JRC Technical Notes

IPTS WORKING PAPER on
CORPORATE R&D AND INNOVATION - No. 6/2011

Intangible resources: the relevance of training for European firms' innovative performance

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December 2011

EUROPEAN COMMISSION JRC

Institute for Prospective Technological Studies

DIRECTORATE GENERAL FOR RESEARCH AND INNOVATION
EUROPEAN COMMISSION

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This Working Paper (No. 6/2011 – December) is issued in the context of ***the Industrial Research Monitoring and Analysis (IRMA)***[1] activities that are jointly carried out by the European Commission's Joint Research Centre (JRC) – Institute for Prospective Technological Studies (IPTS) and the Directorate General Research - Directorate C, European Research Area: Knowledge-based economy.

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The author of this paper is Daria Ciriaci. The work has benefited from the input of A. Garcia and F. Bogliacino to earlier versions of the paper.

The *IPTS Working Papers on Corporate R&D and Innovation* are published under the editorial responsibility of Fernando Hervás, Pietro Moncada-Paternò-Castello and Andries Brandsma at the Knowledge for Growth Unit – Economics of Industrial Research and Innovation Action of IPTS / Joint Research Centre of the European Commission, Michele Cincera of the Solvay Brussels School of Economics and Management, Université Libre de Bruxelles, and Enrico Santarelli of the University of Bologna.

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DG RTD-C website: http://ec.europa.eu/invest-in-research/monitoring/analyses01_en.htm

IPTS WORKING PAPER on CORPORATE R&D AND INNOVATION - No. 6/2011
Full electronic version of the paper can be downloaded at http://iri.jrc.es/

JRC68195
EUR 24747 EN/6
ISBN 978-92-79-22647-2
ISSN 1831-9408
ISSN 1831-9424
doi:10.2791/70648

Luxembourg: Publications Office of the European Union, 2011

Printed in Spain

[1] IRMA activities are according to the approach set out in "Investing in research: an action plan for Europe" (COM, 2003) and in further Communications of the Commission: "More Research and Innovation – Investing for Growth and Employment – A common approach", COM (2005) 488 final, "Implementing the Community Lisbon Programme: A policy framework to strengthen EU manufacturing – Towards a more integrated approach for industrial policy", COM (2005) 474 final.

Abstract

This paper assesses whether European firms' innovative performance is impacted by investments in training directly aimed at developing and/or introducing innovation, in addition to the scale of a firm's investments in innovation proxied by the number of R&D personnels. In particular, it explores the complementarity between these two factors (in the presence of a well-trained workforce, the knowledge created by a firm's R&D personnel can be better exploited), and their dependence on a firm's knowledge intensity (high versus low % of tertiary-educated workforce) and size (SMEs versus large firms). Using European CIS non-anonymised data for the period 1998-2000, this paper estimates a system of simultaneous equations in which investments in training and stock of R&D personnel are treated as endogenous in relation to the innovative sales on which they are presumed to have an effect. The choice to use this time period rather than more recent ones – to which I had access at the Eurostat Safe Centre – is data-driven. It has better information on training expenditures and it is the last period to provide firm-level information on the number of employees with tertiary education. Unlike the majority of CIS-based studies, the main variables of interest are continuous ones, while dummy variables are used as controls only. Empirical evidence confirms most previous results – investment in training and stock of R&D personnel positively affects firms' innovativeness – but also provides some important additional insights. C*eteris paribus*, returns to training and R&D personnel are not affected by the knowledge intensity of the firm, while are always statistically significantly higher in large than in small and medium sized firms. However, while in the case of training the differences in returns between SME and large firms are small, in the case of R&D personnel are quite pronounced.

JEL Classification: O30, O31, O32, D83, D62.

Keywords: Intangibles, R&D investment, human capital, CIS, CDM model.

1 Introduction

The broad literature on the role that intangible resources play in a firm's competitive advantage and on the impact of human capital on a firm's performance were the starting point for this study, which investigates the effect that human capital (proxied by the expenditure on internal and external training directly aimed at introducing innovation) and the scale of investment in R&D (proxied by the number of people employed in R&D activities) on European firms' innovative performance[1].

To this end, I followed the approach of Crepon et al. (1998), and estimated a system of structural equations in which the number of people employed in R&D activities, the amount of training investments and the amount of innovative sales are all endogenous variables. The hypothesis that underlies the econometric model is that of complementarity (Milgrom and Roberts, 1990, 1995) between training and R&D personnel: the firm's decisions to invest in human capital, training and innovation inputs are complementary, as the innovation capacity of a firm is strongly affected by the quality of its labour force (Acemoglu, 1998). Stated simply, with a workforce trained to develop and/or introduce innovations, the knowledge created by people employed in R&D activities can be better exploited. It can be better socialised and circulated within the firm, which would improve, for instance, the sharing of tacit knowledge between individuals (Nonaka *et al* 2000), and the absorptive capacity (Cohen and Levinthal 1990, 1989) of the firm. In addition, as *other things being equal* the innovation ability of a firm with a relatively higher proportion of high-skill laborers might cause it to generate more innovations, the second hypothesis tested examines whether returns to investments in training and R&D personnel in *knowledge-intensive* and *non-knowledge intensive* firms differ to statistically significant degree or not. To this end I borrowed the Eurostat concept of knowledge intensive activities (KIA; Eurostat NACE Rev. 2 definition), which are identified by considering the educational attainment of the workforce, and I defined all firms in which over 33% of the workforce is educated to a tertiary level as knowledge-intensive. Thirdly, given the fact that the impact on the innovativeness of these investments might be affected by a firm's production scale (as, for instance, small firms can coordinate fewer complementary relationships among inputs than large firms), I also tested whether returns on human capital

[1] The Community Innovation Survey defines an innovation as a new or significantly improved product (good or service) that is introduced to the market, however, what really matters is that an innovation is new to the firm concerned. As such, if product innovations are taken into account, the CIS questionnaire distinguishes between two categories of innovative product: *new to the market* and *new to the firm.* This paper uses the latter category, although the results which will be presented also hold true in the case of products that are new to the market. Results are available on request.

differ between small and medium enterprises and large firms. All in all, I expect that, apart from training and R&D, other intangibles (such as management and organizational capabilities, marketing and design strategies) are likely to emerge as fundamental determinants of the innovative performance of European firms.

This paper achieves its aim by using the third wave of European CIS non anonymous data[2] which concerns the years 1988-2000 and covers 23 European countries (Belgium, Bulgaria, Check Republic, Germany, Denmark, Estonia, Finland, France, Greece, Hungary, Island, Italy, Latvia, Lithuania, Luxemburg, Netherland, Norway, Portugal, Romania, Slovenia, Slovakia, Spain and Sweden). The choice to use this wave rather than more recent ones, to which I had access, was data-driven, as it has better information on training expenditures and it is the last wave to have firm-level information on the number of employees with tertiary education. The latter two features allowed me, unlike the majority of CIS-based studies[3], to use continuous variables as the main variables of interest (R&D personnel and investments in training), while dummy variables were used as controls only.

The design of the paper is as follows. Section 2 provides a theoretical framework for reviewing the relevant literature on intangible corporate assets and, in particular, on the effect of human capital on a firms' performance; section 3 relies on this theoretical framework and on the hypothesis of complementarity between different categories of human capital, and presents an empirical model for estimating the impact of work-based training and R&D employees on innovativeness and of the variables that are supposed to affect the intensity of training, the number of R&D employees, and the firm's innovative behavior. It also describes the dataset used for the subsequent empirical analysis. In section 4 I discuss the empirical results and in section 5 some concluding remarks and provides some implications for policy are presented.

2 Theoretical background

Broadly speaking, it is possible to catalogue intangibles into three major classes: those created primarily through innovation and discovery, those that underlie organization practices (including also investments in customer satisfaction, product quality and brand reputation), and those related to human capital (see Hand and Lev, 2003). Hence, intangibles comprise investment in R&D, innovation and technology development, training and education of workers, internal organization structures, customer and institutional networks, market exploration and development (marketing), and software and information technology. The

[2] The research was carried out at the Eurostat's safe-center in Luxemburg.
[3] Garcia (2011) is an exception.

literature on intangible assets typically seeks to explain and estimate the relationship between intangible resources as an input and a set of outcomes such as productivity, market value, new products (Hitt et al., 2000; Villalonga, 2004; Ramirez and Hachiya, 2008).

Among a firm's intangible resources, those dependent on human capital were among the first non-innovation related intangibles to have their effect on firms' performance analysed (Fernandez et al 2000), often together with R&D or innovation (e.g Crepon et al., 1998; Loof and Heshmati, 2002). All in all, the traditional Beckerian framework - the economics of employer-provided training - remains the principal theoretical economic construct used to understand the process of skill formation and development within firms, although it was Mincer (1989) who pointed out the dual role of human capital (as a stock of skills is a factor of production and as a stock of knowledge is a source of innovation) in the process of economic growth. Among Becker's several contributions, the theoretical distinction between "general" skills, which have a broad application and use across many employers, and those that are "specific" as they can only be used within one firm, is especially relevant to this paper. In Becker's view, what makes a firm willing to train its workforce is the possibility of enhancing its "specific" skills, which are not easily replicable. Firms are unwilling to invest in general skills training (Becker, 1964) for their workers because they cannot recoup said investment, since workers could simply decide to move to a new/different firm. The more specific the training, the lower the possibility that workers can "sell" it to other firms[4]. On the other hand, firms and workers both "share in" investments in training that develops firm-specific skills which are productive at the current firm but not at the others. The fact that specific skills have no (or limited) value outside of the current employer generates what is known as a "hold up" incentive, which creates an ex ante incentive for the workers to under-invest (Hansson, 2009; Layard *et al*., 1995). It is also possible that firms, especially the smallest firms, could face liquidity constraints that prevent them from borrowing to invest in training that might generate returns that exceed the cost of the borrowed funds. While, in the case of general training, it is the firm that has an incentive to under-invest in training, in the case of specific training, this switches to the individual worker. To these two categories of skill, Stevens (1999) added a third, discussing the implication of those "transferable" skills, which are neither completely specific nor completely general. Clearly, in this last case positive externalities from training are the general rule: because of turnover, the investment made by one employer in an employee's training has the potential to generate profit for another. This externality creates an incentive

[4] Furthermore, if the firm is a public one, since investments in training are typically accounted for as a "cost", these investments have the effect of lowering short term earnings, with a negative effect on share price. That is why managers who are focused on share price have an incentive to reduce training investments, despite their potential for maximizing the long-term value of the firm.

for poaching, which increases turnover and reduces the incentive to train (Hansson, 2009; Stevens, 1996; Katz and Zinderman, 1990).

As far as the more managerial-oriented approaches to human capital are concerned, the *knowledge-base view* (KBV; Spender, 1989; Grant, 1996) and *human resource management* (HRM; Baird and Meshoulam, 1988; Jackson and Schuler, 1995; Huselid *et al*., 1997; Leiponen, 2005) both stress that skills are an important component of absorptive capacity, as they are complementary to internal R&D and external collaboration strategies, and have a positive on firms' profit margins (Leiponen, 2005). This latter aspect is at the core of the *human resource management* approach, which emphasises that knowledge acquisition is about recruiting outstanding people and about helping them to learn and grow as individuals and professionals, and is achieved by creating a supportive environment and investing in human resources training and development (Senge, 1994). As stressed by Huselid et al. (1997) because of the complexity inherent to human resource management practices, competitors can neither easily copy these practices nor readily replicate the unique pool of human capital that such practices help create. However, the HRM approach focuses primarily on the impact that organizational changes in the management of human resources have on a firm's performance, generally defined in terms of sales or profit, rather than on firms' innovativeness (Laursen and Foss 2003, for instance, are an exception). Common to this literature is the idea that intangible investments such as human capital, R&D, training, organizational changes, management and marketing strategies and human resource management techniques are complement to one another, and jointly enhance firm performance.

This paper refers to the HRM approach primarily in terms of its focus on the idea that, assuming heterogeneity among firms with respect to their human capital, competitive advantage is possible if a company ensures that its workers add value to its production processes, and ensures that its pool of human capital is a unique resource, i.e. both difficult to replicate and to replace. As such, a firm creates value through the selection, development and use of its human capital, as the former is not only brought into a firm by means of recruitment and selection but is also developed within the firm through investment in it. This paper also refers to the empirical-oriented literature that focuses on the impact that human capital has on a firm's innovative performance. This literature generally shows that when a firm has the possibility of generating a human capital[5] advantage and attracting a stock of human talent, it is more innovative than the average firm (Svetlic and Stavrou-Costea, 2007; Lundvall and

[5] In the empirical literature on the impact of human capital on firms' performance, the most common proxies used for this category of intangibles are labour costs (Lin 2007), the level of education of the workforce (Aiello and Pupo 2004; Loof and Heshmati 2002; Crepon et al. 1988), the number of researchers (Heshmati et al 2006), and the level of training.

Nielsen, 2007). Skilled people can deal with complexity, and job complexity has a positive relationship with innovation, suggestion-making, and creativity (Song *et al*., 2003; Piva and Vivarelli, 2009). Overall, the empirical evidence on training is primarily micro-based and uses the employee as unit of reference, because, while there are a number of cross-sectional and longitudinal individual-based surveys, firm-level data regarding the amount and/or nature of training provided is scarce. Notwithstanding, there is increasing evidence that training generates substantial benefits for employers (Hansson, 2009), although there is mixed evidence regarding the various kinds of training (Tamkin *et al*., 2004). The most compelling evidence is found in several empirical papers that link training investment with changes in firms' productivity, profitability, and stock market performances (Barrett and O'Connell, 1999; Dearden *et al*., 2000; Groot, 1999; Hansson, 2001; d'Arcimoles, 1997; Bassi *et al*., 2001). Ballot et al. (2001) use firm-sponsored training to examine the effect of human capital - measured by the percentage of the wage devoted to continuous training and by the hours of training paid for by the firm - on performance in a sample of 90 large French firms and 272 large Swedish firms in the period 1987-1993. Results show that, in addition to R&D capital, human capital also has a significant and positive effect on performance. Human capital has also been using both training- related and education-related data. For instance, Lybaert et al (2006) uses the proportion of highly educated personnel and the percentage of personnel involved in training programs to measure the effect of knowledge capital on a sample of 259 Belgian firms. However, these results depend heavily on the performance measure used. In addition, only education level appears to positively affect performance, while conclusive results cannot be reached for training levels. Withfield (2000), using a data set based on a nationally representative sample of British establishments, suggests that those exhibiting high-performance work practices have higher levels of training and those with a comprehensive set (or bundle) of these practices exhibit much higher levels than those which do not. Overall, however, empirical results are not always conclusive as there are also a number of studies that do not support the idea that training and human capital have a positive effect on a firm's performance (e.g. Heshmati et al., 2006; Lybaert et al., 2006).

Finally, it is worth highlighting the fact that, while proxies of human capital (such as the education level) are more individual-related, the amount of training is more firm-related. In fact, a firm can decide what types of skills and competences to create in the labour force through specific training programs. The knowledge product of firm-specific training activities is likely to become firm-specific and organisational. These considerations support the choice to use the amount of expenditures in external and internal training directly aiming at the introduction of innovations as human capital proxy in the case of innovative firms. This involves creating skills that are quite specific to the firm and, as such, are unlikely to be replicable by would-be competitors.

3 Methodological approach

From the previous discussion it emerged that when modeling the impact of investments in intangible resources such as training and R&D and the way they relate to output entails addressing a series of aspects – besides the endogenous character of R&D and training investments (Crepon *et al.*, 1998) - that must be properly examined. First of all, expenditures on human capital, training and innovation inputs are likely to be complementary[6] (Mincer, 1989; Acemoglu, 1998). The effectiveness of innovation is contingent upon investment in the necessary human capital to support new technologies[7] as there are technical capital-skill complementarities (Piva and Vivarelli, 2009): the better trained the people who manage a firm's knowledge are in developing or introducing innovation, the better the firm's performance (O'Dell and Jackson, 1998). Likewise, a shortage of qualified personnel and organisational rigidities can be expected to lead to problems for the feasibility and eventual success of innovations (Dodgson and Rothwell, 1994), as they constitute a prerequisite for innovation (OECD 2000). Organizational arrangements have to be capable of creating, sharing and transferring knowledge via adequate internal communications between various departments (R&D, marketing, production). Secondly, investments in training and the stock of R&D employees not only affect a firm's performance, but are likely to produce positive externalities and thus also affect said firm's competitors as they increase the pool of knowledge available to other firms (Aghion et al. 1998; Romer 1994). For instance, in the presence of workforce turnover, one employer's investment in an employee's training has the potential to generate profit for another employer. The same applies to R&D expenditures and personnel: the effort made by one firm may generate profits for other firms in the same sector or located in the same region (Breschi and Lissoni, 2001) through knowledge spillovers, spin-off, and other informal mechanisms (interpersonal contacts, face-to-face communications, meetings, seminars, *etc*.).

[6] Though the choice of the econometric model is driven by the hyphothesis of complementarity (Milgrom and Roberts 1990) between R&D departments and training expenditures, I do not test directly for it (Cassiman and Veugelers 2004). Future works will be devoted to theorizing the links between complementary training, R&D departments and innovation performance more comprehensively.

7 If skills are in short supply, a firm may decide not to invest in technologies for which a high level of human capital is complimentary.

To tackle these issues, following (and adapting) the model of Crepon *et al*. (1998), I estimated a system of structural equations in which the inputs to the innovation process (the number of people employed in R&D and training investments) are related to its output (innovative sales) and all are treated as endogenous variables. More specifically, the model includes three relationships: the first equation (*TR*) explains the investment in training (both internally – in-house training - and external training) directly aimed at developing and/or introducing innovations; the second equation (*Rdpers*) explains the stock of human capital defined as the number of workers directly involved in R&D activities; finally, the third equation (*INNO*) explains the innovative performance of a firm based on the investments in training and RD personnel. In other terms, the latter equation consists of a knowledge production function (as in Pakes and Griliches 1984), which relates innovation output to innovation input (training and R&D employees) and other factors. As such, the model summarises the process from the firm's decision about how much to invest in workforce training and in R&D personnel, to the introduction of products new to the firm. Within this methodological framework, endogeneity and selectivity are clearly taken into account. Unlike Heckman's selection models, no correlation between the selection error terms and outcome equations is allowed, while a latent variable is estimated for training and R&D personnel for every firm in the sample (see Garcia, 2011) and introduced in the third equation, which was estimated with bootstrap re-sampling procedures (Efron 1982) using 50 replications to check for robustness and estimate consistency. The model is structured as follows:

$$
\begin{array}{lll}
TR = TR^* & if & TR^* = \beta_{TR} z_1 + \beta_{TR} z_c + \varepsilon_{TR} \geq 0 \\
0 & if & TR^* = \beta_{TR} z_1 + \beta_{TR} z_c + \varepsilon_{TR} < 0 \\
RDpers = RDpers^* & if & RDpers^* = \beta_{HK} z_2 + \beta_{HK} z_c + \varepsilon_{HK} \geq 0 \\
0 & if & RDpers^* = \beta_{HK} z_2 + \beta_{HK} z_c + \varepsilon_{HK} < 0 \\
INNO = INNO^* & if & INNO^* = \beta_{INNO} TR^* + \beta_{INNO} RDpers^* + \beta_{INNO} z_3 + \beta_{INNO} z_c + \varepsilon_{INNO} \geq 0 \\
0 & if & INNO^* = \beta_{INNO} TR^* + \beta_{INNO} RDpers^* + \beta_{INNO} z_3 + \beta_{INNO} z_c + \varepsilon_{INNO} < 0
\end{array}
$$

where TR* is a latent training variable and Rdpers* is a latent R&D personnel variable, z_1, z_2, z_3 are vectors of explanatory variables specific-to-each-equation, z_c is a vector of common control variables, and ε_{TR}, ε_{HK}, and ε_{INNO} are normally-distributed error terms with zero mean and standard deviations of $\sigma^2_{t,}$ σ^2_h and σ^2_i respectively. As such, the use of the two latent variables (TR* and RDpers*) is justified both on methodological grounds - it is the only way a system can be defined using non linear estimations – and theoretical grounds. Furthermore, the use of the latent variables for training and R&D personnel (and not of their observed values) implies that I am not restricting the sample to training performing firms or firms with R&D workers. In fact, the inclusion of the predicted training effort and of R&D personnel in the regression accounts for the fact that all firms may have some kind of innovative effort, even though only some of them invest in training and/or have R&D employees. Besides, using the predicted values instead of the realized/observed ones is also a wise way to instrument the innovative effort in the knowledge production function to deal with the simultaneity issue between R&D/training effort and the expectation of innovative success (Hall et al 2009).

The three relationships are estimated with a generalised tobit model (Crepon *et al*., 1998) because, although the sample is restricted to innovative firms, a large proportion of these reported zero expenditures on training and/or R&D employees or zero innovative sales. The Tobit model allows for correlation of the level of training expenditures (R&D employees) with the decision to undertake them and produces consistent estimates. Finally, it is worth noting that given the cross-section structure of the CIS, the causality links between variables are generally thought as "weak links", and that the objective of the following analysis is not to test cause-effect relationships, but to assess the significance and intensity of the correlation relationships between the main variables of interest.

3.2 Measurement issues

The CIS asked firms that engaged in technological innovation activities between 1998 and 2000 (20,920 out of a total of 61,540[8] firms are innovators according to the CIS definition of an innovator), whether or not they invested in training, marketing and/or design in 2000. Unfortunately, the only information available at the Eurostat Safe Center is on the overall expenditure made by firms on these innovation-related activities (this variable is labelled *rothx* in CIS 3 and it is *not available* for successive CIS waves). Therefore, to be able to correctly identify investment in training, I considered only those firms that have stated in the questionnaire that they had invested in training and not in marketing and design (in this case the amount invested in training coincides with *rothx*). On the one hand, this option allowed me to calculate the amount invested in internal and/or external training by the firm - it is “how much” a firm invests in training which makes the difference (Hansson, 2009) - and, consequently, to isolate the direct effects of expenditures in training on innovative sales. On the other hand, however, this option could lead to the underestimation of the number of firms that actually invest in training and of the importance of complementarity among intangible expenditures (i.e. training, marketing, and design), as those that invested in marketing activities directly aimed at the introduction into the market of new or significantly improved products *and* design are not considered[9]. To partly account for this, a control for firms who have adopted new marketing strategies and another for those that introduced aesthetic changes in the appearance of their products are introduced in z_3 the innovative sale equation (see next section).

Tab 1

Overall, 13,447 firms stated that they had engaged in training related innovation activities in the year 2000. Of these firms, 5,134 have engaged in training, marketing and design activities and 4,125 stated that they had engaged in training activities only (*see* Table 1)[10]. About one third (1,480) are knowledge-intensive firms (*see* Table 2), that is to say that more than 33% of their employees are tertiary educated (International Standard Classification of Education – ISCED 97 levels 5 and 6). Finally, almost 83% of those firms investing in training are small and medium enterprises (EC definition 2003/361/EC: a firm is a SME if the number of employees is <250 and the amount of sales is <=50,000,000). Standard checks for outliers were performed and only one abnormal value of training expenditures was identified (and removed from the observations).

Tab 2

As far as the other two dependent variables are concerned, *RDpers* is the natural logarithm of the number of workers who were involved in intramural R&D activities in 2000[11], and *INNO* is the natural logarithm of the firm's innovative sales[12] in 2000 (these measure product innovation). The latter was calculated by multiplying the proportion of innovative sales (new or

[8] The original dataset has been cleaned by eliminating the firms that reported zero turnover or zero employees.

[9] There is another source of measurement bias, which implies an under-evaluation of the firm's total investment in training (and not of the number as in the previous case) as spending on firm specific human capital consists of two types of expenses (Corrado *et al*., 2005), the amount and the time spent on training. Given the information available and data used, I can consider only consider the former.

[10] Besides, 2,701 have engaged in training and marketing but not in design activities, while 1,487 have engaged in training and design but not in marketing activities.

[11] As robustness check the system of equation has been estimated also considering R&D total investments (intramural and extramural R&D) instead of the amount of R&D personnel as a proxy of innovative input. Significance and signs of the variables of interest do not vary.

[12] In both cases I calculated the log of (innovative sales + 1) and the log of (R&D personnel + 1). Laursen and Salter (2006).

significantly improved products/services) introduced during the period 1998-2000 by the firm's 2000 total turnover.

3.3 The estimated system of equation

In the following, I present the explanatory variables included in the system of equations that, according to the relevant literature, may play a role in affecting firms' decisions about their stock of R&D employees and about how much to train workers. To ensure parameter identification, in each of the three equations some exclusion restrictions are imposed. As such, their choice continues to be motivated on theoretical grounds (i.e. training expenditures might be more relevant to a firm that has introduced some advanced management techniques or implemented new or significantly changed organisational structures, whereas the latter might be of lower importance for R&D), however, it is also based on the significance of the estimated coefficients - as non-significant coefficients might be poor instruments with which to identify the model's key parameters (Greene, 2007) -, and on data constraints.
For the sake of simplicity, in the following I firstly describe the variables which are common to the entire set of equations (z_c), and secondly the set of variables specific to each equation (z_1, z_2, z_3). Both the choice of the common factors affecting firms' choices (z_c) and of the control variables included in z_1, z_2, z_3 are based on the literature. Table 2 reports the description of the dependent and the explanatory variables included, while Table 3 details the usual descriptive statistics. To check for robustness, four slightly different systems of equations are estimated, and these differences are illustrated in Table 4.

Table 2

The common set of independent variables (z_c) includes those that identify a firm's structural characteristics[13] (Antonelli et al 2010): firm size (*lnempl*), firm location (23 country controls, d*ummycountry1- dummycountry18*), firm specialization (9 industry controls for low, medium-low, medium-high and high-tech manufacturing and service sectors, following the Eurostat classification; see Table 4 for a description), and a dummy accounting for whether a firm belongs to a group or not (*group*). The control for firm size was introduced because it is

[13] The relevance of these variables stems from casual empiricism and it is not rooted in any theoretical framework (Guidetti and Mazzanti 2007) as the theoretical human capital literature usually ignores the influence of structural variables, as it mainly addresses the effects of deviation from the standard assumptions of perfect competition on the behaviour of maximizing agents.

generally recognized that large firms tend to exploit economies of scale and scope better. Smaller firms are more flexible but often tend to have limited resources and competences, and thus fail to exploit economies of scale. As a consequence, R&D returns tend to be greater in larger firms (Lichtenberg and Siegel, 1991). Antonelli et al (2010) demonstrated, using a sample of Italian manufacturing firms, that larger firms tend to train a higher proportion of their workforce when compared with small and medium sized firms, but that medium-sized firms tend to spend more on average than their small and large competitors. As far as sectoral controls are concerned, it is often argued that some industries have higher or lower average of R&D "by nature", and that a firm's new products sales are decisively influenced by the typical product life cycle length (Paananen and Kleinkneicht, 2010). As such, firms that experience shorter life cycles will introduce new products relatively more frequently and will have a higher proportion of total sales of such products than firms whose products are characterised by longer life cycles. Furthermore, sectoral controls may help to identify the technology constraints imposed on the conversion of skills acquired into skills used (Guidetti and Mazzanti 2007). In addition, according to the RBV, in order for intangibles resources to be a source of superior performance for a firm, the owners of said firm must be able to appropriate at least some of their value (Ghemawat, 1991). In addition, the efficacy of different mechanisms for ensuring a firm's appropriation of the value generated is likely to vary across industries (Villalonga, 2004) and countries. Similarly, innovative activity has a higher propensity for spatial clustering in high-tech industries (pharmaceuticals, electronic components, semiconductors, photographic equipment, surgical and medical instruments *etc*.), sectors where new economic knowledge predominates (Audretsch and Feldman 1996). Finally, the control for the impact of foreign subsidiaries was introduced to account for the fact that their innovative output may be consistently higher as they can take advantage of knowledge transfers from their mother company (Antonelli et al., 2010).

Table 3

As far as the TR equation is concerned, the specific-to-TR variables included in the model change as a robustness check, giving rise to four different TR equations and, consequently, to four different systems of equations (*see* Table 4). In any case, given the focus on firm-specific knowledge as a source of comparative advantage, in all four different specifications I inserted a dummy to account for the implementation of advanced management techniques within a firm (*actman*) during the period 1998-2000. This variable was inserted to capture the positive contribution of human resource management practices and of a firm's management skills – resources that are unique, valuable and difficult to imitate - in line with the firm's KBV (i.e. it will enter the INNO equation indirectly through the TR latent variable), and, as such is expected to enter the equation with a positive sign. As stressed by the literature (*see*, for instance, Antonelli et al., 2010), the propensity to invest in training and the amount of these expenditures can be partly explained by the organisation of knowledge within the firm and by the capability to introduce and exploit organizational innovations. In addition, in order to properly take account of a firm's "general" propensity to invest in intangibles and other strategically and organizational changes, I alternatively inserted a dummy that accounts for changed marketing concepts/strategies (*actmar*) and for a products' aesthetic appearance (*actaes*), both of which are expected to have a positive effect on the amount invested in training. I also inserted a dummy to assess the role of universities or other higher education institutions as a source of information for innovation (*sunizeroone*) for two different reasons; one theory-driven and the second one more empirical-driven. *Sunizeroone* was inserted to capture the idea that skills are complementary to external collaboration strategies (Coen and Levinthal, 1990; Leiponen, 2005) and to test whether firms that have an established network with universities are keener to train their staff and if these collaborations contribute to the firm's awareness of the role of human capital enhancing choices. As such, I do not have a-priori expectations about its sign. Furthermore, I alternatively inserted a dummy to account for the lack of qualified personnel (*Hperszeroone*) or a dummy to account for the presence of organizational rigidities (*Horgzeroone*) within firms during the years 1998-2000, to approximate the "need" felt by firms to improve the productivity and the organisational capabilities of its workers (I expect these two dummies to enter the TR equation with a positive sign). To sum up, the training equation is supposed to capture the importance that firms place on firm-specific knowledge, including management' skills and organizational processes, and its sources (universities) whose "degree" is supposed to affect the intensity of the effort made to invest in training. This decision also depends on how -to-date a firm is in terms of organisational and managerial capabilities: a firm that undertakes activities which significantly improve/change its strategies to invest in training its employees.

Table 4

Among the specific-to-Rdpers equation variables, there is a dummy that accounts for financial support for innovation activities from local or regional authorities, central government and the European Union (*funding*; Bérubé and Mohnen 2007, Busom 2000, David et al 2000), and a dummy for firms that identified the existence of organizational rigidities within the firm (*Horgzeroone*) as a factor that hampered innovative activities (Leonard-Burton 1992), giving rise to the need to increase productivity. In both cases I expect the dummies to have a positive effect on the stock of R&D personnel. In addition, I controlled for those firms that continously invest in R&D (*rdconst*), for those that applied for at least one patent (*paap*) during the period 1998-2000, and for cooperation on innovation activities with other enterprises or institutions over the same period (*co*; Coen and Levinthal 1990)[14]. These last three dummies are expected to enter the RD-pers equation with a positive sign as they were inserted to control for continuous and established R&D activity, namely to account for those firms with an intensive and continuous innovation effort. These firms are expected to develop a higher "absorptive capacity", which implies that they can better benefit from knowledge spillovers (Paananen and Kleinknecht, 2010), and systematically exhibit more dedicated R&D personnel. Furthermore, as far as the *co* and *paap* controls are concerned, it is established in the theoretical literature, that the lower the appropriability of results from the innovation process, the lower the probability that a firm will invest and, at the same time, the higher the incentives from cooperative R&D agreements. More specifically, when spillovers are high enough (i.e., above a critical level), cooperating firms will spend more on R&D and are increasingly more profitable compared to non cooperating enterprises (d'Aspremont and Jacquemin, 1988; Kamien *et al*., 1992; De Bondt, 1997; Cassiman and Veuglers, 2002). Finally to check for the robustness of the different specifications and for the role of changes in a firm's strategy, I alternatively inserted dummies to account for changes in a product's aesthetic appearance or design (*actaes*) or in marketing concept and strategies (actmar). These are all expected to be positively correlated with the size of the R&D department.

In the *INNO* equation, I always included the two latent variables TR* and Rdpers*, a dummy for those firms that introduced significant changes in the theirs marketing concepts and strategies (*actmar*) and for those firms that implemented significant changes in the aesthetic appearance or design of theirs products (*actaes*) in the years 1998-2000 as "sources" of competitive advantage. The latter two dummies were included to account for complementarities between intangible investments, namely marketing, design, R&D and training, and to partly limit the bias due to the choice of considering only those firms investing in training to correctly identify these expenditures. Finally, I also controlled for those firms that identified their customers or clients as a main source of information for suggesting new innovation projects or contributing to the implementation of existing projects (*sclizeroone*). In fact, the recognition of the needs of potential users or, more precisely, a potential market for new products or processes that involves a process of matching technical possibilities and market opportunities (Freeman and Soete, 1997) is likely to be fundamental for the success of an innovation. In model 4, I also inserted a dummy accounting for the existence of valid patents at the end of 2000 to protect innovation developed within firms, to account for the level

[14] Many authors find that cooperating firms spend more on R&D (*see* for instance Mairesse and Mohnen, 2010).

of *appropriability* of innovations developed within firms, which may give rise to temporary monopolies (Cooper and Kleinschmidt, 1991), enhancing innovative sales.

Finally, to address whether *ceteris paribus* an investment in training and an investment in R&D personnel have the same returns to innovation in knowledge and non knowledge intensive firms, instead of inserting the two latent variables TR* and Rdpers*, I inserted two interaction terms for each of them (latent training in knowledge intensive firms: *training KIA*; latent training in non knowledge intensive firms: *training nonKIA*; latent R&D personnel in knowledge intensive firms: *lnrdper KIA*; and latent R&D personnel in non-knowledge intensive firms: *lnrdper nonKIA*) and a dummy to identify knowledge intensive firms (*dummyKIA*). The same was done in the case of small and medium enterprises and non-SMEs (*training sme*, *training big*, *lnrdper sme*, *lnrdper big*). To assess whether returns to expenditures in training and to the stock of R&D personnel differ depending on the knowledge intensity and/or the size category of the firm in question Ftests on linear restriction on coefficients have been run.

4 Descriptive and econometric analysis

In this section I comment on the results obtained when estimating the aforementioned system of equations. Table 5 reports the results for the baseline (with no interaction terms) system of equation for the four models (as previously stressed each model is characterized by a slightly different specification as a robustness check; *see* table 4). Table 6 reports the results obtained when the interaction terms are introduced to control for differences in the returns to expenditures in training and R&D personnel in knowledge intensive and non-knowledge intensive firms, and to control for size effects. Given the fact that results are confirmed across models, I will comment only on the empirical evidence obtained estimating *model 1*. In addition, it should be remembered that, while for continuous variables marginal effects can be interpreted as elasticities, for dummy variables they represent changes in the predicted probabilities for unit change from a status of 0 to a status of 1.

Table 5

The TR equation estimate (Table 5) showed that a firm's structural characteristics are highly significant: both a firm's size and belonging to a group enter the equation with the expected positive sign. In addition, the amount spent on external or internal training directly aimed at introducing of innovations in 2000 is higher when a firm introduced and implemented advanced management techniques (*actman*) in the period 1998-2000. At the same time, the amount invested is higher for those firms that considered the lack of qualified personnel during the years 1998-2000 (*Hperszeroone*) as a hampering factor and for those that had established networks with universities (*sunizeroone*) or other higher education institutions. These results are in line with those obtained in model 2, 3 and 4 where, all in all, the positive impact of intangible managerial-organizational investments is always found to be significant and positive. Furthermore, the results obtained from the other three specifications suggest that firms that identified a lack of qualified personnel (*Hperszeroone*) or the presence of organisational rigidities (*Horgzeroone*) as hampering factors during the years 1998-2000 were investing more in training in 2000 likely to improve the productivity and the organisational capabilities of their workers.

As far as the decision to hire R&D personnel is concerned (Table 5), if the structural characteristics of the firm are taken into account, it is found that (in line with previous literature) that the larger the firm, the larger its R&D related workforce, and that belonging to a manufacturing high-tech or to a medium-high-tech sectors (or to a service sector) significantly increases the number of R&D employees. The results also confirms that the three indicators of the firm's degree of involvement in R&D activities during the period 1998-2000 - continously investing in R&D (*rdconst*), having applied for a patent (*paap*) and cooperating on innovation activities with other enterprises or institutions (*co*) - are significant explanatory variable of the stock of R&D-related human capital and enter the equation with the expected positive sign. The variables inserted to control for the firm's overall commitment to intangible expenditures - especially those in design (*actaes*) and marketing (*actmar*) - are positive and significant, suggesting that those firms that invest in R&D-complementary activities are those with larger R&D departments.

Table 6

As far as the determinants of the innovative sales equation (INNO) are concerned, the estimates suggest that investing in training directly aimed at the introduction of innovation and investing in the stock of personnel employed in R&D activities enhance firms' innovative performance. In line with the theoretical conclusions of both the economic and management-oriented literatures on human capital, investing in "specific to the firm" human capital, namely training your employees in the development and/or introduction of innovations and hiring skilled and "specific" employees, fosters firms' competitive advantage. In line with previous empirical evidence (Song *et al*., 2003; Piva and Vivarelli, 2009), this suggests that skilled people manage to deal with complexity, and job complexity positively interacts with innovation, suggestion-making, and creativity.

If we compare the returns to expenditures in training directly aimed at the introduction of new products in the case of knowledge intensive firms and non-knowledge intensive firms (Table 6), returns do not statistically differ[15] from each other. In addition, contrary to what initially expected and in line with the results of the Ftest for training expenditures, there is no significant difference between returns to expenditures in R&D personnel in knowledge intensive and non-knowledge intensive enterprises. That is to say, the innovation ability of firms featuring a relatively higher proportion of tertiary educated workers does not cause more “valuable” innovations to be created. This finding may also be due to the fact that the proxy used captures differences in the skills acquired by the workforce whereas it does not captures differences in the skills used by the workforce.

Interestingly, when the impact of expenditures in training and R&D are assessed for small and medium enterprises, in line with the theoretical expectations, in both cases the Ftest suggest that returns between SME and large firms are statistically different and higher in larger firms. In addition, while for training expenditures these differences are small, in the case of R&D expenditures they are quite pronounced: the impact that hiring extra R&D personnel has on innovative sales is almost 80% higher in the case of large firms, confirming the idea that economies of scale are fundamental in order to exploit this kind of investment. These findings may be interpreted as stressing that the socialization of knowledge (i.e. knowledge diffusion) is higher and easier in larger firms, and the structural nature of training expenditures, the importance of which is less affected by the scale of production as they are not "production-related" investments. Training expenditures increase both the stock of knowledge and the way it diffuses within the firm. Returns to R&D employees, however, are more affected by the scale of production itself than training expenditures and by the existence of complementary resources such as structured marketing and design departments, which are more likely to be found in larger firms. In line with the emerging economic literature on complementarities in innovation, these findings support the view according that what really matters for innovativeness is the degree to which skills are used within the production and innovative process, and how this degree is strongly affected by the amount of differentiated skills, complementary assets, and routines available within the firm (Leonard-Barton 1992; Teece et al 1990).

Finally, as far as the role of other intangible investments is concerned, results suggest that a firm’s capacity to deploy creativity in user direction and to sell its products depends on whether they have introduced new marketing strategies and modified the aesthetic appearance of products. These expenditures have a positive and significant impact on innovative sales, confirming that they are necessary when launching a new product or

[15] An Ftest on linear restriction on coefficients has been computed.

developing a new brand (Corrado *et al*., 2005, p. 28; Garcia, 2011). In line with these findings, the dummy included in the INNO equation to assess the role of clients and customers as a source of information for a firm's innovative purposes is positive and significant: user-driven innovation enhances a firm's ability to sell its new products.

5 Conclusions & policy implications

The notion of complementarities was the theoretical hypothesis behind the choice of the econometric model used to assess the crucial role that skilled workers play in innovation through the new knowledge they generate, the way they combine and adapt different ideas to a changing environment, and their ability to learn new competencies through training.
In line with this theoretical background the empirical findings presented in this study shown that both training and R&D human capital, are significant explanatory variables of European firms' innovative performance. The more a firm invests in training its workers to develop and/or to introduce innovation and in R&D personnel, the higher its innovative sales. These results also support the idea that if a firm has the possibility to generate a "specific" human capital advantage and to capture a stock of human talent, it is more innovative than the average firm. In addition, while we do not observe ant statistically significant difference between the returns to training and R&D personnel between more and less knowledge intensive firms, in line with what initially expected returns to these expenditures are affected by a firm's size. However, while in the case of training these differences are quite limited (confirming their structural relevance), in the case of the returns to human capital in R&D activities, the difference between SMEs and large firms is significantly more pronounced. The impact that hiring extra R&D personnel has on innovative sales is almost 80% higher for large firms, confirming the idea that economies of scale are fundamental in order to exploit this kind of investments. R&D departments needs a larger amount of "complemetary" resources (and among them of training), and as such their impact is heavily determined by the scale of production. In any case, this is not the whole story. The CIS3 data highlighted that in the case of European firms in addition to those intangibles created through innovation and discovery and those related to human capital, intangibles underlying organization practices are fundamental in explaining their innovative performance. The smaller difference in terms of returns observed for training expenditures between SME and large firms might be partly due to their structural nature less influenced by the scale of production than R&D-oriented investments. This is in line with the idea that verbalised and un-verbalised knowledge about "how to get things done" and how to

organize and train human resources are particularly important when technology is changing rapidly. Clearly, firms that have learnt how to organise their human resources effectively and train them to utilise new technology or create new products have an edge over those that do not.

From a policy perspective, these findings suggest the need for policies that solve the market imperfections (such as risk aversion, information asymmetries, and externalities; Hansson, 2009) that often lead to a systematic and variously motivated under provision of training, especially for those firms characterised by a less skilled labour force. Globalisation and technological change have increased the importance of the productive capacity embedded in people. As is often stressed, to sustain high profits and wages in European countries it is necessary to improve the skill level of the European workforce (and employer-provided training represents one way to do that), and/or develop superior capacity for managing these skills and, more broadly, human capital. Especially in the current economic climate, where resources for innovation are scarce, these results strongly support the idea that non-technological innovation drivers, such as organisational development, employee involvement and training, branding and design, user-driven innovation, become particularly relevant.

Acknowledgements

The author wishes to thank Sergiu Parvan for his support at the Eurostat Safe Center in Luxemburg, the IRI team – especially Pietro Moncada-Paterno' Castello and Sandro Montresor -, and three anonymous referees for the useful comments on previous versions of the paper.

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Annexes

Tables

Table 1. European firms that have engaged in training activities in 2000

		Did your enterprise engage in design activities in 2000?		
		yes	no	
Did your enterprise engage in marketing activities in 2000?	yes	5,134	2,701	7,835
	no	1,487	4,125	5,612
Total		6,621	6,826	13,447

Source: Author's elaboration on CIS data, Eurostat.

Table 2. Training activities in European knowledge and non-knowledge intensive firms, 2000.

	Knowledge intensive firms		Non-knowledge intensive firms	
Training activities*	Number of firms	%	Number of firms	%
No	9,836	86.92	28,589	91.53
Yes	1,480	13.08	2,645	8.47
Total	11,316	100.00	31,234	100.00

* Firms that did not engage in marketing and design innovative activities.

Table 3. Description of the variables included in the estimated models.

Name of the variable	Description	Obs	Mean	S. E.	Min	Max
TR	Amount of investment in training direct at the introduction of new products (log)	42349	.420113	1.57574	0	15.99219
RDpers	Number of R&D personnel (log)	58357	.5634781	1.120578	0	9.577172
Inno	Amount of innovative sales, i.e. new to the firm products (log)	62933	5.455105	7.035876	0	24.69164
Actman	Dummy variable taking up the value 1 if the firm implemented advanced management techniques during the period 1998-2000, zero otherwise.	85882	.2445565	.4298264	0	1
Actorg	Dummy variable taking up the value 1 if the firm implemented new or significantly changed organizational structures during the period 1998-2000, zero otherwise.	85880	.3150442	.4645362	0	1
Actmar	Dummy variable taking up the value 1 if the firm significantly changed its marketing concepts/strategies during the period 1998-2000, zero otherwise.	85883	.2246195	.417334	0	1
Actaes	Dummy variable taking up the value 1 if the firm significantly changed its product's appearance/design during the period 1998-2000, zero otherwise.	85863	.2448435	.4299969	0	1
Hfinzeroone	Dummy variable taking up the value 1 if the firm declared a lack of appropriate sources of financing as a hampering factor, zero otherwise.	70302	.4793889	.4995786	0	1
Hperzeroone	Dummy variable taking up the value 1 if the firm declared a lack of qualified personnel as a hampering factor, zero otherwise.	70220	.4313016	.4952616	0	1
Horgzeroone	Dummy variable taking up the value 1 if the firm declared an organizational rigidities as a hampering	70157	.3656371	.4816118	0	1

	factor, zero otherwise.					
Funding	Dummy variable taking up the value 1 if the firm received public financial support for innovation activities, zero otherwise.	33821	.2846161	.4512381	0	1
Paap	Dummy variable taking up the value 1 if the firm applied for at least one patent over the period 1998-2000, zero otherwise.	85726	.083032	.2759322	0	1
Paval	Dummy variable taking up the value 1 if the firm have valid patents at the end of 2000, zero otherwise.	85724	.078231	.256432	0	1
co	Dummy variable taking up the value 1 if the firm has cooperated on innovation activities with other enterprises and/or Institutions during the period 1998-2000, zero otherwise.	34409	.2902148	.453868	0	1
rdconst	Dummy variable taking up the value 1 if the firm constantly invest in R&D, zero otherwise.	20062	.5834912	.4929922	0	1
sunizeroone	Dummy variable taking up the value 1 if the firm declared universities as the main source of information needed for suggesting new innovation projects during the period 1998-2000, zero otherwise.	33802	.3513993	.4774145	0	1
sclizeroone	Dummy variable taking up the value 1 if the firm declared clients as the main source of information needed for suggesting new innovation projects during the period 1998-2000, zero otherwise.	33808	.7198888	.44906	0	1
group	Dummy variable taking up the value 1 if the firm belongs to a group, zero otherwise.	86839	.3004526	.4584575	0	1
dummyKIA	Dummy variable taking up the value 1 if the firm has more than 33% of workforce with tertiary education, zero otherwise.	87499	.2675345	.442676	0	1
sme	Dummy variable taking up the value 1 if the firm has a number of employees<250 and an amount of	79845	.9228881	.2667706	0	1

	sales <=50,000,000, zero otherwise.					
lnemp	Number of employees (log)	87344	3.958507	1.320868	.6931472	12.68913
Industry dummies (2 digit level)						
Manufacture						
High tech	NACE 30+32+33	87499	.0305489	.1720931	0	1
Medium high tech	NACE 24+29+31+34+35	87499	.1325158	.3390526	0	1
Medium low tech	NACE 23+25+26+27+28	87499	.1399902	.3469788	0	1
Low tech	NACE 15+16+17+18+19+20+21+22+36+37	87499	.3235008	.4678147	0	1
Electricity	NACE 40+41	87499	.0202745	.1409386	0	1
Services						
Market service low	NACE 51+60+63	87499	.2095338	.4069782	0	1
Financial services	NACE 65+66+67	87499	.0370519	.18889	0	1
High tech services	NACE 64+72+73	87499	.0424919	.2017097	0	1
Low tech services	NACE 50+60+63	87499	.0499663	.2178766	0	1
Country dummies (NUTS 2 level)	Belgium, Bulgaria, Check Republic, Germany, Estonia, Finland, Greece, Hungary, Island, Italy, Latvia, Lithuania, Norway, Portugal, Romania, Slovenia and Slovakia, Spain.					

Table 4. The covariates included in the 3 equations of the 4 estimated models.

	MODEL 1			MODEL 2			MODEL 3			MODEL 4		
	TR	R&D	INNO	TR	R&D	INNO	TR	R&D	INNO	TR	R&D	INNO
Size	x	x	x	x	x	x	x	x	x	x	x	x
group	x	x	x	x	x	x	x	x	x	x	x	x
industry dummies	x	x	x	x	x	x	x	x	x	x	x	x
country dummies	x	x	x	x	x	x	x	x	x	x	x	x
Advanced management strategies	x			x			x			x		
New organizational structures				x								
New marketing concepts/strategies			x			x			x			x
New design (aesthetic changes)			x			x			x			x
Lack of financial resources				x								
Lack of qualified personnel	x						x					
Organizational rigidities		x			x							
Funding		x			x			x			x	
Patent activity		x			x			x			x	
Existence of valid patents												x
Cooperating firm								x			x	
Constant R&D		x			x			x			x	
Universities as source of information										x		
Clients as source of information			x			x			x			x

Table 5. Tobit estimation results, model 1 to 4, new to the firm products (Bootstrapped standard errors).

	Model (1)			**Model (2)**			**Model (3)**			**Model (4)**		
Variables	(a) Training	(b) RDpers	(c) Innovative sales	(a) Training	(b) RDpers	(c) Innovative sales	(a) Training	(b) RDpers	(c) Innovative sales	(a) Training	(b) RDpers	(c) Innovativ e sales
latentstar_tr			0.138***			0.140***			0.135***			0.110***
			(0.0241)			(0.0289)			(0.0280)			(0.0332)
latentstar_rd			1.591***			1.563***			1.612***			1.531***
			(0.135)			(0.104)		0.263***	(0.104)		0.263***	(0.101)
funding		0.313***			0.301***			(0.0162)			(0.0162)	
		(0.0174)			(0.0160)			0.800***			0.800***	
Constant R&D		0.781***			0.817***			(0.0166)			(0.0166)	
		(0.0178)			(0.0166)			0.358***			0.358***	
Patent activity		0.377***			0.377***			(0.0174)			(0.0174)	
		(0.0189)			(0.0174)							
New organizational structures		0.0105 (0.0160)		1.415*** (0.160)								
Advanced management strategies	3.062*** (0.168)			3.103*** (0.168)			3.060*** (0.168)			2.284*** (0.152)		
Lack of qualified personnel	1.851*** (0.162)						1.850*** (0.162)					
Clients as source of information			1.711*** (0.126)			1.717*** (0.125)			1.717*** (0.144)			1.689*** (0.138)
Universities as source of information										1.083*** (0.161)		
New design (aesthetic changes)				7.713*** (0.115)								
New			0.900***			0.900***			0.892***			0.954***

marketing concepts/strategies			(0.0995)			(0.0919)			(0.0937)			(0.0917)
Existence of valid patents												0.593***
												(0.0955)
Cooperating firm								0.195***			0.195***	
								(0.0158)			(0.0158)	
Common controls: log of employees, belonging to a group dummy, 9 nace sector dummies, 23 European country dummies. Results available on request.												
AIC	34647.81	35651.43	83022.76	34668.39	35675.42	83077.13	34647.81	35581.04	83080.8	34647.81	44755.28	101312
BIC	34948.83	35954.35	83318.13	34969.39	35970.8	83372.52	34948.83	35884.02	83376.21	34930.38	45066.44	101615.1
Observations	31,618	14,371	14,372	31,618	14,391	14,393	31,618	14,391	14,393	18,942	17,659	17,493

Bootstrapped standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

For the sake of simplicity only results for relevant variables were inserted. Clearly, results of the regressions with the whole set of explanatory variables are available on request.

Table 6. The impact of training and RD personnel on new to the firm product sales. Tobit estimation results, models 1 to 4 (Bootstrapped std errors).

VARIABLES	**Model (1)** Innovative sales	**Model (2)** Innovative sales	**Model (3)** Innovative sales	**Model (4)** Innovative sales
	Knowledge intensive firms' interaction models			
training_KIA*	0.116***	0.115***	0.113***	0.147***
	(0.0365)	(0.0305)	(0.0293)	(0.0460)
training_nonKIA*	0.146***	0.148***	0.143***	0.0872**
	(0.0355)	(0.0266)	(0.0256)	(0.0395)
lnrdper_KIA*	1.541***	1.522***	1.569***	1.593***
	(0.106)	(0.124)	(0.136)	(0.115)
lnrdper_nonKIA*	1.570***	1.541***	1.589***	1.473***
	(0.110)	(0.117)	(0.132)	(0.105)
Observations	14,378	14,387	14,393	18,432
AIC	83017.4	83071.77	83076.29	101307.7
BIC	83335.49	83389.88	83394.42	101634.1
	SME interaction models			
training_SME*	0.125***	0.122***	0.122***	0.119***
	(0.0266)	(0.0251)	(0.0310)	(0.0381)
training_BIG*	0.168***	0.160***	0.163***	0.145***
	(0.0336)	(0.0329)	(0.0374)	(0.0441)
lnrdper_ SME *	1.376***	1.357***	1.397***	1.335***
	(0.124)	(0.0980)	(0.110)	(0.106)
lnrdper_ BIG *	2.191***	2.168***	2.193***	2.197***
	(0.193)	(0.195)	(0.229)	(0.183)
Observations	12,459	12,467	12,471	15,144
AIC	71672.32	71723.31	71720.14	87436.39
BIC	71984.39	72035.41	72032.25	87756.65

Explanatory variables common to all 4 models: sclizeroone, actmar.
Common controls: dummy KIA or dummy SME, log of employees, group, 9 nace sectoral dummies, 23 European country dummies.

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1
For the sake of simplicity only results for relevant variables were inserted. Clearly, the results of the regressions with the whole set of explanatory variables are available.

The mission of the JRC-IPTS is to provide customer-driven support to the EU policy-making process by developing science-based responses to policy challenges that have both a socio-economic as well as a scientific/technological dimension.

European Commission
EUR 24747EN/6– Joint Research Centre – Institute for Prospective Technological Studies
IPTS WORKING PAPER on CORPORATE R&D AND INNOVATION - No. 6/2011
Title: Intangible resources: the relevance of training for European firms' innovative performance
Author(s): Daria Ciriaci (European Commission, JRC-IPTS)
Luxembourg: Publications Office of the European Union
2011
EUR – Scientific and Technical Research series – ISSN 1831-9408
Technical Note – ISSN 1831-9424
ISBN 978-92-79-22647-2
doi:10.2791/70648

Abstract

This paper assesses the impact of investing in training directly aimed at the development and/or introduction of innovations and R&D personnel on European firms' innovative performance. In particular it quests for the complementarity between these two investments - in the presence of a well trained work force, the knowledge created by the R&D personnel of the firm can be better exploited -, and for their dependence on the firm's knowledge intensity (high versus low % of tertiary educated workforce) and on their size (SMEs versus large firms). Using European CIS non-anonimized data for the period 1998-2000, the paper estimates a system of simultaneous equations in which investments in training and in R&D personnel are treated as endogenous as the innovative sales they are assumed to affect. The choice of using this wave and not more recent ones - to which I had access at the Eurostat safe-center - is data-driven. In fact, it has richer information on training expenditures and it is the last wave having firm level information on the number of employees with tertiary education. Differently from the majority of CIS-based studies, the main variables of interest are continuous ones, while dummy ones are used only as controls. Empirical evidence confirms most previous results - investment in training and the stock of R&D personnel positively affect firms' innovativeness - but also adds some further important insights. C*eteris paribus*, investments in training in those firms which are characterized by a relatively lower percentage of tertiary educated employees shows the highest returns, while those to R&D personnel do not. At the same time, while investing in R&D personnel shows higher returns in terms of innovativeness in big enterprises, returns to training are not affected by firms' size. These last findings suggest that while the impact of structural investments such as those in training are not size-dependent, that of RD departments is higher in larger firms as they need more complementary resources (i.e. among other, of marketing departments) to be exploited.

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LF-NF-24747-EN-N

JRC
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Publications Office

ISBN 978-92-79-22647-2