ELSEVIER

Technovation 24 (2004) 29–39

technovation

www.elsevier.com/locate/technovation

Internal capabilities and external knowledge sources: complements or substitutes for innovative performance?

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Abstract

This paper attempts to investigate the extent to which the existing internal capabilities of firms and their interaction with external sources of knowledge affect their level of innovativeness. Part of these capabilities result from a prolonged process of investment and knowledge accumulation within firms and form what has been addressed as the "absorptive capacity" of firms (Cohen & Levinthal, Admin. Sci Q., 35 (1990) 128). There are however other efforts that enhance the "original" definition of absorptive capacity and these relate to the way firms interact with their environment. Empirical data from an extensive survey that was carried out in seven European countries, namely Greece, Italy, Denmark, UK, France, Germany and the Netherlands, provides evidence for studying the relative effectiveness of specific mechanisms of knowledge creation and knowledge transfer. The results show that both internal capabilities and openness towards knowledge sharing are important for upgrading innovative performance.

Keywords: Innovation; Knowledge flows; Absorptive capacity

1. Introduction

Recent literature on the knowledge-creating view of firms focuses on knowledge as one of the most valuable resources that provides sustainable competitive advantage and on interaction as a key element for the access, acquisition and development of new knowledge. Interaction may take place within a firm and between firms and other organisations. Firms may interact via various ways to access knowledge outside their boundaries. Extensive literature discusses various organizational features corresponding to different mechanisms that facilitate knowledge flows among different actors and enabling dissemination and production of new knowledge.

In this paper we attempt to investigate the extent to which the existing internal capabilities of firms and their interaction with external sources of knowledge affect their level of innovativeness. Part of these capabilities result from a prolonged process of investment and knowledge accumulation within firms and form what has been described as the "absorptive capacity" of firms (Cohen & Levinthal, 1990). There are however other efforts of firms that enhance the absorptive capacity as defined by Cohen and Levinthal and these relate to the way firms interact with their environment. Interaction is a key concept for knowledge creation and innovation. Openness of firms to external knowledge sources is another important element when evaluating their innovative potential. In this paper we assess the impact on the level of innovativeness of firms of their ability to create linkages with other entities and establish channels of knowledge flows between them.

Using an interpretation framework that puts emphasis on the knowledge-based view of firms, we have identified the determinants of innovative performance of firms. Our empirical analysis is based on an extensive survey that was carried out in seven European countries, namely Greece, Italy, Denmark, UK, France, Germany and the Netherlands. We have used data collected from 558 innovative firms belonging to five pre-selected sectors. These sectors are food and beverages, chemicals (pharmaceuticals excluded), radio/television and communication equipment and apparatus, telecommunication services, computer and related activities.

We have investigated the relative effectiveness of spe-

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doi:10.1016/S0166-4972(02)00051-2

cific mechanisms of knowledge creation and knowledge transfer. These mechanisms represent the intensity of efforts made for the development of firms' internal capabilities and for accessing knowledge from external sources. We consider internal efforts in discovering and developing new solutions and acquiring knowledge through training, the extent to which firms seek to obtain ideas for innovation from external sources (patent databases, journals, conferences, the Internet) and the extent to which they create links with other entities (firms and Universities or Research Centers). We have examined possible differences among sectors and countries in an effort to assign sector and country specific characteristics to the process of acquiring and accessing the new knowledge and the ways in which firms seek new ideas for innovation. We conclude that understanding the factors that influence innovative performance can provide strategic insights both to government policy-making and to corporate strategy.

In the following section we present the theoretical framework on which we base our empirical analysis. Emphasis is placed on the economic literature that studies the importance of factors related to the capabilities of firms in analysing their innovative performance. The second section presents the empirical analysis based on a specific dataset containing information about the innovative activities of European firms[1] The last section summarises the results and discusses the main points arising from the analysis. Evidence is provided for the positive role on innovative performance of both internal R&D efforts of firms as well as efforts to establish linkages and access external knowledge. These efforts represent the capability of firms to exploit internal knowledge and also to interact and access knowledge outside their boundaries.

2. Building capabilities for innovation

Factors that relate to innovation are many and varied, and can change over time. The aim of this paper is not to present an exhaustive model of the determinants of innovation but instead to test the importance of a set of widely acknowledged factors that relate to firms' capabilities.

Innovation is an interactive process characterised by technological interrelatedness between various subsystems (Teece, 1996) as well as by organisational complexity as it involves various actors and functions. Complexity and variability of technologies and markets increase the need for external partners for complementary cognition (Nooteboom, 1999a).

The process of knowledge generation relies on interaction and knowledge openness[2] (Llerena, 1997; Nonaka, 1994; Foray, 1997). Interaction between individuals or other entities (groups, organizations) plays a critical role in articulating and amplifying knowledge (Nonaka, 1994). This means that knowledge creation is a process that goes beyond the individual level, as organisations can learn independently of each specific individual (Llerena, 1997); i.e. it is a context specific process and knowledge can be considered as embedded in "*a shared space of emerging relationships*" (Nonaka and Konno, 1998). Knowledge openness may speed up the pace of innovation as competitors are able to build on other innovators' advances, rather than being allowed to block the progress of others (Foray, 1997). Thus, the generation, utilisation and distribution of knowledge depends on the frequency and density of interactions and on the knowledge openness.

Innovation can be better understood as a process in which the organisation creates and defines problems and then actively develops new knowledge to solve them (Nonaka, 1994). In this context, individuals and firms may need outside sources of cognition and competence to complement their own but also need inter-organisational linkages in order to convert knowledge into new types of knowledge and develop new products, processes or services (Nonaka and Takeushi, 1995). Interaction may prove beneficial in two ways: first in establishing channels, which embed knowledge flows, and second in allowing organisational knowledge creation. By organisational knowledge creation we mean the capability of an organisation (such as a firm) to create new knowledge, disseminate it throughout the organisation and embody it in products, services and systems (Nonaka and Takeushi, 1995).

This approach to generation of knowledge and innovation relates to the way theory conceives the firm as an organisation. Rather than being viewed as a vehicle for processing information (i.e. the standard neoclassical view of the firm as an agent that simply reacts to information signals that it receives from the outside), firms must be conceived as a collection of resources and capabilities and considered as organisations that can learn, share, diffuse, and create knowledge through interaction. Cognitive processes are cumulative, idiosyncratic and path-dependent processes as past and accumulated experience determine the capability of firms to absorb knowledge and further develop new products, processes or services (Cohen and Levinthal, 1990). Cohen and Levinthal have developed a framework, which conceptu-

[1] The dataset has been created in the context of the EU funded project "KNOW FOR INNOVATION" (contract number CT98-1118) coordinated by Y. Caloghirou and undertaken by 7 research institutes, namely NTUA/LIEE, MERIT, CESPRI, IKE, BETA, SIRN and ZEW.

[2] By knowledge openness we mean the extent to which a firm accesses external knowledge sources.

alises the effectiveness of processes relating to learning and knowledge creation and the absorptive capacity of firms. The absorptive capacity refers to the ability of firms not only to acquire and assimilate information but also to exploit it (ibid). The absorptive capacity framework relies on two important elements: the existing knowledge base and the intensity of efforts made for the development of technological capabilities (Kim, 1999). As Kogut and Zander (1992), p. 383, point out ". . . *the theoretical challenge is to understand the knowledge base of a firm as leading to a set of capabilities that enhance the chances for growth and survival*". The existing knowledge base increases the ability to search, recognise and represent a problem as well as assimilate and use new knowledge for problem solving. The intensity of effort or commitment in problem solving refers to the amount of energy that organisational members devote to solve problems (Kim, 1999). The capability of a firm to absorb knowledge and information from external sources is one of the pillars in the process of transformation of knowledge and information into new knowledge and its conversion into new value.

People and firms possess different amounts of knowledge to the extent that they have different experiences and have performed different levels of efforts. Internal efforts (such as R&D, training, etc.) intensify interaction among individuals or organisations, amplify existing knowledge and may convert it into new types of knowledge. The investment of a firm in R&D (discovery capability), in appropriating R&D outcomes (patenting), in human resources training (learning and knowledge transfer capability), in new instruments (which allow firms and their members to see and study things that they would not be able to without these instruments), as well as the organisation and design of the firm (procedures within the firm that help to codify knowledge, retrieve information, distribute within the firm and/or effectively recognise and search problems), should be considered among the elements that characterise the knowledge base and the efforts made for its enhancement (for these issues also see Simon, 1999).

According to Cohen and Levinthal, the firm's expertise for in-house development has a considerable positive effect on its capability to assimilate and convert external knowledge and information into new products, processes or services. Processes for creating knowledge involve, among other things, accumulation of capabilities that enable firms to better absorb and exploit the knowledge and information that is available for accessing. These processes are not only related to discovery but also to learning and acquisition of knowledge and skills, to the retention of knowledge and to tangible investments that constitute a technical infrastructure for further technological development.

Having a strong knowledge base, including R&D capacity and a well trained labour force, is a key to successful innovation (Lundvall and Nielsen, 1999). R&D efforts constitute the necessary (although not sufficient) condition for a firm's successful exploitation of knowledge and its conversion to new products or services. Empirical tests confirm and support the argument that higher levels of R&D efforts improve a firm's ability to exploit sources of technical knowledge outside its boundaries (Gambardella, 1992; Mowery et al., 1996).[3] Another indicator of the capability of the firm to develop new solutions and exploit the knowledge that lies outside its boundaries is the skills of the firm's employees. The same is true of learning mechanisms. Education and training enhance competencies and give people and organisations the basis to introduce innovation (Lundvall and Nielsen, 1999). As change is introduced, individuals and organisations are confronted with new problems that can be solved only by developing new skills and competencies (ibid).

The above discussion leads us to formulate the following hypothesis:

The higher the levels of R&D efforts and training within a firm are, the more the firm will be able to create and exploit novelty.

However, the notion of absorptive capacity may be enhanced in a way to encompass the capability of the firm to interact with other actors and access external sources of knowledge (Kastelli et al., 2001). In a world of increasing competition and rapid technological change, the firm cannot rely only on its own capabilities and knowledge base but needs to benefit from the experience and knowledge of other economic actors. More and more innovative companies establish linkages with other actors and access external knowledge in order to benefit from the dynamic effects of interactive processes. A firm's in-house resources and capabilities may not be always adequate for solving complex technical problems. The role of external communication practices and of networking as determinants of innovation has been emphasised repeatedly in the literature and their importance is increasing. There are diverse and numerous communication channels through which information flows and diffuses. Efforts for establishing channels of knowledge flows and linkages can be distinguished into two broad categories (Souitaris, 2001):

1. scanning external information and
2. cooperating with external organisations.

Some of the mechanisms included in the first category, through which knowledge and information can be obtained, are technical reports, use of patent databases,

[3] Admitedly however there is very little empirical evidence.

attendance at conferences, scientific publications, reverse engineering and use of the Internet.

Patents are considered as one useful source of information on technical characteristics of inventions that have been protected. The use of patent databases may provide valuable information on potentially profitable research areas or on how to invent around the patent (Arundel, 2001). Journals are a more conventional way of acquiring codified knowledge and information. The use of patents and journals reflects an interplay between basic/applied scientific research and technological development in the context of corporate R&D efforts. The same is true of conferences but in the context of personal links.

Reverse engineering is a more sophisticated process, which depends on the technology trajectory of the specific industry and the country's technological development. It has been an important mechanism of knowledge flows, especially for less industrialised countries, that has supported innovative performance.

The use of the Internet is a more recent communication and information medium. Firms may use the Internet either to search the World Wide Web for scientific and technical information or to exchange information with customers, suppliers or collaborators via e-mail. Recent studies have identified various benefits from the use of the Internet. These include the know-how obtained through discussion with others on the Internet, the benchmarking of competitor's performance, the creation of new business opportunities, savings in time and money when accessing information (Walcszuch et al., 2000).

The above underpin the following hypothesis:

The more the firm uses the above mechanisms the more is its openness to external sources of knowledge and the more it develops information and knowledge sharing with positive effects on its innovative performance.

The second category, which includes efforts for establishing linkages, refers primarily to cooperations with other firms or with actors from the Academic and Research sector. More and more strategic know-how and competence is developed interactively and shared within subgroups, networks etc. (Lundvall, 1994). Economic literature on innovation positively relates interaction between organisations with innovativeness. Firms need to make relation-specific investments and be able to benefit from interaction with other agents in order to produce high added value and novelty (Nooteboom, 1999b). This interacting capability, which relates to processes of sharing experiences through different practices (often joint practices), refers to the ability of the firm to create and exploit linkages with other entities. Cooperation (formal and/or informal) is one way of interacting. Firms with different skills and knowledge bases benefit from unique learning opportunities in the context of strategic alliances (Inkpen, 1998). It is then challenging for the firms that are involved in partnerships to create an environment that promotes crystallisation and amplification of the knowledge that is accessible in the context of an alliance (Nonaka, 1994; Inkpen, 1998).

A wide range of theoretical approaches that deal with the phenomenon of cooperation, refer to its learning effects. According to Håkansson (1987), by combining experience, new ideas can emerge. Kogut (1988) considers collaboration a vehicle by which knowledge is transferred and by which firms learn from one another. Ciborra (1991) argues that collaborations are institutional arrangements that allow firms to bring in new expertise, tacit and explicit knowledge and know-how. Cooperation potentially constitutes the way for transferring tacit and firm specific knowledge, through close linkages between different organisations. In their approach of dynamic capabilities, Teece et al. (1990) consider cooperation as a mechanism through which firms accumulate, combine and disseminate knowledge and complementary assets. Hagedoorn and Duysters (1997) stress that in a world of rapid technological change firms consider learning through a diversity of contacts as a way to generate positive returns in a long-term perspective.

In the context of cooperation individuals interact with each other and with their organizations. These interactions are considered critical for knowledge acquisition and knowledge creation (Nonaka, 1994; Nonaka and Takeushi, 1995).

University–industry cooperation is a specific type of R&D partnering and its importance has increased in industrialised countries (Fransman and Tanaka, 1995; Geuna, 1997). In such partnerships, participants bring to the consortium different competencies, capabilities and organisational contexts. In a world of increased competition and rapid technological change, firms seek to access external technological resources from the academic sector and complement or substitute expensive R&D efforts. Cooperation with universities or research centers may assure a critical mass of R&D for projects that are considered too expensive or risky for a company (Vavakova, 1995). Recent surveys show that as industrial research is facing pressures to decrease time-to-market for new inventions, basic research in corporate laboratories aiming at the creation of new scientific knowledge has decreased and that the remaining basic research is closely linked to related applied research activities (R&D Magazine, 1997). Partnerships are a way for firms to compensate. On the other hand, universities are also under the pressure of integrating the real world into their research and teaching activity and becoming more applied (Carayannis et al., 2000). That is why the number of collaborations between firms and academia

has increased over the last 15 years. This type of collaboration has been significantly promoted by public national and supranational policies as a way for increasing the interaction between research and markets. In the context of the European Framework Programmes (1984–1998), nearly 65% of the R&D partnerships that have been established involved cooperation between at least one firm and one university (Caloghirou et al., 2001).

Taken together the above arguments seem to support the following hypothesis:

The extent to which a firm undertakes R&D cooperations positively influences its level of innovativeness.

Before presenting the methodology and results of our tests we should address two more issues that are widely discussed in the literature: the role of the size of the firm and the role of competition. Both issues are approached in different ways. The Schumpeterian hypothesis for competition and innovation supports that firms innovate more when they expect high returns on investment and thus monopolistic situations are an incentive to innovate. The Schumpeterian hypothesis for the size and opportunities for R&D is that big firms have the resources and possess a monopolistic power that enable them to face the inherent risk of innovation.

However, empirical evidence does not confirm the role of the size of the firm in relation to innovation and some approaches support that it is also plausible that big firms have rigidities in introducing novelty. Problems with statistics, sectoral specificities or even the technological characteristics of innovation interfere and make the relation between size and innovation much more complex (Freeman and Soete, 1997) and in that sense it is not possible to conclude on that question.

As far as competition is concerned it is also supported that the more is the transformation pressure that the firms are confronted with, the more the firms innovate in order to survive (Lundvall and Nielsen, 1999).

In our empirical analysis we have tested the impact of the above two variables.

In this paper we have investigated the relative effectiveness, in terms of innovation, of specific mechanisms of knowledge creation and knowledge transfer. We consider the level of innovativeness of the firm as measured by the percentage of significantly improved or new products or services on the total sales of the firm during the last three years. We test for the importance of a set of variables that describe what we mentioned above as *enhanced notion of absorptive capacity*. These variables represent the intensity of efforts made for the development of a firm's internal capabilities, for accessing knowledge from external sources and for exploiting the benefits of networking.

3. Empirical insights on factors affecting innovative performance: The European experience

3.1. Data and methodology

The empirical information that is used in this paper is drawn from a rich dataset containing the results of a field survey that was carried out in 7 European countries. More specifically, the survey was conducted in Greece, Italy, Denmark, UK, France, Germany and the Netherlands during the period from February to June 2000. Five target sectors were selected for creating the original sample of examined firms: Manufacture of food products and beverages (NACE 15), Manufacture of chemicals and chemical products, but without pharmaceuticals (NACE 24), Manufacture of radio, television and communication equipment and apparatus (NACE 32), Telecommunication services (NACE 64.2), Computer and related activities (NACE 72). These sectors were selected because it seems that they are the ones that focus on innovative activities and present a significant competitive advantage in Europe today. In addition, they represent a useful counterbalance between traditional (15, 24) and rapidly expanding sectors (32, 64, 72) and between manufacturing (15, 24, 32) and services (64, 72). The sampling methodology included a restriction on the firms' size, to a maximum cut-off point of 1250 employees. The aim was to examine SMEs and middle-sized firms only. Large and very large firms were excluded. This would make the results more reliable as the innovative performance of very large firms might affect the results obtained for SMEs. The aim of the survey was to collect 80 completed questionnaires per country, properly stratified per sector in order to have a balanced European sector sample.

The survey was carried out through telephone interviews, by using the CATI method (Computerized Aided Telephone Interviewing). Only the UK used a postal survey.[4]

The person contacted was either the R&D or technical manager or any person that was responsible for the innovation activity of the firm. This was determined upon the first contact with the firm, although whenever it was necessary (i.e. sales data) other personnel who could report this information were also contacted.

As the aim was to concentrate only on the innovators the total number of available cases reached 632 innovative firms. In addition, responses from firms that ex post proved to belong to non-target sectors (26) were also excluded. Therefore the total number of firms used for our analysis is 558. The country and sectoral distribution

[4] The response rate achieved in each country was: Greece 42.3%, Italy 34.9%, Denmark 76.5%, UK 9.6%, France 12.9%, Germany 22%, the Netherlands 45.6%.

Table 1
Country and sector distribution of the sample

Country	Sectors						%	Weighted %
	15	24	32	64	72	Total		
Germany	18	16	21	4	20	79	14.2%	36.0
France	13	12	14	13	13	65	11.6%	21.2
Italy	19	20	13	2	24	78	14.0%	24.9
Netherlands	35	33	13	4	29	114	20.4%	3.3
UK	6	19	6	4	9	44	7.9%	5.8
Denmark	20	11	15	11	21	78	14.0%	6.9
Greece	21	21	19	10	29	100	17.9%	2.0
Total	132	132	101	48	145	558	100.0%	
%	23.7%	23.7%	18.1%	8.6%	26.0%	23.7%		
Weighted %	48.2	17.9	8.0	2.0	23.9	100.0%		

is presented in Table 1.[5] Although balanced enough, both in terms of country and sectoral representation—as the actual data reveal—when we use the weighting variable, 3 countries seem to dominate the sample: firms from Germany, France and Italy are responsible for 82% of the sample, whereas the effect of the other countries can be attributed only to the remaining 18%. This is in accordance of course with a general view of a "European" sample that is determined in its behaviour by firms from at least two of them (France and Germany), while the effect of firms from a small country like Greece can contribute only 2% in the overall sample. However, it raises questions about the proper balancing in the composition of the examined sample. In any case, the reader should always interpret the weighted results as reflecting actually the effect of these 3 countries.

The questionnaire was structured into 5 parts: The first part contained some general information about the surveyed firms. The second part asked for general innovative behaviour characteristics. The third and probably the core part concentrated on the firm's economically most important innovation during the last 3 years. Part four asked questions about the firm's most important external source of knowledge for the completion of this innovation. Finally, in the last part, some additional information was collected regarding the R&D activity of the firm, the participation in funded joint research activities, the scientific level of its employees and their possible participation in training or educational programs, the ownership status and the level of its sales during the last fiscal year.[6]

We tried to examine the extent to which internal capabilities and capability to interact and access external sources of knowledge affect the level of innovativeness of the firm.

The innovativeness of the firm (named as INNOV) is constructed upon the percentage of firms' sales that can be attributed to products or services that were significantly improved or new to the firm in the last three years.[7] This percentage can be considered as a proxy of the innovative performance of the firm and is consistent with the definition of innovation according to the OSLO manual that has been adopted in the survey. This variable is used as the dependent variable in our regression model.

The regression analysis investigates the effect of a set of variables that follow the theoretical analysis that has been presented in the earlier section, on the level of innovativeness.

Investment in R&D and human resources training is indicative of the internal efforts of the firm in creating and acquiring knowledge. R&D intensity of the firm (RDINT) is captured by the ratio given by R&D employees/total employees. The percentage of the firm's employees that has participated in training programs either inside or outside of the firm composes the variable TRAIN. The qualifications of the employees are captured in the model by the number of employees that have an academic degree in a scientific or engineering field (HSKILL).

[5] We have calculated a separate variable to be used as a weighting variable for our sample. The calculation took into consideration the need to have a stratified sample according to both the sectoral distribution of firms across countries (sector's capacity in each country), but also the size of the firm across countries (in accordance with the general "size characteristics" of the firms in each country). This variable is used only for the descriptive results, in order to examine the changes that occur in the results, when using the actual number of firms compared to the weighted one.

[6] For the non-respondents a sixth section was used, identifying whether they perform R&D activities at all, and the main reason for refusing to respond.

[7] The question was phrased as follows: "In the most recent fiscal years what percentage of your firm's sales can be attributed to product or services that were significantly improved or new for your firm in the last three years?".

Efforts for establishing channels of knowledge flows and linkages are indicative of the capability of the firm to access and exploit knowledge, which is outside its boundaries. Efforts for scanning external information are introduced in the model with five dummies that represent possible sources of ideas for innovation: A firm may regularly seek to obtain ideas for innovation by searching patent databases (PATDB), by reading scientific or business journals (JOUR), by attending trade fairs and conferences (CONF), by technical analysis of competitor's products—reverse engineering—(REVENG) or by using the Internet (INTERNET). Each of these dummies can take the value of 1 when the specific source is used by the firm and 0 otherwise.

Efforts for establishing linkages with other organisations are represented in the model by two variables. The first (ALLIA) is a dummy that indicates whether the firm has joined strategic alliances during the last three years. The second is the variable COOPUNIV that represents the extent to which a firm has participated in R&D cooperation with universities or research institutes. It is constructed based on the number of R&D projects that the firm has undertaken in collaboration with such organisations in the last three years.

Competition (COMP) is measured by the natural logarithm of the number of competitors that the firm has in its main business. This proxy may not be the proper one to measure competition, as the number of competitors may not be a good measure for the intensity of competition. However, in the absence of an alternative (based on the information we have) we have used it while being aware of the limitations.

The size of the firm (SIZE) is represented by the natural logarithm of its total number of employees.[8]

In addition, sector (SECT) and country (CNTR) dummies have been constructed in order to examine their effect on the dependent variable, along with the robustness of the results across sectors and countries.

Therefore, the final equation that will be run, can be represented by the following relationship:

$$\text{INNOV} = f\{\text{COMP, SIZE, RDINT, TRAIN, HSKILL, PATDB, JOUR, CONF, REVENG, INTERNET, COOPUNIV, ALLIA, SECT, CNTR}\} \quad (1)$$

In the following section some descriptive statistics regarding the above variables are presented in order to have a clearer picture of the dataset that we used (Table 2).

Table 2
Descriptive statistics for "extent of innovation"

INNOV	Number of firms	%	Weighted %
0	25	4.5%	3.2%
1 to 10%	91	16.3%	21.2%
11 to 25%	118	21.1%	24.6%
26 to 50%	189	33.9%	27.8%
50 to 75%	63	11.3%	13.4%
76 to 100%	72	12.9%	9.8%
Total	558	100.0%	100.00%

For more than half of our sample, 11% to 50% of its sales in the most recent fiscal year refer to products or services that were significantly improved or new to the firm during the last three years. Just 3% of the firms could not attribute any part of their sales to a specific innovative product/service. The above shows that our sample is dominated by innovative firms.

Some further descriptive indication of the variables that we are using in this paper is necessary in order to understand the characteristics of the sample. Generally, the average firm of our sample is a small firm (<50 employees), which reports from 1 to 10 competitors in its main business. Even though it presents an R&D intensity ratio between 10 and 25%, it has not been engaged in cooperation with universities or public/private research institutes, during the last three years, or has cooperated only once. Almost half of its personnel has participated in training programs, either inside or outside the firm, during the last 3 years. The personnel with an academic degree is on average almost 27%, although 15% of our sample reports no employees with an academic degree, which is rather surprising since they claim to have presented some innovative activity.

Finally, Table 3 gives an indication of the distribution for the dummy variables that are used in our estimations. It seems that the vast majority of the firms uses as a regular method for seeking ideas for innovation the attendance at trade fairs and conferences, followed closely by searching in scientific and business journals. On the other hand, searching in patent databases doesn't

Table 3
Dummy variables

Variable	Value=1	%	Weighted %
PATDB	133/558	23.8%	14.9%
JOUR	456/558	81.7%	83.1%
CONF	489/558	87.6%	87.1%
REVENG	375/558	67.2%	58.0%
ALLIA	245/558	44.0%	40.7%
INTERNET	521/558	93.4%	80.6%

[8] We have also constructed a size variable based on the firm's sales, but the total number of observations is reduced. However, we have tested our model with this variable and no significant changes have occurred, although all attempts provided better overall fitness (slightly higher *R*-squared values).

seem to be a popular method, while reverse engineering still captures the interest of the innovating firms (58%). The Internet is vastly used in our sample, while 41% of the sample has been engaged in strategic alliances.

3.2. Results

In order to examine the proposed relationship we have estimated a simple Ordinary Least Squares (OLS) model, which is the most appropriate in this case. The model has also been estimated with country and sector dummies, separately, producing thus 3 final "models". Table 4 presents the estimated results.

All 3 estimations are reliable and interpretable as the *F*-statistic values proved significant at the $p<1\%$ level. Results show that RDINT (at the $p<5\%$ level), HSKILL and ALLIA (at the $p<1\%$ level both) are significantly and positively related with the dependent variable. That means that firms that are more R&D intensive, with high skilled personnel and in strategic alliances, tend to innovate more. In addition, JOUR takes also a positive sign at the 5% level, indicating a strong effect of scientific/business journals as a way for seeking ideas for innovation. On the other hand, the use of patent databases affects negatively the level of innovativeness, indicating that the firms that innovate more tend not to use this particular source for information. Despite the fact that the proportion of firms in the sample making use of this mechanism is low, this result may point to the fact that innovative firms do not need to search information in patent databases in order to obtain ideas. From the descriptive statistics on our sample any explanation has not been evident for this result. Further research on that issue might be of interest. All other variables are not significant, whereas the overall fit of the model is satisfactory (nearly 14%).

Including sector dummies in our model does not alter the results obtained, indicating a relative robustness and apparently no sector effect in the examined relationship. RDINT, HSKILL, ALLIA and JOUR remain significantly positive, even if some changes regarding the level of its significance occur. The same goes for the negative effect of PATDB (although at a very marginal level), whereas INTERNET becomes also significantly negative

Table 4
Parameter estimates for OLS (*N*=484) Dependent Y1=How much innovative (%)

Variable[a]	Model 1		Model 1 with sector dummies[b]		Model 1 with country dummies	
	Coef.	Std err.	Coef.	Std err.	Coef.	Std err.
Constant	19.96***(3.02)	6.61	35.51***(4.61)	7.70	19.56**(2.43)	8.03
COMP	0.10(0.13)	0.80	−0.24(−0.30)	0.78	0.08(0.09)	0.84
ALLIA	10.47***(4.21)	2.48	5.88**(2.44)	2.41	10.14***(4.03)	2.52
PATDB	−5.80**(−2.01)	2.88	−4.32*(−1.58)	2.74	−5.13*(−1.77)	2.90
JOUR	7.14**(2.20)	3.22	5.47**(2.00)	2.72	8.21**(2.45)	3.36
CONF	391(1.01)	3.87	4.54(1.43)	3.17	3.54(0.90)	3.92
REVENG	−0.71(−0.27)	2.61	1.10(0.44)	2.50	0.44(0.16)	2.68
INTERNET	2.45(0.54)	4.57	−7.66*(−1.79)	4.27	3.15(0.68)	4.60
COOPUNIV	-0.21(−1.20)	0.18	−0.11(−1.32)	0.08	−0.19(−1.07)	0.18
TRAIN	−0.01(−0.23)	0.04	−0.02(−0.56)	0.04	0.01(0.27)	0.04
RDINT	15.04**(2.42)	6.21	15.86***(2.83)	5.60	16.74***(2.58)	6.47
HSKILL	19.51***(4.02)	4.86	11.60**(2.14)	5.41	16.80***(3.15)	5.33
SIZE	−0.61(−0.63)	0.96	0.58(0.61)	0.94	−0.78(0.71)	0.99
NACE 15			−22.08***(−5.48)	4.03		
NACE 24			−12.21***(−3.02)	4.04		
NACE 32			3.81(0.90)	4.24		
NACE 64			6.70(1.23)	5.44		
France					0.91(0.19)	4.75
Italy					−5.57(−1.21)	4.61
Netherlands					−6.71(−1.49)	4.52
UK					1.36(0.24)	5.59
Denmark					0.00(0.00)	4.70
Greece					1.32(0.29)	4.56
Adjusted R^2	13.79%		24.6%		13.9%	
Log Likelihood	−2244.44		−2210.69		−2240.81	
F-statistic	7.43***		10.72***		5.36***	

Values in parentheses are *t*-statistic values for the estimated coefficients. Asterisks ***, **, * denote statistically significant coefficients at 1%, 5% and 10% level of significance.

[a] All variables have been checked for multicollinearity.

[b] The coeeficients in this model have been corrected for heteroscedasticity by White (1980). The other two models had no problems of this nature.

(also at a marginal level). This means that there are some sector specific characteristics regarding this particular variable. Regarding the examined sectors, results show a highly negative significance for food (NACE 15) and chemicals (NACE 24) compared to the reference sector, which is the computer and related activities (NACE 72). Firms from these two sectors seem to innovate less, which is something that is rather expected as these two sectors represent the more "traditional" ones where innovation seems to follow a slower rate, whereas the latter is a rapidly changing sector. The remaining sectors proved insignificant. The overall fit of the model increases, as expected, reaching almost a 25% fit.[9]

When we include the country dummies in our model the results remain robust in an even more evident way than when sector dummies were used, indicating apparently no country effect. All significant variables retain their signs, at almost identical levels of significance. R&D intensity, high skilled personnel, participation in strategic alliances and searching in journals still affect positively the extent of innovation of the firms, whereas searching in patent databases has still a negative effect. The overall fit of this model reaches 14%. All country dummies prove insignificant, indicating that we cannot obtain significant variation among countries.[10]

4. Discussion

In this paper we have adopted an approach that puts interaction and linkages at the center of the discussion on knowledge creation and innovation. We have examined the importance of the capability of the firm to recognize, assess and exploit information and knowledge outside its boundaries in the generation of innovation. This capability has been described by a set of variables that represent the efforts of the firm for technological development, acquisition of knowledge and establishment of mechanisms that embody knowledge flows and corresponds to an enhanced notion of absorptive capacity.

The results from our estimations show a strong positive relationship between the extent of innovation of the firms and their R&D intensity and personnel qualifications, whereas the human resources training factor is not significant in this relationship. As for the methods that firms are using in a regular manner for seeking new ideas for innovation, it seems that the scientific or business journals retain a positive relationship in all estimations. Scanning external information and knowledge via scientific or business journals may thus prove to be beneficial for the firms. It could be argued that academic research may affect positively and indirectly innovative performance of firms through publications in journals that constitute a mechanism of knowledge diffusion.

Another robust conclusion from our estimations is the positive effect of strategic alliances in innovation. Participation in collaborations in general is indicative of an ability for interactive knowledge sharing that may prove very beneficial for further exploitation of knowledge and thus interfirm linkages seem to promote innovativeness.

Regarding competition and size, the estimations show that there is no significant effect to the level of innovativeness. However it should be mentioned that the number of competitors is not an accurate measure for the extent of competition. As far as size is concerned, it should be mentioned that the dataset does not include the very large firms by default and that more than 70% of the sample represents firms with less than 250 employees.

There is no sectoral effect in the examined relationship, indicating that the variables that we tested affect the innovative performance irrespective of the sector that the firms belong to. Food and chemicals sectors are likely to innovate less than the computer and related activities, which is used as a reference category. This is not surprising as the latter is more dynamic than the two more traditional sectors.

The same is true of country effect, as no changes occur in the significant variables and results remained robust.[11]

The most important point arising from our analysis relates to the parallel positive role of both internal R&D capabilities captured by the intensity of R&D efforts and the highly-qualified personnel (traditional notion of absorptive capacity) and the ability to interact and access external sources of knowledge (enhanced absorptive

[9] We have also estimated the proposed relationship for each sector separately in order to identify any important sectoral characteristics. We have obtained significant results only for the sector of radio, television and communication equipment and apparatus (NACE 32), as for the other 4 sectors the model doesn't fit the data well (*F*-statistic turns out insignificant even at the 10% probability level). In that specific sector the use of journals (JOUR) as a source for information and the training of the employees (TRAIN) influences positively the innovative performance.

[10] We have also estimated the proposed relationship for each country separately to further examine this issue. Unfortunately, results are unsatisfactory for 4 out of 7 countries. The model does not fit the data well for these 4 countries (*F*-statistic turns out insignificant even at the 10% probability level), whereas specifically for the UK we have not an adequate sample data (below 40 observations). Only for Germany, Greece and the Netherlands the results can be reliably interpreted. In the first two, R&D intensity is the only positively significant variable, whereas in the latter, the significant variable is participation in strategic alliances. Limitations in interpreting these results arise from the differences in the perception of innovation in each country and from the small samples used.

[11] If the opposite were true, then any effect of the country of origin might be explained by differences in contextual elements and what Abramovitz (1986) calls "social capability".

capacity) in raising innovative performance. This points to the necessity of the development of internal R&D capabilities and human skills in conjunction with networking capabilities and use of external sources of knowledge and information in order to produce high added value and innovation. Efforts for establishing interaction mechanisms and openness to knowledge sharing might not be seen as substituting internal efforts for creation of new value but complementing them. At the same time an inward looking approach to innovation according to which the firm relies on its own resources appears to be a conservative strategic option as in that case the firm misses the dynamic effects of interaction.

Actions improving the R&D potential and human resources' skills may result in an overall improvement of the innovative performance of European firms. The same goes for policy measures that aim at the promotion of interfirm linkages.

Evidence showed that we should expect policy at a European level to have more or less the same results regardless of the country. Actions promoting R&D cooperation may prove beneficial in improving the overall European innovative performance. Also, measures improving the R&D potential and human resources could result in positive effects for the development of new or improved products.[12]

Another comment of policy relevance is that as competition and size do not seem significant, one might not expect any particular trade-off between competition policy and technical progress.

Acknowledgements

This paper builds on empirical work carried out in the context of the project "KNOW FOR INNOVATION". We gratefully acknowledge the financial support of the European Commission under the TSER programme. An earlier version of the paper has been presented to the EAEPE Conference 2001 in Siena. We wish to thank all participants of the Conference and particularly Nicolai Foss and Thorbjorn Knudsen for their interesting comments. We also wish to thank Stavros Ioannidis for careful reading and comments on the final version.

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[12] However, although we should be very cautious in such conclusions because of the quality of the data, there is some evidence for differentiations at the national level. This might justify accordingly some distinction between European and national S&T policies.

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