Mairesse, 1983; Hall and Mairesse, 1995; Crepon, Duguet and Mairesse, 1998). The idea is that a company, an industry or a geographical area (Jaffe, 1986; Acs, Audretsch and Feldman, 1992; Feldman, 1994) have to invest in R&D expenses (input) in order to increase the production of innovations (output). These in their turn imply an increase of the added value (species through product innovations) and productivity (particularly through process innovations). In the years, the original formulation was significantly and suitably enriched through the consideration of the effects of feedback (Kline and Rosenberg, 1986), as well as through the realization that knowledge spillovers can take root only in the presence of a sufficient level of absorptive capacity (Cohen and Levinthal, 1989): this is in fact an adequate level of internal knowledge resources which can "absorb" the external knowledge. According to Mangematin and Nesta (1999) firms with a high level of absorptive capacity will be in a better position to assimilate and utilise external knowledge, thus to increase the innovative performance.

Therefore, in the sophisticated context of the evolutionary theory of the firm, it is reclaimed the idea of Nelson and Phelps (1966), born in the macroeconomic sphere, that “internal” knowledge is needed to absorb new knowledge produced outside, showing a kind of inverse causal process between intellectual capital and innovation. Despite these important theoretical improvements, the setting of this prevailing trend of studies remains focused on the role of the R&D as a primary factor. This is capable of generating innovation, to support the productivity, the competitiveness of products and, finally, the economic growth.

Compared to the profusion of studies on the effects of human capital in the macroeconomic sphere or on the effects of R&D at the firm level, there are less frequent studies on the effects of human capital on innovation at the firm level (Schneider, Guenther and Brandenburg, 2010). In many cases the link highlighted is indirect, in the sense that human capital is seen as a prerequisite for investment in other factors or other changes in firm that in turn lead to innovation. For example Arrighetti, Landini and Lasagni (2011), in a study on Italian data, referring to a vision of the firm based on *capabilities,* stress that the propensity to invest in *intangible assets.* Such assets, which have a strong impact on innovation and firm performance, depend on the level of human capital in the firm, as well as on the firm size, on the organizational complexity and on many firm specific factors. Abowd et al. (2002), studying US data, show that human capital affects the productivity of businesses either directly either with its complementary role with respect to the most advanced technologies, business models and organizational practices. Even Piva, Santarelli and Vivarelli (2005), again on Italian data, highlight the link between organizational change and demand for workers with high levels of *skills.* Blundell et al. (1999), in their literature review about the returns

to human capital at a macroeconomic (the whole economy) and microeconomic (firm and individual) levels, underline the twofold role of a highly educated and skilled workforce. They are able to adapt to new tasks and technology and they are also a direct source of innovation, as education increase a worker's ability to be innovative on the job. They report the results of several empirical studies, like Bosworth and Wilson (1993), which suggest strong links between the employment of graduates, including professional scientists and engineers, and the adoption and use of high-level technologies in the firm. In their paper Blundell et al. (1999) also underline the role of the training on the job, as a component of human capital, and, besides innovation, they also consider the effect of the human capital on productivity and profitability.

Some papers, similarly to ours, take into account both the human capital and R&D at the firm level Ballot, Fakhfakh and Taymal (2001) analysing data from France and Sweden, consider the effect of R&D and human capital on firm performance, measured by the value added, and find a positive effect. They also highlight the interaction between these two factors showing a positive effect). The second work is based on EFIGE data. The share of graduated workers in the firm is placed in connection with the introduction of an innovation in firm, as well as with the number of patents filed at the European Patent Office (the report found is positive); expenditure on R&D is not included in the same estimate of the determinants of innovation, but it is placed in relation to human capital, in the sense that the latter (measured with the share of graduates) positively affects the expenditure on R&D. The paper by D'Amore, Iorio and Lubrano Lavadera (2014) shares with the present paper the same theoretical background and some central empirical questions. They find similar results: a statistically significant and positive relationship between the number of graduates and the number of employees in R&D on the one hand, and the likelihood of introducing both a product and a process innovation on the other. They also study the interaction term between graduates and R&D and they find that it has a negative sign: it seems to prevail an effect of "substitution" between the two components of the cognitive capital of the firm, so the relationship between human capital and innovation is stronger where the level of R&D is lower. In that paper differently from the present one, it is not introduced quadratic terms for human capital and R&D and this may be one reason of a different result from the present paper (we anticipate that, also considering quadratic terms, we find a complementarity between human capital and R&D); besides, they analyze only Italian data (a rotating *panel* of Italian firms, for a period of nine years), while our analysis is at an European level (seven countries).

3.1 Data and objectives of the empirical analysis; univariate and bivariate analysis

For our analysis we used data of the EFIGE survey. EFIGE (European Firms in a Global Economy) is an international research project under the auspices of the European Commission. A large survey in six sections has been submitted to a sample of 14.911 firms in seven European countries: 3.019 in Italy, 2975 in France, 2973 in Germany, 2832 in Spain, 2142 in the United Kingdom, 488 in Hungary, 482 in Austria. The stratification of the sample was made according to the size and business sector, taking into account the main geographical areas of each country. The questions are related to the period 2007-2009.

The goal of this work is to correlate the innovativeness of the firm with its cognitive capital. As a measure of innovativeness we take two variables into consideration, both deriving from two specific questions of the EFIGE survey: the first one is a dummy variable assuming value 1 if the firm introduced any product innovation in the years 2007-2009 and 0 otherwise; the second variable ~~one~~ is the percentage of turnover from innovative products sales on average in the same years[1]. We take as a measure of cognitive capital the share of graduates and personnel engaged in R&D. It is investigated not only if and to what extent human capital and R&D are related to innovation at the firm level, but also the non-linearity of the relationship and the effects on innovation of the interactions between the two components of the cognitive capital. Referring to the review of the literature of the previous chapter, we can say that our theoretical reference is the function of knowledge production à la Audretsch and Feldman (2004). Attending this framework, innovation at the firm level (I) is a function of R&D (RD) and the internal human capital (HK), as well as of an error term. The non-linear formulation of the function implies non constant effects of R&D and human capital on innovation and the existence of effects of interaction between the two inputs (the effect of one depends on the size of the other), formally:

$$I_i = \alpha RD^{\beta}{}_i HK^{\gamma}{}_i \varepsilon_i$$

Table 1 shows, in the first column the percentage of firms that claim to have introduced product innovations, in the second the mean percentage of turnover deriving from innovative products, in the third the same mean as before but only considering innovative firms

[1] In the EFIGE questionnaire only those who have introduced a product innovation are invited to indicate the percentage of turnover deriving from innovative product sales; therefore, for those who declared to have not introduced any product innovation, we clearly supposed that percentage was zero.

Table 1- Percentage of innovative firms

Firms introducing Product innovation (a)	Average percentage of turnover from innovative product sales- all firms	Average percentage of turnover from innovative product sales- only innovative firms
49.1%	10,2%	21.2%

Table 2 shows the correlation between the product innovation (the variable assumes value 1 if the firm has introduced at least one product innovation in the three years considered in the survey, value 0 if no product innovation has been introduced), the percentage of turnover deriving from innovative products, the percentage of university graduates in the workforce and the percentage of employees involved in R&D activities .

Table 2- Pearson correlations

	Product innovation	Percentage of turnover from innovative products sales	Share of workers with university degree
Percentage of turnover from innovative products	0.56***	-	
Share of workers with university degree	0.15***	0.19***	-
Share of workers involved n R&D	0,18***	0.22***	0.26***

***Significant al 1%

All correlations are positive and significant at 1%. So, there is a positive relationship between the components of the cognitive capital of the firm and the innovativeness of the firms. On the other hand, there is a strong relationship between the number of graduates and the number of employees in R&D: this is obvious considering that, among those involved in R&D, there is a high percentage of science graduates. In order to highlight the effect of each of the two components of cognitive capital on the innovation, it is necessary a multivariate analysis, which also takes into account a number of other “control” variables, correlated both to innovation and to the cognitive capital of the firm.

3.2 Multivariate analysis

In the multivariate analysis, the dependent variables are:

- *innoprod,* a dummy variable assuming value 1 if the 'firm introduced any product innovation in the period 2007-2009;
- *innoturn,* the average percentage of turnover deriving from innovative product sales.

The independent variables under study are:

- *gradperc,* the percentage of university graduates in the workforce ;
- *gradperc2,* the quadratic term of *gradperc*;
- *rdperc,* the percentage of employees involved in R&D activities;
- *rdperc2,* the quadratic term of *rdperc*;
- *Xgradrdperc,* the product of the variables *gradperc* and *rdperc*
- *grad_[name country],* the product of the variable *gradperc* and the dummy variables for countries.

In the regression with instrumental variable, we use as instrument for *gradperc* the variable:

- *extceo,* a dummy variable assuming value 1 if the chief executive office (CEO) is a manager recruited outside of the firm, 0 otherwise (if he is a member of the proprietary family or a manager appointed within the firm).

Control variables are:

- *workforce*, the total number of employees in the firm's home country;
- *export,* dummy variable indicating whether the firm is exporting or not; in fact a broad literature identifies a link between innovation and export (see, among others, Dosi, Pavitt and Soete, 1990);
- dummy variables indicating which of the groups identified by Pavitt taxonomy (Pavitt, 1984) the firm belongs to: the reference category is the first group, the *supplier dominated* firms; the second group is that of *business scale intensive* firm, the third one is the group of *specialised suppliers* and the fourth group is that of the *science based* firms;
- dummy variables for countries (the reference variable is United Kingdom).

We tested other control variables in the models, but they resulted non significant or they were missing in several observation, reducing therefore the number of the observation, without

modifying significantly the effectiveness of the estimate.

In the regressions having *innoprod as* dependent variable, being this variable dichotomous, we adopted both *probit* and *logit* models; the dependent variable *innoturn* is a percentage, assuming therefore positive values only, from 0 to 100: such kind of data may be properly treated with a Tobit model (as suggested by Long, 1997) or with a Generalized Linear Model (as suggested by Papke and Wooldridge, 1996)[2]; we also estimated a classical OLS linear regression model. Besides, we have to consider that the process which determines whether a firm is innovative may be different from the process which determines the percentage of innovative turnover. An Heckman selection model estimates the two different but linked processes. We considered the same covariates for the two steps, supposing that they have a different effect in the two processes[3]. In studying the relation between human capital and innovation, problems of endogeneity and reverse causality may arise, as our data are cross-sectional. Therefore we also estimated *probit* (for *innoprod*), linear and tobit regression (for *innoturn*). with instrumental variables.

We always did, when possible, robust estimates.

We estimated several models: Model 1 is the "basic" model, including only first degree terms for human capital and R&D variables, without interactions, plus the control variables illustrated above. Model 2 adds to the previous model the interaction and the quadratic terms of human capital and R&D variables. Model 3 adds to the previous model the interaction terms between the human capital variable and the dummy variables for countries.

As a threshold of significance we considered the 5% level, but we remarked all the cases when coefficients and tests are below the 1% level; on the other hand we signaled when a threshold of 10% would be however overcome.

In the following we report the formulas for each model (for the sake of simplicity, when the dependent variable is *innoturn* we report only the linear model), the result of the estimates for every models, followed by a brief comment.

We begin our analysis from Model 1, the basic model.

Model 1

$$\Phi^{-1}(innoprod_i) = \beta_0 + \beta_1\, gradperc_i + \beta_3\, rdperc_i + \beta_3 workforce + \beta_4\, export + \boldsymbol{\beta_{5\text{-}7}}\,(\text{Pavitt dummies}) + \boldsymbol{\beta_{8\text{-}13}}\,(\text{country dummies}) + \varepsilon_i$$

[2] In STATA 14 we adopted the options family (binomial) link (logit).

[3] Because of the computational difficulties to estimates the maximum likelihood specification of the Heckman selection model, we adopted the two-steps specification.

$innoturn_i = \beta_0 + \beta_1\ gradperc_i + \beta_3\ rdperc_i + \beta_3 workforce + \beta_4\ export + \boldsymbol{\beta_{5\text{-}7}}$ (Pavitt dummies) + $+ \boldsymbol{\beta_{8\text{-}13}}$ (country dummies) $+\varepsilon_i$

Table 3. Determinants of product innovation - Model 1

	probit	logit
gradperc	0.00871***	0.0146***
	(0.00101)	(0.00172)
rdperc	0.0142***	0.0262***
	(0.00114)	(0.00240)
workforce	0.00127***	0.00216***
	(0.000122)	(0.000207)
export	0.494***	0.793***
	(0.0231)	(0.0377)
pavitt2	0.0176	0.0320
	(0.0269)	(0.0438)
pavitt3	0.191***	0.307***
	(0.0332)	(0.0538)
pavitt4	0.349***	0.571***
	(0.0590)	(0.0973)
Benchmark: pavitt1		
Italy	-0.253***	-0.409***
	(0.0373)	(0.0603)
France	-0.363***	-0.592***
	(0.0382)	(0.0622)
Spain	-0.307***	-0.503***
	(0.0382)	(0.0621)
Germany	-0.292***	-0.474***
	(0.0384)	(0.0624)
Austria	0.0931	0.157
	(0.0790)	(0.131)
Hungary	-0.403***	-0.648***
	(0.0672)	(0.110)
Benchmark: United Kingdom		
_cons	-0.389***	-0.653***
	(0.0375)	(0.0609)
N	14046	14046
pseudo R-sq	0.083	0.085

Standard errors in parentheses
° p<0.10, ** p<0.05, *** p<0.01

Table 4. Determinants of turnover from innovative product sales -Model 1

	OLS	Tobit	GLM	Heckman (2nd step)
gradperc	0.175***	0.319***	0.0140***	0.240***
	(0.0174)	(0.0286)	(0.00120)	(0.0445)
rdperc	0.242***	0.476***	0.0185***	0.361***
	(0.0173)	(0.0296)	(0.00107)	(0.0649)
workforce	0.000992	0.0171***	0.000107	-0.00147
	(0.00158)	(0.00285)	(0.000155)	(0.00625)
export	4.630***	13.78***	0.610***	6.628**
	(0.314)	(0.731)	(0.0410)	(2.834)
pavitt2	-0.0923	0.189	-0.0236	-0.294
	(0.370)	(0.812)	(0.0443)	(0.718)
pavitt3	1.360***	4.293***	0.154***	1.608
	(0.479)	(0.948)	(0.0500)	(1.273)
pavitt4	2.931***	6.902***	0.251***	2.704
	(0.923)	(1.544)	(0.0763)	(2.012)
Benchmark: pavitt1				
Italy	-0.157	-2.189*	-0.00886	0.859
	(0.590)	(1.117)	(0.0586)	(1.297)
France	-3.721***	-9.828***	-0.434***	-5.753***
	(0.562)	(1.156)	(0.0646)	(2.024)
Spain	-2.595***	-7.229***	-0.252***	-3.208**
	(0.567)	(1.145)	(0.0601)	(1.501)
Germany	-2.930***	-5.782***	-0.285***	-3.734**
	(0.565)	(1.106)	(0.0594)	(1.536)
Austria	2.217°	4.456**	0.197°	3.411°
	(1.236)	(2.101)	(0.108)	(1.901)
Hungary	-3.623***	-11.98***	-0.392***	-4.459°
	(1.000)	(2.271)	(0.127)	(2.402)
Benchmark: United Kingdom				
_cons	5.474***	-18.66***	-2.763***	0.822
	(0.529)	(1.129)	(0.0603)	(9.211)
sigma				
_cons		32.89***		
		(0.507)		
mills				
lambda				14.73°
				(8.387)
N	13727	13727	13727	13727
adj. R-sq	0.092			

Standard errors in parentheses
° p<0.10, ** p<0.05, *** p<0.01

Table 3 reports the results for *probit* and *logit* estimate for *innoprod* as dependent variable, Table 4 reports the results for OLS, Tobit, GLM and Heckman selection model for *innoturn* as

dependent variable (we report only the results of the second step of the Heckman selection model, having *innoturn* as dependent variable)[4]. The variables representing the cognitive capital of the firm show similar results whatever the measure of innovation and the estimated model. The positive and significant (at 1% level) sign for *rdperc* was largely expected: firms with an higher ratio of employees involved R&D have an higher degree of innovativeness (an higher probability to introduce an innovation and an higher impact of the innovations on firm's returns). The sign for *gradperc* is always positive and significant (at 1% level) too: this means that, even controlling for the employees in R&D, an higher ratio of graduated workers is associated with an higher level of innovativeness. As for the control variables, we observe that exporting firms are more innovative than non exporting ones; the effect of the size (expressed by the number of workers) is significantly positive on the capacity to innovate, while the effect on the innovative turnover is significant (at 1%) and positive only in the Tobit model. Regarding the Pavitt classification, we may conclude that, as expected, the *specialized suppliers* and *science based* firms are more innovative than *supplier dominated* firms. Anyway, if we suppose that the process to generate an innovation is different from the process determining the percentage of innovative turnover, the Pavitt classification has no significant effect on this second process, as expressed by the results of the second step of the Heckman selection model. The correctness of the hypotheses of the non identity of the two processes, therefore of the need to estimate a selection model, is estimated by the mills lambda test. This has a significance threshold of 5%, this hypothesis should be rejected (the test is significant only at 10%); but we may anticipate that, for more complex models like Model 2 and Model 3, the test becomes significant at 1%; therefore the presence of an estimate with the Heckman selection model is largely justified.

The signs and significance of the coefficients for country dummy variables show that the firms of United Kingdom have an higher probability to introduce product innovation than all the other countries except Austria and this result is significant at 1%. Regarding the percentage of turnover deriving from innovations, the prevalence of British firms is confirmed against France, Spain, Germany and Hungary (at 1% level, except for the Heckman selection model, which shows similar results but at a lower level of significance for Spain, Germany and Hungary). It is remarkable the positive sign for Austrian firms for *innoturn*, even though at 5% level of significance only in the Tobit model (~~anyway~~ at 10% in the other three models),

[4] *Innoprod* is the dependent variable of the probit representing the first step; the independent variables are the same of the probit model shown in Table 3; the number of cases is almost the same, except the few (339 over 14,046) firms having 1 for *innoprod* and a missing for *innoturn*, which have been dropped from the first step of the Heckman selection model. As the variables are the same and the cases are almost the same, the results are very similar, therefore we preferred not to show the results of the first step of the Heckman selection model. The same happens for Model 2 and Model 3.

We turn now to Model 2, which adds to Model 1 the interaction term of *gradperc* and *rdperc* (*Xgradpercrdperc*) and their quadratic terms (*gradperc2* and *rdperc2*).

Model 2

$$\Phi^{-1}(innoprod_i) = \beta_0 + \beta_1\, gradperc_i + \beta_2\, gradperc2_i + \beta_3\, rdperc_i + \beta_4\, rdperc2_i + \beta_5\, Xgradrdperc_i + \beta_6\, workforce + \beta_7\, export + \mathbf{B_{8\text{-}10}}\,(\text{Pavitt dummies}) + \boldsymbol{\beta_{11\text{-}15}}\,(\text{country dummies}) + \varepsilon_i$$

$$innoturn_i = \beta_0 + \beta_1\, gradperc_i + \beta_2\, gradperc2_i + \beta_3\, rdperc_i + \beta_4\, rdperc2_i + \beta_5\, Xgradrdperc_i + \beta_6\, workforce + \beta_7\, export + \mathbf{B_{8\text{-}10}}\,(\text{Pavitt dummies}) + \boldsymbol{\beta_{11\text{-}15}}\,(\text{country dummies}) + \varepsilon_i$$

Table 5. Determinants of product innovation - Model 2

	probit	logit
gradperc	0.0176***	0.0290***
	(0.00202)	(0.00336)
gradperc2	-0.000177***	-0.000295***
	(0.0000306)	(0.0000516)
rdperc	0.0521***	0.0870***
	(0.00212)	(0.00364)
rdperc2	-0.000524***	-0.000875***
	(0.0000256)	(0.0000440)
Xgradrdperc	-0.0000138	-0.00000801
	(0.0000425)	(0.0000762)
workforce	0.00138***	0.00234***
	(0.000125)	(0.000212)
export	0.423***	0.687***
	(0.0236)	(0.0387)
pavitt2	0.0307	0.0524
	(0.0272)	(0.0448)
pavitt3	0.159***	0.260***
	(0.0336)	(0.0549)
pavitt4	0.280***	0.461***
	(0.0598)	(0.100)
Benchmark: pavitt1		
Italy	-0.266***	-0.430***
	(0.0378)	(0.0614)
France	-0.394***	-0.646***
	(0.0386)	(0.0633)
Spain	-0.337***	-0.551***
	(0.0388)	(0.0635)
Germany	-0.337***	-0.550***
	(0.0389)	(0.0638)

Austria	0.125	0.203
	(0.0796)	(0.132)
Hungary	-0.332***	-0.540***
	(0.0670)	(0.110)
Benchmark: United Kingdom		
_cons	-0.528***	-0.874***
	(0.0383)	(0.0627)
N	14046	14046
pseudo R-sq	0.113	0.114

Standard errors in parentheses
° p<0.10, ** p<0.05, *** p<0.01

Table 6. Determinants of turnover from innovative product sales -Model 2

	OLS	Tobit	GLM	Heckman (2nd step)
gradperc	0.159***	0.438***	0.0186***	0.378***
	(0.0321)	(0.0601)	(0.00298)	(0.0971)
gradperc2	-0.000936°	-0.00345***	-0.000123***	-0.00249**
	(0.000513)	(0.000921)	(0.0000427)	(0.00118)
rdperc	0.654***	1.486***	0.0621***	1.451***
	(0.0338)	(0.0615)	(0.00285)	(0.223)
rdperc2	-0.00641***	-0.0146***	-0.000591***	-0.0141***
	(0.000418)	(0.000811)	(0.0000428)	(0.00233)
Xgradrdperc	0.00263***	0.00168	0.0000459	0.00191°
	(0.000912)	(0.00148)	(0.0000611)	(0.00109)
workforce	0.00215	0.0196***	0.000244	0.0130**
	(0.00156)	(0.00282)	(0.000154)	(0.00620)
export	3.752***	11.39***	0.502***	10.28***
	(0.314)	(0.723)	(0.0411)	(2.137)
pavitt2	0.0322	0.646	0.000508	0.239
	(0.364)	(0.798)	(0.0441)	(0.853)
pavitt3	1.035**	3.305***	0.117**	2.822**
	(0.472)	(0.931)	(0.0495)	(1.209)
pavitt4	1.913**	4.620***	0.151**	3.829**
	(0.914)	(1.526)	(0.0754)	(1.878)
Italy	-0.270	-2.520**	-0.0332	-1.414
	(0.581)	(1.096)	(0.0585)	(1.414)
France	-3.889***	-10.37***	-0.464***	-9.995***
	(0.552)	(1.131)	(0.0640)	(2.023)
Spain	-2.551***	-7.419***	-0.262***	-5.674***
	(0.556)	(1.121)	(0.0595)	(1.612)

Germany	-3.249***	-6.711***	-0.328***	-7.093***
	(0.557)	(1.083)	(0.0586)	(1.696)
Austria	2.322°	4.726**	0.206**	4.521**
	(1.191)	(2.010)	(0.103)	(2.298)
Hungary	-2.409**	-9.406***	-0.272**	-5.376**
	(0.987)	(2.217)	(0.124)	(2.340)
_cons	4.499***	-21.76***	-2.942***	-21.19**
	(0.516)	(1.131)	(0.0603)	(8.591)
sigma				
_cons		32.15***		
		(0.501)		
mills				
lambda				31.88***
				(7.170)
N	13727	13727	13727	13727
adj. R-sq	0.119			

Standard errors in parentheses
° p<0.1, ** p<0.05, *** p<0.01

A comparison between the values of the pseudo R-square (for *probit* and *logit* estimate) and adjusted R-square (for linear regression) for Model 2 (respectively 0.113, 0.114 and 0.119) are larger than and the values obtained for Model 1 (respectively 0.083, 0.085 and 0.092). Thus, the introduction of the quadratic and interaction terms of *gradperc* and *rdperc* increases the goodness of fit and the explicative power of the model. The results of the estimation show the non linearity of the relationship between the human capital embodied in the workforce and the R&D intensity of the firm on one side and the innovativeness of the firm on the other. In fact, the term of first degree of *gradperc* and *rdperc* are positive and significant, while their square terms are negative and almost in any case significant at 1% (the only exceptions concern *gradperc2*, which is significant at 5% in the Heckman selection model and not significant in the OLS, where however the 10% threshold would be overcome). This means that the increase in the probability to innovate and in the percentage of innovative turnover is the larger, the smaller is the percentage of graduate employers. The same holds for the percentage of employers involved in R&D activities. In other words, these results are consistent with decreasing returns, both for human capital embodied in the workforce and for the firm's R&D intensity.

The interaction term between *gradperc* and *rdperc* is negative but not significant for *innoprod*. For *innoturn* the sign is positive and significant (at 1% only in the OLS model, in the Heckman selection model it would overcome a threshold of 10%). Thus, with a higher–R&D intensity, an increase in the percentage of graduated workers is associated with a stronger increase of the

innovative turnover. At the same time, when the percentage of graduated workers increases, an increase in the percentage of R&D workers is associated with a stronger increase of the innovative turnover. In other words, it is possible to think to a multiplicative effect between human capital and R&D in terms of firm innovativeness.

Besides the usual regression analysis, we also implemented a semi-parametric analysis, precisely a local polynomial regression (Cleveland, Grosse and Shyu, 1992) with the same variables of the parametric analysis above. The control variables enter parametrically and variable of interest (*gradperc* and *rdperc*) are regressed non–parametrically. The results are graphically represented in the Graph 1 of the Appendix: on the axes there are *gradperc*, *rdperc* and a linear predictor of the independent variables; the clearly visible saddle confirms the non linearity of the relationship between human capital and R&D, on one side, and innovation on the other. This analysis support the idea that a quadratic specification of the model can explain a large part of effect of *gradperc* and *rdperc* on innovativeness.

We analyze now Model 3, which adds to the variables included in Model 2 the interactions of country dummy variables with *gradperc*.

Model 3

Φ^{-1} ($innoprod_i$) = $\beta_0 + \beta_1$ *gradperc* $_i$ + β_2 *gradperc2* $_i$ + β_3 *rdperc* $_i$ + β_4 *rdperc2* $_i$ + β_5 *Xgradrdperc* $_i$ + β_6 *workforce* + β_7 *export* + $\mathbf{B_{8\text{-}10}}$ (Pavitt dummies) + $\boldsymbol{\beta_{11\text{-}15}}$ (country dummies) + $\boldsymbol{\beta_{16\text{-}20}}$ (dummies *grad*_[name country]) +ε_i

$innoturn_i$ = $\beta_0 + \beta_1$ *gradperc* $_i$ + β_2 *gradperc2* $_i$ + β_3 *rdperc* $_i$ + β_4 *rdperc2* $_i$ + β_5 *Xgradrdperc* $_i$ + + β_6 *workforce* + β_7 *export* + $\mathbf{B_{8\text{-}10}}$ (Pavitt dummies) + $\boldsymbol{\beta_{11\text{-}15}}$ (country dummies) + $\boldsymbol{\beta_{16\text{-}20}}$ (dummies *grad*_[name country]) +ε_i

Table 7. Determinants of product innovation - Model 3

	probit	logit
gradperc	0.0221***	0.0372***
	(0.00303)	(0.00517)
gradperc2	-0.000175***	-0.000292***
	(0.0000321)	(0.0000547)
rdperc	0.0521***	0.0869***
	(0.00212)	(0.00364)
rdperc2	-0.000525***	-0.000877***
	(0.0000257)	(0.0000442)
Xgradrdperc	0.00000979	0.0000309
	(0.0000440)	(0.0000792)
workforce	0.00137***	0.00233***
	(0.000125)	(0.000212)
export	0.422***	0.685***
	(0.0236)	(0.0387)
pavitt2	0.0328	0.0559
	(0.0273)	(0.0448)
pavitt3	0.163***	0.267***
	(0.0337)	(0.0550)
pavitt4	0.283***	0.465***
	(0.0599)	(0.100)
Benchmark: pavitt1		
Italy	-0.249***	-0.399***
	(0.0447)	(0.0731)
France	-0.341***	-0.554***
	(0.0461)	(0.0757)
Spain	-0.317***	-0.517***
	(0.0478)	(0.0785)
Germany	-0.254***	-0.411***
	(0.0469)	(0.0771)
Austria	0.180**	0.296°
	(0.0913)	(0.151)
Hungary	-0.257***	-0.419***
	(0.0873)	(0.144)
Benchmark: United Kingdom		
grad_Italy	-0.00160	-0.00351
	(0.00347)	(0.00597)
grad_France	-0.00663**	-0.0120**
	(0.00315)	(0.00539)
grad_Spain	-0.00313	-0.00592
	(0.00316)	(0.00539)
grad_Germany	-0.00915***	-0.0159***
	(0.00303)	(0.00522)
grad_Austria	-0.00833	-0.0147
	(0.00803)	(0.0134)
grad_Hungary	-0.00726°	-0.0125°
	(0.00424)	(0.00727)
Benchmark: grad_United Kingdom		

_cons	-0.566***	-0.937***
	(0.0418)	(0.0685)
N	14046	14046
pseudo R-sq	0.114	0.114

Standard errors in parentheses
° p<0.10, ** p<0.05, *** p<0.01

Table 8. Determinants of turnover from innovative product sales -Model 3

	OLS	Tobit	GLM	Heckman (2nd step)
gradperc	0.288***	0.602***	0.0240***	0.503***
	(0.0551)	(0.0876)	(0.00404)	(0.114)
gradperc2	-0.000972°	-0.00355***	-0.000133***	-0.00250**
	(0.000527)	(0.000941)	(0.0000441)	(0.00117)
rdperc	0.650***	1.480***	0.0618***	1.368***
	(0.0338)	(0.0614)	(0.00285)	(0.217)
rdperc2	-0.00637***	-0.0146***	-0.000587***	-0.0132***
	(0.000418)	(0.000810)	(0.0000427)	(0.00228)
Xgradrdperc	0.00269***	0.00195	0.0000514	0.00230**
	(0.000931)	(0.00150)	(0.0000630)	(0.00107)
workforce	0.00233	0.0198***	0.000258°	0.0117°
	(0.00156)	(0.00282)	(0.000153)	(0.00601)
export	3.723***	11.32***	0.498***	9.459***
	(0.313)	(0.722)	(0.0410)	(2.079)
pavitt2	0.0449	0.669	-0.000521	0.214
	(0.363)	(0.798)	(0.0441)	(0.829)
pavitt3	1.108**	3.416***	0.118**	2.645**
	(0.471)	(0.932)	(0.0495)	(1.181)
pavitt4	1.920**	4.703***	0.152**	3.489°
	(0.918)	(1.532)	(0.0761)	(1.825)
Benchmark: pavitt1				
Italy	1.160°	-0.481	0.0812	1.427
	(0.683)	(1.354)	(0.0735)	(1.553)
France	-2.546***	-8.641***	-0.414***	-7.760***
	(0.659)	(1.406)	(0.0823)	(2.050)
Spain	-1.214°	-5.980***	-0.198***	-3.585**
	(0.653)	(1.411)	(0.0763)	(1.801)
Germany	-1.727***	-4.066***	-0.243***	-4.880***
	(0.654)	(1.338)	(0.0737)	(1.664)
Austria	2.242°	6.085***	0.237°	4.881°
	(1.296)	(2.341)	(0.122)	(2.733)
Hungary	-0.467	-6.354**	-0.152	-3.253
	(1.344)	(3.108)	(0.174)	(2.807)
Benchmark: United Kingdom				
grad_Italy	-0.168**	-0.214**	-0.0104**	-0.252***
	(0.0660)	(0.100)	(0.00444)	(0.0819)

grad_France	-0.149**	-0.171°	-0.00376	-0.156**
	(0.0624)	(0.0922)	(0.00402)	(0.0766)
grad_Spain	-0.145***	-0.145°	-0.00487	-0.154**
	(0.0555)	(0.0860)	(0.00371)	(0.0778)
grad_Germany	-0.161***	-0.246***	-0.00618°	-0.168**
	(0.0581)	(0.0859)	(0.00363)	(0.0746)
grad_Austria	0.0820	-0.118	-0.000567	-0.000825
	(0.157)	(0.213)	(0.00861)	(0.223)
grad_Hungary	-0.179**	-0.251	-0.00777	-0.157
	(0.0884)	(0.165)	(0.00766)	(0.120)
Benchmark: grad_United Kingdom				
_cons	3.342***	-23.37***	-3.007***	-19.70**
	(0.575)	(1.269)	(0.0680)	(8.499)
sigma				
_cons		32.12***		
		(0.500)		
mills				
lambda				29.33***
				(7.012)
N	13727	13727	13727	13727
adj. R-sq	0.121			

Standard errors in parentheses
* p<0.1, ** p<0.05, *** p<0.01

This model has both the dummy variables for the seven countries and their interactions with the percentage of graduated workers. We are supposing that the relationship between *gradperc* and *innoturn* is represented by different regression lines for different countries. These lines have different vertical intercepts (expressed by the intercepts of the dummy variables for countries) and different slopes (expressed by the coefficients of the interaction terms between *gradperc* and the dummy variables for countries).

We test therefore if the magnitude of the relationship between the human capital and the innovativeness of the firm is significantly different across different countries. We find that in the United Kingdom the magnitude is higher then in the other countries; regarding the probability to introduce an innovation, this result is significant for France (at 5%), Germany (at 1%) (Hungary would be significant at 10%); regarding the percentage of innovative turnover, this result is significant for Italy (at 1%), France, Spain and Germany (at 5%): we refer to the results of the Heckman selection model, because the significance of the mills lambda test (1%) assures that this kind of model should be preferred to other models which hypothesize a unique process for determining whether a firm is innovative or not and the percentage of innovative product. In any case, all the other models confirm the negative and significant (at 5%) sign for Italy. while, in the

GLM model the signs for the other countries are not significant at 5% (Germany would be significant at 10%).

Instrumental variables

In the text above, we usually preferred to use the term *relationship* between human capital and innovativeness rather than *effect* of the first one on the second. This is because the causal relationship between human capital and innovation may be twofold: as reported in the introduction and confirmed by several contributions in the literature, reported above, more educated workers may introduce more innovations but it is also true that they are needed to absorb and manage innovations. For this inverse causal relationship, it is possible to think to the skill biased technical change theory. That is, the introduction of more sophisticated technologies requires an upgrade of the workers' skills (Sanders, 2004). Therefore more human capital may imply more innovation, but more innovation may require more human capital. This twofold relation may imply endogeneity of the relation, therefore a correlation with the residuals of the regression model and bias in the estimate. To overcome this problem, we use an instrumental variable estimation. We use as instrument the variable *extceo* for the percentage of graduated workers. *Extceo* indicates if the management of the firm is external or internal (belonging to the same family who owns the firms or appointed within the firm). In fact we find that an external management has an higher propensity to assume more qualified workers (the variable *exteceo* is significantly correlated with *gradperc* and the relationship exists even in a multivariate analysis, controlling for the same control variables of the analyses above) and that the positive impact of the external management on innovation happens through such higher propensity to assume more qualified workers (including *extceo* among the covariates of Model 1, it results not significant -at5%-, but, if *gradperc* is excluded from the covariates, *extceo* becomes significant). Therefore *extceo* meets the requirement for an instrumental variable: it is correlated with the covariate which may suffer from endogeneity (*gradperc*), but, having an impact on the dependent variable only through that covariate, it results not correlated with the residuals.

We estimated Model 1, both for *innoprod* (probit model) and *innoturn* (linear regression and Tobit), having *extceo* as instrumental variable for *gradperc.*[5]

It is not possible to estimate Model 2 with instrumental variables, because, as instrumental variable for *gradperc2* we should have the quadratic term of *extceo*, but it is perfectly collinear with

[5] Because, as seen before analysing the results of Model 1 without instrumental variable, at a 5% level of significance there is no reason to prefer an Heckman selection model to an OLS linear regression , we did not estimate the Heckman selection model with instrumental variables.

the first degree term, as it is a binary variable. Besides, if the variable *gradperc* is endogenous respect to *innoprod* and *innoturn,* the interactions between *gradperc* and the country dummy variables (introduced in Model 3) are endogenous too and we need to instrument them; they could be instrumented with the interactions between *extceo* and the country dummy variables, but the dicothomic nature of *extceo* generate an high degree of multicollinearity in the estimate; therefore we could not reliably estimate with instrumental variables the different effect of the human capital in different countries.

Table 9. Instrumental variables estimate – Model 1

	IV-probit	IV-lin.reg	IV-tobit
Dep.var.	*innoprod*	*innoturn*	*innoturn*
gradperc	0.0512***	0.175***	1.449°
	(0.0188)	(0.0123)	(0.768)
rdperc	0.00419	0.242***	0.224°
	(0.00492)	(0.0117)	(0.133)
workforce	0.00102***	0.000992	0.0138**
	(0.000356)	(0.00157)	(0.00699)
export	0.345***	4.630***	10.79***
	(0.110)	(0.324)	(2.198)
pavitt2	0.155**	-0.0923	4.367
	(0.0714)	(0.376)	(2.805)
pavitt3	0.186***	1.360***	5.085***
	(0.0410)	(0.465)	(1.298)
pavitt4	0.0559	2.931***	1.401
	(0.178)	(0.786)	(5.101)
Italy	-0.146**	-0.157	0.593
	(0.0586)	(0.531)	(1.565)
France	-0.293***	-3.721***	-8.825***
	(0.0484)	(0.542)	(1.773)
Spain	-0.358***	-2.595***	-9.063***
	(0.0507)	(0.539)	(2.524)
Germany	-0.356***	-2.930***	-7.897***
	(0.0472)	(0.541)	(2.274)
Austria	0.224**	2.217**	8.119**
	(0.0916)	(1.087)	(3.179)
Hungary	-0.603***	-3.623***	-17.15***
	(0.135)	(0.922)	(6.261)
_cons	-0.605***	5.474***	-25.32***
	(0.0804)	(0.526)	(4.640)

Dep. var.: gradperc			
rdperc	0.167***		0.168***
	(0.0150)		(0.0152)
workforce	0.00622***		0.00611***
	(0.00172)		(0.00176)
export	2.494***		2.569***
	(0.230)		(0.231)
pavitt2	-3.284***		-3.356***
	(0.296)		(0.298)
pavitt3	-0.444		-0.544
	(0.392)		(0.395)
pavitt4	5.994***		6.012***
	(0.930)		(0.941)
Italy	-0.785**		-0.790**
	(0.387)		(0.392)
France	0.998**		1.055**
	(0.430)		(0.438)
Spain	2.699***		2.707***
	(0.404)		(0.409)
Germany	2.341***		2.361***
	(0.430)		(0.436)
Austria	-2.704***		-2.680***
	(0.593)		(0.612)
Hungary	6.996***		7.003***
	(0.949)		(0.951)
extceo	2.451***		2.440***
	(0.620)		(0.628)
_cons	5.623***		5.633***
	(0.439)		(0.438)
Wald test of exogeneity (prob.>chi2)	0.0782°		0.1476
Durbin-Wu-Hausman Test of endogeneity (prob.>chi2)		0.0001***	
N	9743	13727	9538
adj. R-sq		0.092	

Standard errors in parentheses
° p<0.1, ** p<0.05, *** p<0.01

Table 9 reports the results of the three instrumental variable estimates (IV probit for *innoprod*, IV-linear regression and IV-Tobit for *innoturn*), followed by other two regression: on the left,

below the IV-probit, there is the OLS regression having *gradperc* as dependent variable, run among the cases considered in the IV-probit; on the right, below the IV-Tobit, there is the same regression but run among the case considered in the IV-Tobit. In the rows below we have the statistical test for endogeneity, therefore on the need of the instrumental variable estimates.

The discussion of the results may start from the result of these tests: even though the hypothesis of endogeneity of innovation respect to firm's human capital has a theoretical and logical background, the statistical tests do not seem to give confirm to such hypothesis: according to the Wald test, the hypothesis of exogeneity for the *probit* and Tobit model can not be rejected having 5% as a significance threshold, (in the *probit* model the hypothesis would be rejected with a 10% threshold). If the hypothesis of exogeneity is not rejected, ordinary *probit* and Tobit models should be preferred to the correspondent estimates with instrumental variable; however, even under the hypothesis of exogeneity, instrumental variable estimates are consistent, even though inefficient. Besides, it must be underlined that the results of the Wald test dramatically change even with little variations in the model (even excluding one single covariate).

On the contrary, the Hausman test for the linear regression for *innoturn* clearly reject (at 1% level) the hypothesis of exogeneity: the estimate with instrumental variables of the linear regression model has therefore full statistical justification in confront to the correspondent model without instrumental variable.

Despite the expected high standard errors of the IV-*probit* model, because of its inefficiency, *gradperc* has a significant (at 1%) and positive effect on *innoprod.* The effect of *gradperc* on *innoturn* is positive and significant (at 1%) in the IV-linear regression model, while the inefficiency of the IV-Tobit model may explain its non significance at 5% (however it would be significant at 10%): it seems therefore possible to conclude that, even controlling for the possible endogeneity, an increase in the percentage of graduate workers increases the probability to obtain one or more product innovations and the effectiveness of that/those innovation(s) in terms of share of turnover deriving from their sales.

It is worth nothing that *rdperc* is significant only in the IV-linear regression (it has a 10% level of significance in the *Tobit* model): controlling for the endogeneity, the firm's R&D seems to have less capacity then the human capital to explain the firm's innovativeness.

Synthesis of results

The results exposed above, obtained with different techniques of regression analysis, let us to answer the questions posed in the Introduction.

At the first question about the existence of a relationship between the human capital embodied in the workforce (expressed by the share of graduated workforce) and the innovativeness of the firm (expressed by its probability to introduce a product innovation and the percentage of turnover deriving from innovative product sales) we can answer that the relationship is positive and significant, even controlling for the R&D intensity (expressed by the percentage of employees involved in R&D activities) and for other relevant variables.

Such relation is not linear: our results suggest an increasing but concave relation both between human capital and innovativeness and between R&D intensity and innovativeness. The reliability of this result is also supported by a non-parametric analysis.

We also asked what kind of interaction exists between these two components of the firm's "cognitive capital": we find a multiplicative effect, indicating a complementarity between human capital and R&D: when R&D is higher the strength of the relation between human capital and innovativeness increase.

Another result is that the intensity of the relation between human capital and innovativeness is significantly different across different countries. Because of the cross-sectional nature of our data, these results should be read more in terms of "relation" than of "effect", but the analysis with instrumental variable supports their interpretation as a positive effect of the human capital embodied in the workforce on the innovative capability of the firm.

4. Conclusions

Several studies theorize or empirically test the link between human capital and economic growth at a macroeconomic level. Less frequent are the studies investigating this relationship at a microeconomic level. At the firm level the link between human capital and innovation is often seen as indirect, in the sense that a skilled workforce is considered a precondition for those elements (R&D investments in information technology, business organization, etc.) that generate innovation. The intent of this work is to empirically verify whether there is a direct relationship between the skills of the workforce and the innovative capacity of the firm, even "controlling" for other crucial factors for innovation (especially R&D). The analysis, conducted on data of firms of seven European countries in the period 2007-2009, reveals that an increase in the share of graduated workers in the firm increases the likelihood of introducing a product innovation and the share of turnover deriving from such innovation; the human capital and the R&D intensity at firm level

show decreasing returns, but they have reciprocally a multiplicative effect: the effectiveness, in an innovative sense, of the "human capital" embodied in the workforce is higher in those firms where the ratio of workers employed in R&D services higher; i.e. an higher education of the workforce has a multiplicative effect on the R&D intensity of the firm; we find therefore a complementarity between human capital and R&D at a firm level. We also find that the intensity of the relationship between human capital and innovativeness at firm level is significantly different across countries.

This study has of course some limits: from the cross-sectional nature of the data, to the lack of detailed information on the innovations. The information on the level of education of the workforce is limited too (there is only the distinction between graduates and non-graduates, therefore not the type of degree, nor the exact level of study reached), Nevertheless, even with the limitations just mentioned, this analysis, conducts to interesting results, both because relatively little explored and because it seems may have important implications in terms of *policy:* it appears evident that the education of workforce is crucial for industry, as it may boost its innovative capacity, both for a direct effect and through a multiplicative effect on the R&D function. It is therefore clear that the way to reverse the downward trend in the competitiveness of European firms necessarily steps to increase attention and resources for investment, public and private, in human capital.

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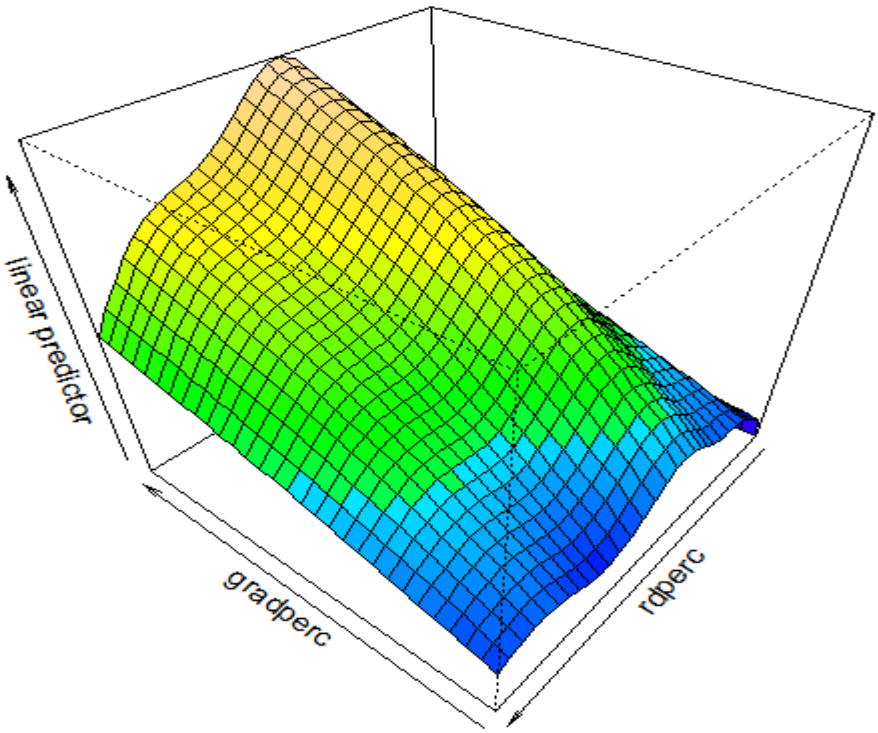
Appendix

Graph 1