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Not Searching, But Finding: Innovation As A Non-Linear Source Of The Private Use Of Public Knowledge

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Abstract

The use of universities and public research organisations as a source of information is increasing as firms adopt search strategies based on current models of information use. The theory of this paper is that in order to predict companies' perceptions of the usefulness of such knowledge, their practical experience in technological innovation becomes a determinant, not directly but by enabling certain internal changes which result in firms finding public research more useful. Using a sample of 1,031 Spanish manufacturing firms, we give an illustration of how practical experience in

technological innovation produces encounters between three of their choices (to increase in size, the skills of the workforce and the abandonment of strategic innovation) and public research. In reality, the lack of such practical experience produces a "disencounter" in which only monopolistic firms can take full advantage of public research. Some managerial and policy implications are discussed below.

1 Introduction

Information is a crucial ingredient of entrepreneurial discovery (Fiet and Patel 2008). Firms with good access to information are better placed to innovate and even to adopt new technology appropriate for them (Hall 2005); conversely, information constraints may be the main barrier to the adoption of innovations. Scientific and technological information can increase the efficiency of applied R&D in industry (Mowery and Sampat 2005), contribute to reducing the risks of mistaken entrepreneurial decisions (Yeoh 2000), and improve corporate competitiveness.

Enterprises obtain the information they need to improve their innovation-related activities from a variety of internal and external sources, such as their own R&D departments, clients, competitors or universities. Universities and government laboratories play a decisive role in national and regional systems of innovation (Mowery and Sampat 2005). They are especially important sources of information for high-tech industries and radical innovators (Amara and Landry 2005). Cohen et al. (2002) found that public R&D has an important and positive influence on industrial R&D across most of the US manufacturing sector. It is therefore important to understand what factors shape company perceptions of the usefulness of information provided by universities and public research organisations (U-PROs hereafter).

Our research objectives are twofold. Firstly, we expand previous research on the importance on public knowledge to firms, which has been almost exclusively focused on innovators. Secondly, we inquire as to whether non-innovators also value public knowledge, and we investigate antecedents associated to their perceptions of this specific source of information.

The second objective is particularly important, because most previous analyses of the usefulness of innovation-related information, and more specifically of knowledge provided by U-PROs (hereafter, public knowledge), focus exclusively on innovators or single out *radical* innovators for analysis (see examples in the Appendix). In some countries, such as Canada or Finland, the vast majority of manufacturing firms are innovative (since they have launched new products onto the market or implemented new industrial processes). Logically enough, authors who analyse companies located there find such a definition of innovative firms too broad. They prefer to focus, when studying innovation-related information, on companies which have launched products new to the market or even world premieres (see, for instance, Amara and Landry 2005; Varis and Littunen 2010).

We provide a complementary view of the question, arguing that it is profitable to differentiate the factors associated with the perception of public knowledge in companies which have practical experience of product or process innovation (i.e. innovators) and companies which have not (i.e. non-innovators). This exercise is especially overdue in analyses of countries or industries where non-innovators account for the vast majority of companies.

Firms which have not yet launched new products onto the market or have not yet implemented new processes may, nevertheless, perform certain innovation-related activities. These include the introduction of advanced manufacturing technology, the development of own machinery and software or prototype testing. Such companies may acknowledge the sourcing of public knowledge to be useful in improving their activities.

There are good reasons to study whether companies who are not yet innovators value public knowledge with regard to their innovation-related activities. In most developing countries, emerging markets and transition countries, a substantial share of companies are not innovative, according to the narrow definition of innovators above (see, for instance, Quadros *et al.*. 2001). Moreover, the proportion of non-innovators is quite large even in some developed countries: 61.2% of European Union (EU-27) manufacturing firms were not innovative in 2006; and the share of non-innovators was higher than the EU-27 average in the manufacturing industries of 18 member countries, including Italy, Spain, the UK and most of the new member states of the 2004 enlargement (EUROSTAT, 2010).

The percentage of non-innovators is even higher in EU low-tech industries, such as food and drinks (Christensen *et al.*. 1996). In many countries, industrial policies have been directed at strengthening the relationship between universities and business (Tether and Swann 2003), and it is therefore important to understand whether all company firm types perceive the information provided by U-PROs as useful and to establish which factors influence their perceptions.

The rest of the paper is organised as follows. Section 2 presents a review of the literature and the hypotheses: the resource based view of the firm and the exponential theory of learning are used to argue that innovators and non-innovators may have different perceptions of the value of such knowledge, making it interesting to analyse the two groups separately. Section 3 indicates the research context, namely Spain. International comparisons of the recent technological development of nations characterize Spain as a catch-up country (Fagerberg and Godinho 2006). At the same time, Spain has substantial public participation in the National Innovation System, and its case is therefore interesting to study. Section 4 presents the data: the hypotheses presented are tested, using a database representative of Spain's medium-sized and large manufacturing companies and containing information on 1,031 firms with over 50 employees. Section 5 and Section 6 present, respectively, the descriptive results and the econometric analysis. Section 7 discusses the results and Section 8 offers some conclusions, including a discussion of possible implications of the research performed for public policies.

2 Theoretical background and research hypotheses

2.1 Information and perceptions of usefulness

Fiet and Patel (2008 , p. 216) define information as "a collection of facts from which a conclusion may be drawn". U-PROs can provide information to industry through conferences, public meetings, informal interactions with companies, consulting, publications, patents, etc. (Arvanitis *et al.*. 2008; Cohen *et al.*. 2002).

Following Agarwal and Prasad (1998), the perceived usefulness of information is defined here as company assessment of the extent to which a source of information may contribute to improving its innovation-related activities. In line with the managerial literature (Agarwal and Prasad 1998), the present study considers that ease of use and

compatibility of information are important properties for understanding the perceived usefulness of information.

Ease of use is determined by the degree to which decision-makers view usage of the information to be relatively free of effort. Compatibility refers to the degree to which the information is perceived as being consistent with the needs and past experience of the firm; compatibility is related to the cognitive costs of using a specific source of information (Cohen and Levinthal 1989). Agarwall and Prasada (1998) consider that innovators have a propensity to risk taking and may, therefore, develop stronger intentions to use innovation-related information in the future.

Two strands of research stand out in the literature on information sources used by firms for their innovative activities. The first group analyses company information sources to predict innovation at enterprise level, which is the dependent variable in the following authors' models (see, for instance, Amara and Landry 2005; Mention 2010; Varis and Littunen 2010). Although these studies have provided important results for understanding corporate information acquisition, in our opinion they suffer from two methodological problems.

Firstly, they tacitly assume that company responses regarding the usefulness of information can approximate the objective influence of different sources of information. Our approach is less ambitious, although arguably more realistic. It assumes that firms' responses indicate the perceived usefulness of information for the innovative activities of the company. In our opinion, these responses provide indications only of how companies value the usefulness of the information gathered from U-PROs for improving their own innovation-related activities.

A second problem concerns the time elapsed since a specific information source presumably came into use. As various authors recognise, the "continuity" and "longevity" of use of information are not revealed by this sort of data (Varis and Littunen 2010). By contrast, the approximation here is limited to perceptions held at the time of data collection.

To summarise, this approach to the data is more conservative. However, the importance of perceptual factors is well established in the literature on organisations. The strategy process begins with company awareness of the resources at its disposal, including external sources of information. In addition, perceptions play a pivotal role in

technology models (Agarwal and Prasad 1998), which explains the interest of our analysis.

Like the surveys used in this strand of research, the data here (see below) do not necessarily reflect the objective importance of information for innovative activities, which is very difficult to measure. There is, however, a striking difference between the interpretation offered here of the data and that of other work in this research field.

The second group of studies investigates factors which influence company perception of information obtained from U-PROs, and examines which firm types are more likely to use this source of information (see, for instance, Laursen and Salter 2004; Swann 2002). The present article attempts to contribute to this second strand of literature.

Firstly, we identify some factors the literature associates to the perceived usefulness of public knowledge on the part of companies, and formulate some hypotheses. We distinguish between hypotheses that have been already tested and completely new hypotheses. Next, we build a hypothesis to test for differences between innovators and non- innovators in this respect.

2.2 A review of current models of the private use of information from U-PROs

Analysing 2,655 British manufacturing firms, Laursen and Salter (2004) find that firms which used many sources of information, such as clients, suppliers and their own R&D departments etc., were also more likely to use university research more intensively (size, R&D and other variables controlled). They conclude that the "openness" of a firm's innovation search, namely the number of external knowledge sources it draws upon, is strongly associated to the use of knowledge produced by universities.

We therefore formulate the following hypothesis:

Hypothesis 1 Companies which draw on numerous external sources of knowledge are more likely to perceive U-PROs as important sources of information.

In order to absorb external knowledge, companies need to develop their own innovative capabilities (Cohen and Levinthal 1989). Moreover, the staff of companies which perform formal R&D are more likely to possess the necessary educational background to communicate with the research world (Hansen (1995)(Cuervo and Un, 2010). In fact,

Laursen and Salter (2004) find that R&D intensity is strongly associated to a firm's appreciation of information provided by universities. Using pooled CIS (Community Innovation Survey) data for French, German, Irish and Spanish firms in manufacturing and services, Mohnen and Hoareau (2002) find R&D intensity is associated with knowledge sourcing from U-PROs (size, government support and other variables controlled for). We therefore formulate the following hypothesis:

Hypothesis 2 Companies which perform R&D are more likely to perceive U-PROs as important sources of information.

Company size indicates the dimensions of its financial and human resources. Small firms may lack resources for information scanning. They may be more likely, therefore, to use personal sources of information such as family, friends or close business associates, since such sources are less costly and time-consuming. As a result, however, they may fail to perceive clearly the usefulness of U-PRO information.

Using a database of British companies, Laursen and Salter (2004) find that the larger the firm, the greater the possibility that it appreciates knowledge produced by universities. Similarly, in a sample of US firms, Cohen et al. (2002) find that the influence of public R&D on industrial R&D is disproportionally greater in larger firms. In Mohnen and Hoareau's (2002) abovementioned European sample, large firms are also more likely to value knowledge obtained from U-PROs. This is also the case of the Aragon region (Spain), where large firms are more likely to form relations with universities, irrespectively of the type of channel used (Martinez-Sanchez and Pastor-Tejedor, 1995). We test, therefore, the following hypothesis:

Hypothesis 3 Large firms are more likely to perceive U-PROs as important sources of information.

2.3 Expanding the models of company perceptions of the usefulness of information obtained from U-PROs

A study of French agribusiness finds that firms with no formal R&D activities may nevertheless benefit from public research (Mangematin and Mandran 2000). In a similar vein, a national survey of Brazil shows that a substantial share of non-R&D performers consider universities to be important sources of information (Rapini *et al.*. 2009). A

possible reason for such results is that firms may develop some absorptive capacity beyond the R&D department; for instance, at the shop floor level.

However, the possible association between innovation expenditure other than on R&D (e.g. training) and knowledge sourcing has rarely been tested. In fact, Mohnen and Hoareau (2002) find that firms which make such investments are not necessarily inclined to tap into knowledge produced by U-PROs. By contrast, Beneito (2002) analyses Spanish manufacturers, taking into account the skills composition of the workforce among the sources of knowledge available to the firm.

In our view, when the average manual worker performs technical complex tasks the company's human capital is likely to be highly specialised and internal learning processes are probably in place. We argue that, within the company, the skills of the workforce, as measured by the technical complexity of their tasks, may help us to measure (in addition to R&D) the absorptive capacity of a firm. Therefore, we formulate the following hypothesis:

Hypothesis 4 Companies where the workforce is highly skilled are more likely to perceive U-PROs as important sources of information.

In their theoretical model, Dosi et al. (1992, p.194) conjecture that firms which attempt to enter new markets with new technologies can be unsuccessful "because the effort is likely to be outside the firm's learning range". This suggests that, most likely due to scarce managerial resources, enterprises may have more chances to launch innovative products if they do not attempt the simultaneous implementation of strategic innovation, such as entry into a new geographic market.

Regarding specific product families, production methods, supply chains, customers and distribution channels, innovating routines have always faced the need to match corporate technology to specific organisational practices. However, strategic innovation is risky, as it may involve difficulties in recognising and responding to new customers' demands, distribution channels, production methods and supply chains (Pavitt, 2002). In our view, decision-makers may feel that a firm is unable to simultaneously undertake strategic change and fruitfully absorb complex technological information; given such circumstances, the information provided by U-PROs could be seen as less useful.

In addition, changes in strategic orientation tend to be more reactive than proactive: they respond to corporate need to adapt to adverse or unforeseen situations, generating turbulence within the company and thereby affecting the search for external knowledge sources. This may be the case, in particular, for knowledge provided by U-PROs, which is far more expendable than information originating in the productive chain, crucial for the day-to-day survival of the company. We test the following hypothesis:

Hypothesis 5 The greater the company reliance on strategic innovation, the less likely it is that they perceive U-PROs as important sources of information.

Turbulent environments, such as those which involve the entry of new competitors in the market, may increase company perception of risks and threats. In addition, in competitive markets, products are likely to become obsolete quickly (Amara and Landry 2005). In short, environmental complexity is likely to be higher when firms operate in markets with many competitors. In these circumstances, information search is likely to increase. However, there are few research results regarding the information sources which firms will use in such circumstances, and these are not conclusive (Elenkov 1997; McGee and Sawyerr 2003).

On the other hand, Schumpeterian economics of technological change predict that market power has a positive effect on innovation (Cohen, 1995). Excessive rivalry, it is argued, may generate unpredictability and, as a result, dissuade potential innovators. By contrast, the possession of "ex ante" market power may provide companies with the financial resources to invest in R&D. Most empirical studies which examine the relationship between market concentration and R&D have actually found a positive relationship (Cohen 1995). In a sample of Spanish firms, Beneito (2002) finds that high levels of innovation activities are associated with high levels of market concentration (innovation results, size, workers' skills and other variables are also checked). More specifically, the theoretical model constructed by Levinthal and March (1981) suggests that company propensity to engage in information search depends on the level of environmental uncertainty.

Therefore, we formulate the following hypothesis:

Hypothesis 6 Firms which operate in highly competitive markets are less likely to perceive U-PROs as important sources of information.

One of the reasons why companies launch R&D alliances is that information sharing with partners may generate spillovers of knowledge (Barajas and Huergo 2010). More specifically, firms which collaborate with public research organisations often aim to learn from public research in order to generate highly innovative products and processes (Busom and Fernández-Ribas 2008). Collaboration performance increases with past collaboration experience (Núñez-Sánchez et al. 2010). Organisational learning capability, which includes interaction with the external environment (notably universities), improves innovation performance (Alegre and Chiva, 2008). Cohen et al. (2002), analysing a sample of US companies, find that firms who have cooperated with universities and government laboratories are more likely to use public research. They conclude that joint ventures and cooperation between universities and industry may stimulate the use of academic research by industry.

For a sample of innovative Belgian firms, Cassiman and Veugelers (2002) find that cooperation with research institutes, such as universities and public or private research labs, increases the chances of a firm benefiting from incoming spillovers (size of the firm, R&D and other variables controlled for). They consider that cooperation increases opportunities for information sharing between partners. Using a Spanish sample, López (2008) finds that the likelihood of an enterprise benefiting from incoming spillovers increases when it cooperates with a PRO, but not necessarily when it cooperates with other types of partners. Here, we test the following hypothesis:

Hypothesis 7 Companies which have cooperated with U-PROS are more likely to perceive them as important sources of information.

2.4 Differences between innovators and non-innovators regarding the perceived usefulness of public information

Thus far, we have reviewed the literature most closely related to our research and constructed some verifiable hypotheses concerning the degree to which firms value public knowledge. However, one of the few articles which distinguishes the perceptions of different types of firms finds that innovators and non-innovators tend to value different sources of information (Varis and Littunen 2010).

Here, we argue that factors associated to the perception of public knowledge are not necessarily the same for innovators and non innovators. To justify such an assumption, we combine two strands of thought: the resource based view (RBV) of the firm and the theory of experiential learning, which is used in management literature. The RBV sees the firm as a bundle of resources, competencies and capabilities (Foss 1998; Teece and Pisano 1994). Learning by doing and learning by interacting with customers are two important sources of knowledge, which require the commitment of time and resources on the part of the firm (Malerba 1992).

Von Tunzelmann (2009) distinguishes between competencies and capabilities of the firm. In his view, while competencies are related to inputs, capabilities are related to outputs. For instance, he argues, competencies are related to human and R&D capital, while capabilities are related to "know-how accumulated through actual experience directly in the production of outputs" (p. 448). He views both capabilities and competencies as linked to people (not to the acquisition of equipment); consequently, learning processes are important in his theory.

In the learning realm, he says, competencies are characterised by learning by searching, while capabilities are defined by learning by doing. Therefore, we deduce that innovators will have more opportunities to learn and to accumulate know-how than companies which regularly produce year after year the same unmodified products, have not introduced new processes or have failed in the attempt; in other words, innovators might possess additional capabilities.

According to von Tunzelmann (2009, p.453), "competencies and capabilities are essential albeit in their different ways". Capabilities, he argues may "'feed back' into more and deeper needs for strengthening or extending the range of competencies, but this involves complex learning procedures (e.g. 'learning to learn')". We argue that capabilities, such as those acquired by innovators through learning by doing and consumer feedback, might influence the search strategies of companies and their perception of the usefulness of information.

Levinthal and March's (1981) theoretical model suggests that organisations are likely to modify their search strategies related to innovation on the basis of experience. Moreover, according to the experiential theory of learning, based on Dewey, Lewin and Piaget, ideas are formed and re-formed through experience (Kolb 1984). Emphasizing the importance of feedback, this theory proposes that experience provides people and

organisations with unique opportunities to practice and to make errors. Therefore, knowledge is created through the transformation of here-and-now concrete experience. Goal-directed learning is important to support the efficient gathering of information, since organisations may be clogged by data (Kolb 1984). This explains the importance of the feedback received by innovators.

The experiential theory of learning has antecedents and similarities in managerial literature. For instance, according to Simon's (1957) theory of "bounded rationality" individuals and firms face constraints such as the amount of information they can acquire and process. In this context, a successful search strategy may depend, among other things, on the skills and the experience that the firm already possesses (Nelson 1982).

Knowledge is frequently generated only by "actual experience with a new technology and its operating environment" (Rosenberg 1992, p.82-83). Since academic knowledge is particularly complex, as shown by patent analysis (Czarnizki *et al.* 2011), we argue that goal-oriented search may be especially necessary when a company attempts to profit from information provided by U-PROS.

As stated above, the idea that experience may influence information search has also been developed by the managerial literature. Knowledgeable consumers (as defined by their actual experience with concrete products) search more efficiently for information and are more likely to use complex (rather than simple) information on products (Brucks 1985). A number of studies show that consumer experience with a product class facilitates the acquisition of new pre-purchase information (Brucks 1985). This last author concludes that the specific "usage situations" of buyers, that is to say their experience as users of the product, should be taken into consideration to study consumer searches for product information. Equally, we claim, it may be useful to analyse separately factors affecting the respective perceptions of innovators and non-innovators of information provided by U-PROs.

Hypothesis 8 Factors associated with the perception of information provided by U-PROS will differ between innovators and non-innovators.

As already stated, previous research has seldom analysed whether non-innovators find the knowledge produced by U-PROs useful (the Appendix offers a synthesis of some selected studies). Given the lack of stylized facts in this field, our analysis of non-

innovators' search behaviour is, therefore, necessarily of an exploratory nature. We do not test formal hypotheses regarding specific factors associated to the perception of knowledge provided by U-PROs by such companies, but we will offer some preliminary explanations.

3 Research context: R&D, universities and the manufacturing industry in Spain

According to EUROSTAT (data from 13/10/2010), Spain's gross expenditure on R&D (GERD) represented 1.35% of gross domestic product in 2008. Total full-time equivalent R&D personnel accounted for 0.94% of the active population. To put these figures in perspective, the estimates of these indicators in the EU-27 for 2008 were 1.9% and 1.03%, and thus i.e. the values are significantly lower in Spain.

The same source shows that the central government *financed* 44% of the Spanish GERD in 2007, compared to an estimated 33% in the EU-27 and only 28% in the USA. In Spain, industry, higher education and government performed, respectively, 54%, 27% and 18% of GERD in 2008. On average, higher education and government accounted for smaller shares in the EU-27 (63%, 23% and 13%) and the USA (73%, 13% and 11%). This does not imply that industrial interest in public R&D is low: business funding of university R&D was 9% in Spain *versus* 6% in the EU-27 and USA. Funding pressure and other societal changes have motivated many research centres to make excellence and technology transfer compatible (Cruz-Castro et al. 2010). By contrast, the capacity of the corporate sector to innovate, as measured by R&D expenditure, R&D employees and number of patents appears to be quite weak (Busom 2004).

Conversely, Fagerberg and Godinho (2006) mention Spain among a number of catch-up European economies, owing to its impressive increase in higher education enrolment and the emphasis placed on natural sciences and engineering. To summarise, Spain is an interesting case study since U-PROs would appear to have the potential to positively influence industrial R&D; at the same time, the share of non-innovative firms is still quite high.

With an added value of 118 billion euros in 2004, Spain's manufacturing industry ranked fifth in the EU-27, after Germany, the United Kingdom, France and Italy (European-Commission 2008).

4 Data

The data employed in the following analysis were obtained from a plant-level survey, targeting firms in the Spanish manufacturing industry and conducted in 2003. All the companies, 1,031 in total, had 50 or more employees. In order to establish the dimension of the population of plants in terms of sector, region and size, we used the information provided by the Central Directory of Companies (DIRCE), available from the National Statistics Institute.

To select the sample, the regional and sectoral distribution of plants indicated by DIRCE was taken into account. Sectors were defined according to the National Classification of Economic Activities (CNAE), which follows the standards of the European NACE rev1. We selected companies for analysis from the Dun & Bradstreet Spain list. Given their size, sector and geographic location, the sampled firms are statistically representative of firms with over 50 employees in Spanish manufacturing industry. At a confidence level of 95.5%, the sampling error is ± 2.8%. At the company level, in most cases we interviewed Directors of Production, each personal interview lasting approximately one hour. The survey does not suffer from significant item non-response.

Companies were asked to report how useful 16 different sources of information were in improving their innovation-related activities. These activities include product and process innovation, basic research, technical design, product design, imitation, development activities, adaptation of products to local conditions, testing of prototypes, reverse engineering, etc. We do not attempt to measure the extent to which information has been objectively useful to improve the innovative activities of the firm. As stated earlier (see Section 2.1), we consider that the data correctly approximate the perceived usefulness of information for the innovation-related activities of the firm at the time of data collection.

To split the sample, we use the variable "Innovation", which distinguishes between technological innovators and non-innovators. Innovators are defined in this context as firms which introduced at least one product or process innovation in 2000-2002 (the three year-period before the year of the survey). This is a similar approach to that adopted, for instance, by Thether and Swann (2003) who consider "innovation active" firms as those which engaged in innovation in a similar period of time.

The dummy variable indicates that 82 per cent of the firms (somewhat over 800) have introduced a product or process innovation. The remaining 18 percent are non-innovators (less than 200). These percentages are similar to those obtained from PITEC, the Spanish equivalent of the Community Innovation Survey (CIS) survey (Vega-Jurado 2010).

Non-innovators, as stated in the introduction, can nevertheless undertake some innovative activities. For instance, in our sample, 14 per cent of these non-innovators manufacture unique products (per project), and 31 per cent fabricate small lots of a wide variety of product (jobs-shop), adapting products to consumers' tastes and needs.

The introduction of advanced manufacturing technology is also frequent; for example, 41 per cent of non-innovators use computer assisted design (CAD) or engineering (CAE); 26 per cent employ computer assisted manufacturing (CAD/CAM); 20 percent use pick & place robots; 10 per cent use lasers for treating materials, etc. Moreover, 24 per cent of the non-innovators frequently develop their own machinery and equipment and 30 per cent their own software and computer programmes. 24 per cent acquire new equipment, unrelated to new products or processes.

These figures reflect technological innovation. Some of these firms also conduct non-technological innovation. For instance, 35 percent of non-innovators frequently put new management techniques into practice. Finally, in almost all of them (91 percent), there is a person in charge of quality control. It is likely, therefore that these firms find U-PROs a useful information source.

5 Descriptive results

As shown by Table 1, which lists the perceived importance of sources of information on a 1-10 Likert scale, customers are viewed as the most important source of information for the innovative firms sampled. After customers, the four most important sources reported by respondents are all internal to the firm or the group, followed by trade associations. Among internal sources, Production Departments rank first, while R&D Departments rank last (we shall return to this question below).

(Table 1 around here)

U-PROs were mentioned among the least important sources of information, below other sources such as consultants, industrial publications, etc. However, the vast majority of the sampled firms considered that knowledge drawn from U-PROs had at least some utility. The substantial importance which innovative firms assign to their own manufacturing operations as a source of information is also apparent in studies of the US and Brazil (Cohen *et al.*. 2002; Rapini *et al.* 2009). Studies of Canada, Luxembourg and the UK suggest that internal and intra-group sources of information are those most highly valued by firms (Amara and Landry 2005; Laursen and Salter 2004; Mention 2010). By contrast, the sampled firms tended to mention customers first; 42% of them reported that these were their most important source of information (Table 1). Cohen et al. (2002) also find, analysing US firms, that customers were considered to be the predominant source of ideas, followed by internal information, but only for the initiation of new projects.

Differences from other studies concerning the relative importance assigned to customers as sources of information may be due to the deeper breakdown of our data, which distinguishes several internal sources, whereas the typical CIS-type survey does not; or, more substantially, to the higher scientific and technological intensity of the other developed countries compared to Spain. In such countries, specialised in high-tech sectors, a supply-push model may be more successful, whereas in Spain, specialised in traditional sectors, a demand-pull model makes more sense for firms.

As noted by Dosi (1988a, p.71), the heuristics involved in the search process are specific to each technology; for instance, in sectors such as textiles, clothing, leather and shoemaking, he argues that search skills are the capabilities of understanding trends in

tastes and fashion. Logically enough, in such industries customers are more likely to be viewed as crucial sources of information. On the other hand, firms strongly appreciate both information sources (internal sources and customers) in all the above mentioned countries (see Appendix). Other similarities between Spain, on the one hand, and Canada, the UK, Finland and Brazil on the other are the importance companies assign to trade fairs and trade associations (this source of information is not taken into account in the study on US firms).

In the UK, the US and Canada the number of firms which declare that they profit from universities in their innovative activities is, however, small and well below the scores for "market-related" sources (Amara and Landry 2005; Cohen *et al.*. 2002; Laursen and Salter 2004). Although the innovative firms sampled rank U-PROs[1] among the least important sources of information, the vast majority of them (77% of firms) consider that the information U-PROs provide has at least some utility for them.

Precise percentages in the lower tier differ considerably from other studies since, in other countries, the share of firms which report that they profit from information provided by U-PROs seems to be lower (see the Appendix for some comparisons). The high percentage of innovative firms in our sample which declare that they draw useful information from universities may be attributable to several factors, for instance the refinement of our variable which is measured on a 1-10 Likert scale.

However, our results are in line with a study of the European food industry (Christensen et al., 1996). What is more, previous research acknowledges differences across countries with regard to the importance attributed by firms to U-PROs as information sources. An empirical study suggests, for instance, that British industry may be less interested than US industry in university technology (Decter *et al.*. 2007). Brazilian firms rate universities as sources of information more highly than US firms do; Rapini et al (Rapini *et al.*. 2009) suggest that this may be due to the R&D weaknesses of industry in immature systems of innovation.

This may be also the case in Spain, since the direct engagement of firms in corporate R&D is weak (see Section 3). Another possible reason for the high percentage of sampled innovative firms which benefit from public knowledge may be related to its

[1] As in some previous studies (see Annex 1), our data also include non-university public research organisations. These institutions accounted for 18% of total expenditure on R&D in 2008 while universities provided 27%.

specific content. As Section 3 shows, company involvement in the financing of R&D performed by U-PROs is relatively high; this may enable firms to model to a certain degree the content and, consequently, the tangible usefulness of part of the knowledge produced by U-PROs.

In accordance with this peculiarity of corporate funding, partial evidence suggests that Spanish public researchers focus strongly on applied research, compared with their Swiss or Italian colleagues. Spanish researchers in various fields of engineering, telematics and electronics feel their research is directed at a business rather than a scholarly audience (Gómez *et al.*. 2009). These are probably reasons for the vast majority of the sample firms assigning at least some importance to U-PRO information.

Table 2 replicates Table 1 for the sample of non-innovators. These companies tend to assign less value to all sources of information than innovators do. However, the rankings do not vary much. The top three categories are the same for both groups. So are the bottom five, with some small changes of order. There is some variation in the central categories, the highest one corresponding to the perceived value of "Own R&D Department", which ranks 5 for innovators and 11 for non-innovators. The reason is probably because many non-innovators do not have an R&D department. This is relevant to the econometric estimation performed in the next section.

(Table 2 around here)

6 Econometric analysis

6.1 Dependent variable

The dependent variable is the degree of importance of U-PROs as information sources for innovation: 0 if none, 4 if maximum. The original variable has been recoded, as required for econometric treatment, as follows: first, a contingency analysis was performed to avoid thin cells (with values lower than 2 in the cross tabulation against the qualitative independent variables); second, close examination was made of the predictions of the econometric estimations, to avoid naïve models (which only predict

zeros for certain values of the dependent variable). A discrete choice model is applied to take into account the fact that the data are ordered (i.e. ordered logit[2]).

Table 3 shows descriptive statistics for each group of companies, and a t-test confirms that innovators perceive knowledge sourcing from U-PROs as more useful than innovators in improving their innovation-related activities. The evidence clearly shows that non-innovators also find that information provided by PROs is useful for them, although to a lesser extent than innovators. While non-innovators have not achieved product or process innovations, they may perceive such sources as useful to perform other innovation-related activities.

(Table 3 around here)

6.2 Independent variables

Among the independent variables, dummy and ordered variables have also been recoded, as necessary following a contingency analysis. As Table 3 shows, and given that previous research points to openness as an essential ingredient in corporate perception of public knowledge (see, for instance (Laursen and Salter 2004), it is notable that, in our sample, innovators value a larger pool of information sources than non- innovators.

This finding is in line with studies that suggest that prior experience may encourage information search by facilitating the processing of information by consumers or companies (Brucks 1985; Swann 2002). In our sample, innovators' experience may have contributed to reducing the perceived costs of using information, notably science-based information. Our result also provides some support for the idea that innovative and non-innovative firms tend to value different sources of information (Varis and Littunen 2010). To summarize, innovators display higher levels of openness, R&D activities, size, skills and strategic innovation. The degree of market competition is nevertheless similar in the two groups of firms. It is notable that the variable "cooperation" is always zero for non-innovators, and thus it is only defined for innovators.

[2] For the sake of robustness, we checked the results with ordered probit models and they were identical.

The correlation between variables for each group of companies is low (coefficients never higher than 0.25), so there is little relation between independent variables (correlation matrixes available upon request).

We use thirteen industry dummies as control variables. For reasons of space, we do not give breakdowns of the values of the dependent variable by industry here, but the tables are available upon request. Among the findings, we should like to highlight that the companies which assign most importance to knowledge from U-PROs are those which operate in chemical and basic metals, pharmaceuticals, and machinery and equipment. This ranking is quite similar to previous research in the UK and US.

6.3 Econometric results

Table 4, column 1, displays a typical model of the private use of information from U-PROs by innovative firms, as well as evidence in favour of Hypotheses 1 and 3. Openness and firm size are also valid variables in Spain: both have a positive influence on the value firms assign to U-PROs as information sources.

(Table 4 around here)

The evidence is contrary to Hypothesis 2. R&D is not significant in innovators. This result may be due to a combination of statistical and substantive reasons. The statistical reason is that many innovators perform R&D activities (54% of all the observations), so the two categories overlap somewhat. However, this does not explain everything, because the correlation between the two variables is low (28%) and the proportion of less intuitive cases (innovators without R&D or non-innovators with R&D) is considerable (34%). Substantive reasons for such differences between the two types of firms are analysed in the Discussion.

Table 4, column 2, extends the model with other variables. The evidence supports Hypotheses 1 and 3, but not Hypothesis 2.

There is some evidence in favour of Hypothesis 4: the importance given to human capital, as a source of absorptive capacity, increases the value firms assign to knowledge obtained from U-PROs. It is noteworthy that, according to the correlation matrix (not shown – available on request), companies which perform most R&D are not necessarily those with more qualified personnel. Consequently, the relation between the

variable "skills" and the dependent variable is not due to "skills" being associated to the variable "R&D activities".

The evidence also supports Hypothesis 5: the implementation of strategic innovation has a negative effect on company perceptions of the usefulness of knowledge from U-PROs.

Competition is not significant, so Hypothesis 6 has no support.

Collaboration with U-PROs appears to be associated to the perceived usefulness of information provided by these sources. This means support for Hypothesis 7.

We move on now to the comparison with non-innovators. Before continuing with the econometric analysis a little digression is in order. The linear model assumes that scientific knowledge produced in year 1 leads in a linear progression to technological innovation in year 1+n. As observed by Fagerberg (2005), this assumes that innovation is actually applied science. As he notes, this model has been criticised because it does not take into account possible interactions between different stages (research, development, production and marketing of a new product), feedback processes and loops. Here, we take into account one such loop. Distinguishing between innovators and non-innovators may help us to understand better whether practical experience of innovation contributes to shaping companies' current perceptions of information usefulness.

We have established so far that non-innovators are also likely to value information provided by U-PROs, though to a lesser extent than innovators. Table 4, column 3, is a test of whether the perception of the usefulness of U-PROs is shaped by different factors for innovators and non-innovators. For both types of firms, openness exerts a positive effect. Also, R&D is barely significant in non-innovators. If it is tangentially (10%) significant, it may be due to the absence of an in-house R&D department in non-innovators (see descriptive results in Section 5), because the presence of such a department makes a difference, even if small.

The remaining results support Hypothesis 8 (innovators' and non-innovators' perceptions are shaped by different factors). On the one hand, size, skills and strategic innovation matter only for innovators, and do not have a significant effect on non-innovators. For innovators, internal skills are complementary to the search strategy of the company concerning public knowledge, whereas placing excessive emphasis on

strategic innovation is negatively associated with the value the firm assigns to information. On the other hand, competition has a negative, significant effect on non-innovators, absent in the case of innovators.

To summarise, both innovators and non-innovators declaring that they profit from U-PROs information display a high degree of openness of search. At the same time, innovators and non-innovators tend to differ in other important ways.

7 Discussion

In Spanish manufacturing industry, firms which declare that they profit from public knowledge exhibit the following features: large firms with open search strategies, a highly skilled workforce, formal R&D activities and previous collaboration with U-PROs, whatever the type of market in which these companies operate.

Firms which value public knowledge highly appear to have discarded simultaneous strategic change. This is also true even if the focus is on innovators only, except for a less distinctive effect of R&D, which is discussed below. Non-innovators also declare that they profit from public knowledge, although they come to value it in more restrictive circumstances than innovators. This result suggests that companies may be reticent about the usefulness of science-based information, to some extent, because of their own inexperience as active innovators; this is in line with the analysis of British companies by Swann (2002).

Openness is the only common feature which is associated, in both innovative and non-innovative firms, to a positive perception of the usefulness of information generated by U-PROs. In other words, firms which declare that they profit from U-PRO information to develop their own innovation-related activities deploy a substantial heterogeneous interface and appear ready to pool information from a variety of sources.

Among innovators, resources (as measured by size) and some of the internal competencies of companies (as measured by skills) positively influence company perception of the usefulness of new knowledge generated by U-PROs. As stated above, it is not often we find such an association between external knowledge and internal capabilities or resources in non-innovators. As argued in Section 2, the ease of use and

the compatibility of new knowledge with the previous experience of a company are important antecedents of perceptions. Science-based information might be more easily used in companies which have sufficient resources and a well-trained workforce.

Another possible reason for this matching in innovators (and not in non-innovators) might be their focused information search. Innovative search is highly uncertain, especially in the exploratory stages (Dosi 1988b) but practical experience of innovation might help firms to reduce uncertainty, by pointing to clear search directions. This circumstance, particularly important in the case of science-based knowledge, may predispose innovators to rank highly the information provided by U-PROs.

It is arguable that innovators could search for information related to different technical problems than those previously encountered when launching a new product onto the market or implementing a new industrial process. Nevertheless, innovation is largely an accumulative process. As suggested by Dosi et al. (1992, p.185), "there is some coherence in the ways firms diversify; and this coherence is relatively stable over time". Moreover, empirical studies support the theory of corporate coherence. For instance, a study of post-innovation performance in the UK found that, after innovation, two thirds of the sampled companies researched products similar to their previous products (Georghiou *et al.*. 1986). Knowledge is frequently generated only by "actual experience with a new technology and its operating environment" (Rosenberg 1992, p.83).

It is interesting to note that, in our sample, practical experience of innovation is a factor more likely to produce differences between firms' perceptions than performance or otherwise of formal R&D. One reason which may explain the lack of statistical significance of R&D in our sample is the content of university information. As already stated, this is probably more practical in Spain than in scientifically stronger countries. As Busom and Fernández-Ribas (2008) note, a large proportion of Spanish firms focus on technology adoption rather than on technology creation. In our view, while firms are likely to generate new technology in formal R&D departments, adoption processes may well be performed at the shop-floor level. This might indicate that the absorptive capacity of the Spanish manufacturing firm is better defined by a skilled workforce than by the presence of a formal R&D department at the industrial plant.

Other possible explanations are as follows. The value of 10% for R&D activities for non-innovators admits the interpretation that the stronger significance of this variable

for the aggregated sample (Table 1) lies in the impact it has more specifically for non-innovators. By contrast, the impact of R&D is not significant when practical experience in innovation is considered. This difference between innovators and non-innovators is counterintuitive, because R&D is often seen as a complement to external knowledge. Nevertheless, innovative firms which moreover have their own R&D department may be more likely to establish their own internal routines, and this practice may make them more reluctant to source and value external knowledge (Fagerberg, 2005). Our results concerning innovators are actually in line with Vega-Jurado et al. (2009). They analyse a sample of Spanish companies but find no support for the thesis complementing internal knowledge (as measured by R&D) and external scientific knowledge; they explain innovators' behaviour on the grounds of the "not invented here " syndrome.

More closely related to the arguments concerning learning which we have developed in this article, the theoretical model developed by Levinthal and March (1981, p.323) shows that fast learners (as defined by previous performance and experience) "may fairly easily learn to reduce expenditures on search to a low level". They characterize R&D as the resources firms allocate to search. Our results suggest that innovators, owing to their previous experience, might need to allocate fewer resources to search in order to profit from U-PRO information. By contrast, only non-innovators which have such resources declare that they benefit from public knowledge with regard to their innovation-related activities.

Building on von Tunzelmann's (2009) distinction between competencies and capabilities, we could say that firms which have not truly developed their capabilities through practical experience of innovation might need to build internal competencies through the implementation of an R&D department in order to fully profit from public knowledge.

Another difference between the two groups of firms regards the characteristics of markets. Non-innovators tend to value U-PRO information when they operate in non-competitive markets. Such sheltered environments are likely to reduce the uncertainty involved in information search and innovative activities and, therefore, encourage these companies to use science-based information.

Innovators, by contrast, do not need such specific market stimuli, probably because their search is more focused. Previous experience may modify company perception of risks

and opportunities, and such perceptions are likely to be clearer in firms which have practical experience of innovation.

The two groups of firms also differ in that the introduction of strategic change is negatively associated to the perception of public knowledge exclusively in innovators. Firms which have introduced new products onto the market have already made the effort of efficiently coordinating R&D and other functions, such as marketing (Miotti and Sachwald 2003); the additional burden of implementing new strategies may limit their potential to search for science-based information. Finally, non-innovators are deprived of an important stimulus for the use of public knowledge (cooperation with universities) in the launching of new products or the implementation of new processes.

To summarise, with the exception of openness of search, the other factors associated to companies' positive perception of the usefulness of information generated by U-PROs differ between innovators and non-innovators. Non-innovators declare that they profit from knowledge provided by such sources when they operate in sheltered environments and devote internal resources to search. Innovators state that they profit from such information in less restrictive circumstances concerning the market and the internal presence of an R&D department; however, sufficient financial resources and a skilled workforce are necessary to exploit the usefulness of the information provided by U-PROs.

A limitation of the present study is company size. We have defended the need to differentiate between innovators and non-innovators and this principle has guided our empirical research. However, our sample includes only firms with 50 or more employees and we suspect that as a result more non-innovators than innovators are excluded. This circumstance does not diminish the importance of finding distinctive determinants of the use of public knowledge, but makes it advisable to conduct further research with firms of all sizes, especially in the case of non-innovators.

8 Conclusions

The phrase "I do not search, but I find" is attributed to Pablo Picasso. An obscure thought with many interpretations, it may refer to an implicit dichotomy between the conscious and unconscious mechanisms generating creation. A search implies a

conscious effort to bring the pieces together, whereas a finding may also emerge subconsciously. In the latter case, it is an intangible mechanism, possibly the artist's talent or attitude, which makes the creator suddenly aware that the pieces were there and it makes sense to join them up.

It is in this sense that our research has tried to advance our understanding of how firms value knowledge from U-PROs. In theoretical terms, it indicates on the one hand that not only is searching important, but so are other subtle mechanisms which cause companies to be able to search for information profitably. We further claim that practical experience in technological innovation is one such mechanism, providing more arguments for a non-linear view of the innovation process.

On the other hand, our research recommends distinguishing between innovating and non-innovating firms in this type of analysis, because some of the mechanisms leading to the use of public research vary.

The results of our research may have some managerial implications. If technologically innovating firms aspire to use knowledge from universities and PROs, they might need to develop the skills of their workforces. Furthermore, the difficulties involved in combining a search for science-based information and a new organisational strategy make advisable the implementation of agile manufacturing, a specific attempt to meet several objectives as a precondition for survival (Vázquez-Bustelo and Avella, 2006). To fully benefit from science-based information, non-innovators might need to acquire beforehand some practical experience in technological innovation. Naturally, developing criteria to make these conclusions operational would require additional research.

Our results also have some policy implications. Researchers who have investigated latecomer countries and firms suggest that they pass through an improvement capability stage, prior to reaching an innovation capability stage in which they become fully innovative (Von Tunzelmann 2009). In the improvement capability stage, such authors argue, firms are not yet involved in the launching of new products onto the market or in the implementation of new industrial processes, but they are however engaged in other innovation-related activities, such as shop floor experimentation, equipment adaptation and major adaptation of products and inputs to local conditions.

In this stage, it is claimed, regular search for external knowledge and science and technology links may be essential to help firms to reach an innovation capability stage in which they are finally ready to launch new products onto the market or implement new industrial processes. The European Commission has recognised the need for better understanding of "the innovative use of knowledge" in such a stage. This covers a broad base of firms, including low-tech firms, firms which do not perform R&D, etc. The Commission has also acknowledged the importance of strengthening university-industry links (EUROSTAT 2003). However, innovation and technology statistics such as those gathered by the European Union and even by emerging economies (see, for instance, the PINTEC survey in Brazil) focus on the usefulness of external knowledge sourcing exclusively in innovators.

The CIS 2010 survey, for instance, poses questions on information sources (question 6.1) only to companies which have launched a new product onto the market, implemented a new industrial process or abandoned product or process innovation in the three years previous to data collection. However, in many of these countries, innovators (as defined by these characteristics) account for a minority of manufacturing firms.

Our results show that, at least in Spain's manufacturing industry, non-innovators value information obtained from U-PROs, although their perception of the usefulness of such information seems to be conditioned by more limitative factors than innovators'. A better understanding of the conditions in which all types of firms (not only innovators) value public knowledge may be useful to understand catching-up processes both in countries and manufacturing industries. A broader statistical base, taking into realistic account the fact that innovators are not the only firms to value information from U-PROs for their innovation-related activities, might be useful.

Our results suggest that support to innovative activities may not only lead directly to technological innovation but also indirectly help firms to use public research, which in turn, may be positive for further innovation in a complex, non-linear world.

Our results also suggest that in certain countries or industries, policymakers might find it useful to reallocate resources from improving search strategies to supporting practical experience in technological innovation, without reducing the use of public research by firms. Whatever the case, since increasing social interactions and trust may limit the

fostering of innovation (Molina-Morales and Martínez-Fernández, 2009), we do not recommend search practices to be limited to the private use of university knowledge.

References

Agarwal, R., and J. Prasad. (1998). "The antecedents and consequents of user perceptions in information technology adoption." Decision Support Systems 22:15-29.

Alegre, J., Chiva, R., 2008. Assessing the impact of organizational learning capability on product innovation performance: An empirical test. Technovation 28, 315-326.

Amara, N., and R. Landry. (2005). "Sources of information as determinants of novelty of innovation in manufacturing firms: evidence from the 1999 Statistics Canada Survey of Innovation." Technovation 25:245-259.

Arvanitis, S., N. Sydow, and M. Woerter. (2008). "Do specific forms of university-industry knowledge transfer have different impacts on the performance of private enterprises? An empirical analysis based on Swiss firm data." Journal of Technology Transfer 33:504-533.

Barajas, A., and E. Huergo. (2010). "International R&D cooperation within the EU Framework Programme: empirical evidence from Spanish firms." Economics of Innovation & New Technology 19:87-112.

Beneito, P. (2002). "Technological patterns among Spanish manufacturing firms." Entrepreneurial & Regional Development 14:89-115.

Brucks, M. (1985). "The Effects of Product Class Knowledge on Information Search Behavior." The Journal of Consumer Research 12:1-16.

Busom, I. (2004). "Ricerca, desenvolupament i innovació (R+D+I): Una perspectiva sobre la situació de Catalunya i Espanya." Coneixement i Societat 2nd quadrimestre:6-33.

Busom, I., and A. Fernández-Ribas. (2008). "The impact of firm participation in R&D programmes on R&D partnerships." Research Policy 37:240-257.

Cassiman, B., and R. Veugelers. (2002). "R&D Cooperation and Spillovers: Some Empirical Evidence from Belgium." American Economic Review 92:1169-1184.

Christensen, J. L., R. Rama, and N. von Tunzelmann. 1996. "Study on innovation in the European Food Products and Beverages Industry." Pp. 145. EIMS/SPRINT Brussels: The European Commission.

Cohen, W. (1995). "Empirical studies of innovative activity." in Handbook of the Economics of Innovation and Technological Change, edited by P. Stoneman: Blackwell.

Cohen, W.M., and D.A. Levinthal. (1989). "Innovation and learning: The two faces of R&D." Economic Journal 99:569-596.

Cohen, W.M., R.R. Nelson, and J.P. Walsh. (2002). "Links and impacts: the influence of public research on industrial R&D." Management Science 48:1-23.

Cruz-Castro, L., Sanz-Menéndez, L., Martínez, C., 2010. Research centers in transition: patterns of convergence and diversity. Journal of Technology Transfer, forthcoming, DOI 10.1007/s10961-010-9168-5.

Czarnizki, D., K. Hussinger, and C. Schneider. (2011). "The nexus between science and industry: evidence from faculty inventions." Journal of Technology Transfer, published online February 2011.

Decter, M., D. Bennet, and M. Leseure. (2007). "University to business technology transfer - UK and USA comparisons." Technovation 27:145-155.

Dosi, G. (1988a). "The nature of the innovative process." in Technical change and economic theory, edited by G. Dosi, C. Freeman, R. Nelson, G. Silverberg, and L. Soete. London-N.Y.: Pinter Publishers.

—. (1988b). "Sources, procedures, and microeconomic effects of innovation." Journal of Economic Literature 26:1120-1171.

Dosi, G., D. Teece, and S.G. Winter. (1992). "Toward a theory of corporate coherence: preliminary remarks." Pp. 185-211 in Technology and enterprise in a historical perspective, edited by G. Dosi, R. Giannetti, and P. A. Toninelli. Oxford: Clarendon Press.

Elenkov, D.S. (1997). "Uncertainty and environmental scanning: the case of institutional influences on scanning behaviour." Strategic Management Journal 18:287-302.

European Commission. (2008). Europe in figures. EUROSTAT Yearbook 2008. Luxembourg.

EUROSTAT. 2003. "Statistics on science and technology in Europe (1991 - 2002)." Pp. 1-102, edited by European Commission. Luxembourg: European Commission

Fagerberg, J. (2005). "Innovation. A guide to the literature." Pp. 1-26 in The Oxford Handbook of Innovation, edited by J. Fagerberg, D.C. Mowery, and R.R. Nelson. Oxford (UK): Oxford University Press.

Fagerberg, J., and M.M. Godinho. (2006). "Innovation and catching-up." Pp. 514-542 in The Oxford Handbook of Innovation, edited by J. Fagerberg, D.C. Mowery, and R.R. Nelson. Oxford: Oxford University Press.

Fiet, J.O., and P.C. Patel. (2008). "Entrepreneurial discovery and constrained, sytematic search." Small Business Economics 30:215-229.

Foss, N.J. (1998). "The resource-based perspective: an assessment and diagnosis of problems " Scand.J.Mgmt 14:133-149.

Georghiou, L., J.S. Metcalfe, M. Gibbons, T. Ray, and J. Evans. (1986). Post-Innovation Performance. London: McMillan.

Gómez, I., M. Bordons, M.T. Fernández, and F. Morillo. (2009). "Structure and research performance of Spanish universities." Scientometrics 79:131-146.

Hall, B.H. (2005). "Innovation and diffusion." in The Oxford Handbook of Innovation, pp. 459-484, edited by J. Fagerberg, D.C. Mowery, and R.R. Nelson. New York: Oxford University Press.

Hansen, P.A. (1995). "Publicly produced knowledge for business: when is it effective?" Technovation 15:387-397.

Kolb, D.A. (1984). Experiential learning. Experience as a source of learning and development. New Jersey: Prentice Hall.

Laursen, K., and A. Salter. (2004). "Searching high and low: what types of firms use universities as a source of innovation." Research Policy 33:1201-1215.

Levinthal, D.A., and J.G. March. (1981). "A model of adaptive organizational search." Journal of Economic Behavior & Organization 2:308-333.

Lopez, A. (2008). "Determinants of R&D cooperation: Evidence from Spanish manufacturing firms." International Journal of Industrial Organization 26:113-136.

Malerba, F. (1992). "Learning by firms and incremental technical change." The Economic Journal 102:845-859.

Mangematin, V., and N. Mandran. (2000). "Do non-R&D intensive industries benefit from public research spillovers? The case of the agro-food industry." Innovation and firm performance. Econometric explorations of survey data, pp. 23???, edited by A. Kleinknecht and P. Monhen: Edward Elgar.

Martinez-Sanchez, A., Pastor-Tejedor, A.C., 1995. University-industry relationships in peripheral regions: The case of Aragon in Spain. Technovation 15, 613-625.

McGee, J.E., and O.O. Sawyerr. (2003). "Uncertainty and information search activities: A study of owner-managers of small high-technology manufacturing firms." Journal of Small Business Management 41:385-401.

Mention, A.-L. (2010). "Co-operation and co-opetition as open innovation practices in the service sector: Which influence on innovation novelty?" Technovation doi:10.1016/j.technovation.2010.08.002.

Miotti, L., and F. Sachwald. (2003). "Co-operative R&D: why and with whom? An integrated framework of analysis." Research Policy 32:1481-1499.

Mohnen, P., and C. Hoareau. 2002. "What type of enterprise forges close links with universities and government labs? Evidence from CIS 2." in MERIT-Infonomics Research Memorandum series, edited by MERIT-INFONOMICS. Maastrich (The Netherlands).

Molina-Morales, F.X., Martínez-Fernández, M.T., 2009. Too Much Love in the Neighborhood Can Hurt: How an Excess of Intensity and Trust in Relationships May Produce Negative Effects on Firms. Strategic Management Journal 30, 1013–1023.

Mowery, D.C., and B.N. Sampat. (2005). "Universities in national innovation systems." Pp. 209-239 in The Oxford Handbook of Innovation, edited by J. Fagerberg, D.C. Mowery, and R.R. Nelson. Oxford: Oxford University Press

Nelson, R. & Winter, S. (1982). An evolutionary theory of economic change. Cambridge. MA: Harvard University Press.

Núñez Sánchez, Barge-Gil, A., Modrego-Rico, A., 2010. Performance of knowledge interactions between public research centres and industrial firms in Spain: a project-level analysis. Journal of Technology Transfer, forthcoming, DOI 10.1007/s10961-010-9178-3.

Pavitt, K., 2002. Innovating routines in the business firm: what corporate tasks should they be accomplishing? Industrial and Corporate Change 11 (1), 117-133.

Quadros, R., A. Furtado, R. Bernardes, and E. Franco. (2001). "Technological innovation in Brazilian industry: An assessment based on the Sao Paulo innovation survey." Technological Forecasting and Social Change 67:203-219.

Rapini, M.S., E. da M. Albuquerque, C.V. Chave, L.A. Silva, S.G.A. Souza, H.M. Righi, and M.S. da Cruz. (2009). "University-industry interactions in an inmature system of innovation: evidence from Minais Gerais, Brazil." Science and Public Policy 36:373-386.

Rosenberg, A. (1992). "Science and Technology in the Twentieth Century", in Technology and enterprise in a historical perspective, edited by G. Dosi, R. Giannetti and P.A. Toninelli. Oxford: Clarendon Press.

Swann, G.M.P. 2002. "Innovative businesses and the science and technology base: an analysis using CIS3 data." Pp. 57. Manchester, UK: Report for the Department of Trade and Industry.

Teece, D.J., and G. Pisano. (1994). "The dynamic capabilities of firms: An introduction." Industrial and Corporate Change 3.

Tether, B.S., and G.M.P. Swann. 2003. "Sourcing science. The use by industry of the science base for innovation; evidence from the UK's innovation survey." in International Workshop on Innovation in Europe: Empirical Studies on Innovation Surveys and Economic Performance. Rome.

Varis, M., and H. Littunen. (2010). "Types of innovation, sources of information and performance in entrepreneurial SMES." European Journal of Innovation Management 13:128-154.

Vázquez-Bustelo, D., Avella, L., 2006. Agile manufacturing: Industrial case studies in Spain. Technovation 26, 1147–1161.

Vega-Jurado, J. (2010). "Las estrategias de innovación en la industria manufacturera española: sus determinantes y efectos sobre el desempeño innovador". Valencia: Universidad Politécnica de Valencia.

Vega-Jurado, J., A. Guitiérrez-Garcia, and I. Fernández-de-Lucio. (2009). "Does external knowledge sourcing matter for innovation? Evidence from the Spanish manufacturing industry." Industrial and Corporate Change 18:637-670.

Von Tunzelmann, N. (2009). "Competencies versus capabilities: A reassessment." Economia Política XXVI:435-464.

Yeoh, P.-L. (2000). "Information acquisition activities: A study of global start-up exporting companies." Journal of International Marketing 8:36-60.

Tables

Table 1 Perceived usefulness of information sources for innovation-related activities in Spanish manufacturing firms, 2003. Sample of innovators (n ≈ 800, 1 = none, 10 = maximum importance)

Type	Information source	1	2	3	4	5	6	7	8	9	10	Total	Average importance	Ranking
Internal	Own R&D department	20%	2%	1%	1%	6%	3%	10%	17%	16%	25%	100%	6.74	5
	Own production department	2%	1%	1%	1%	4%	4%	11%	27%	18%	31%	100%	8.21	2
	Own marketing department	8%	2%	2%	3%	10%	7%	12%	23%	12%	21%	100%	7.01	4
	Parent company	16%	2%	3%	2%	7%	4%	6%	14%	16%	31%	100%	7.03	3
Market	Customers	2%	2%	2%	2%	4%	4%	8%	17%	18%	42%	100%	8.37	1
	Competitors	8%	3%	3%	4%	13%	8%	15%	23%	10%	12%	100%	6.52	7
	Consultants	17%	9%	8%	6%	18%	10%	14%	11%	4%	2%	100%	4.81	11
Institutions	Universities or PROs	23%	9%	8%	7%	15%	8%	13%	11%	3%	3%	100%	4.49	13
	Public administration	31%	10%	9%	8%	14%	8%	9%	5%	3%	3%	100%	3.82	16
Codified	Patents	34%	9%	7%	3%	10%	4%	6%	8%	4%	13%	100%	4.42	14
	Scientific publications	22%	9%	10%	7%	16%	9%	11%	9%	3%	4%	100%	4.49	12
	Industrial publications	13%	7%	8%	8%	19%	13%	14%	10%	3%	5%	100%	5.12	10
Other	Trade associations	6%	4%	4%	3%	12%	12%	16%	20%	10%	12%	100%	6.61	6
	Trade fairs	10%	6%	6%	5%	16%	10%	13%	19%	6%	8%	100%	5.86	8
	Conferences	25%	11%	8%	7%	16%	10%	9%	9%	3%	3%	100%	4.23	15
	Internet	12%	4%	5%	7%	15%	11%	14%	13%	8%	10%	100%	5.82	9

Table 2 Perceived usefulness of information sources for innovation-related activities in Spanish manufacturing firms, 2003. Sample of non-innovators (n ≈ 180, 1 = none, 10 = maximum importance)

Type	Information source	1	2	3	4	5	6	7	8	9	10	Total	Average importance	Ranking
Internal	Own R&D department	39%	9%	3%	2%	6%	6%	7%	11%	9%	8%	100%	4.39	11
	Own production department	6%	2%	1%	1%	5%	8%	14%	25%	17%	23%	100%	7.56	2
	Own marketing department	19%	4%	4%	2%	11%	6%	16%	19%	8%	9%	100%	5.75	6
	Parent company	19%	3%	1%	3%	5%	10%	8%	20%	11%	20%	100%	6.44	3
Market	Customers	3%	1%	3%	1%	4%	4%	9%	19%	16%	41%	100%	8.26	1
	Competitors	8%	5%	5%	2%	17%	6%	22%	17%	5%	12%	100%	6.21	5
	Consultants	22%	7%	7%	4%	18%	9%	17%	9%	3%	3%	100%	4.72	9
Institutional	Universities or PROs	30%	18%	8%	8%	16%	7%	7%	3%	1%	2%	100%	3.44	14
	Public administration	34%	20%	6%	4%	14%	6%	5%	7%	1%	3%	100%	3.41	15
Codified	Patents	43%	13%	5%	3%	9%	2%	8%	8%	3%	6%	100%	3.63	13
	Scientific publications	29%	17%	7%	7%	17%	6%	9%	4%	1%	4%	100%	3.71	12
	Industrial publications	17%	12%	12%	7%	19%	10%	13%	7%	1%	3%	100%	4.48	10
Other	Trade associations	10%	3%	4%	4%	15%	8%	15%	22%	6%	12%	100%	6.28	4
	Trade fairs	14%	5%	4%	4%	12%	11%	22%	16%	5%	6%	100%	5.69	7
	Conferences	34%	16%	8%	7%	15%	5%	6%	6%	2%	1%	100%	3.35	16
	Internet	16%	6%	8%	7%	16%	14%	14%	9%	5%	6%	100%	5.13	8

Table 3 List of variables and descriptive statistics

Variable	Description	Innovators					Non-innovators					Significance of t-test for mean differences
		Mean	Standard deviation	Min.	Max.	Number of cases	Mean	Standard deviation	Min.	Max.	Number of cases	
Perceived usefulness	Perceived degree of importance of U-PROs as information sources for innovation (0-4 Likert scale)	1.28	1.18	0	4	816	0.81	0.98	0	4	180	*
Openness	Perceived degree of importance of the 11 external sources of information for innovation listed in Table 1 (i.e. excluding "internal" sources and "universities or PROs"). We eliminated observations with more than 5 "don't know" responses.	4.48	1.70	0	9	818	4.00	1.67	0	8	186	*
R&D activities	A dummy variable equal to 1 if the respondent declared that the firm conducted R&D activities, and 0 otherwise.	0.66	0.47	0	1	831	0.33	0.47	0	1	188	*
Firm size	Number of employees (in natural logarithm in the regressions).	162.05	281.03	50	5996	824	119.99	100.98	50	850	185	*
Skills	Degree of technical complexity of tasks (0-5 Likert scale).	1.45	1.41	0	5	827	1.14	1.32	0	5	186	*
Strategic innovation	Degree of non-technological innovation in the last three years, based on important changes in strategic orientation (0-4 Likert scale).	2.18	1.38	0	4	814	1.72	1.47	0	4	185	*
Competition	A coded response to the question, "in your opinion, in the main market where your firm operates, the number of competitors is…" Answers can range from 0 (very low) to 3 (very high).	1.76	0.96	0	3	829	1.82	0.95	0	3	186	n.s.
Collaboration	For innovators, collaboration with universities and PROs in product or process development in the last three years, with a score of 2 if mentioned in first place before other alternatives for product and process development, 1 if mentioned in second place, 0 if not mentioned. Other alternatives were: "mainly by the firm itself", "in collaboration with other firms", "mainly by other firms", "mainly by the group" and "others".	0.14	0.40	0	2	833	-	-	-	-	-	-

* $p<0.05$; n.s. Not significant

Table 4 Ordered logit model of the perceived usefulness of information provided by universities and PROs for innovation-related company activities

	1 Innovators	2 Innovators	3 Non-innovators
Number of observations	804	781	173
Log likelihood function	-953	-917	-150
Prob[$\chi 2$ > value]	0	0	0
	Coeff. (t-ratio)	Coeff. (t-ratio)	Coeff. (t-ratio)
Constant	-3.66 (-5.81) ***	-3.74 (-5.73) ***	-7.02 (-4.34) ***
Openness	0.91 (19.79) ***	0.91 (18.7) ***	1.1 (8.84) ***
R&D activities	0.22 (1.42)	0.21 (1.35)	0.64 (1.72) *
Ln firm size	0.25 (2.41) **	0.27 (2.49) **	0.47 (1.63)
Skills		0.1 (2.01) **	0.13 (0.94)
Strategic innovation		-0.12 (-2.16) **	-0.1 (-0.82)
Competition		-0.02 (-0.25)	-0.5 (-2.8) ***
Collaboration		0.73 (4.3) ***	
Industry dummies	Included	Included	Included

*** p<0.01; ** p<0.05; * p<0.10

Appendix

Table 5 Innovation-related activities of firms and public knowledge. Results of selected studies

Authors	Sample	Region/country and year	Types of firms (innovators and non-innovators)	% of firms drawing information from universities and PROs	Main sources of information
Arvanitis et al. (2008)	671 manufacturing and service firms with over five employees	Switzerland, 2005	Firms reporting knowledge and technology transfers	56.6 % of firms report informal contacts with universities as very important; 15.3% report expertise and consulting provided by universities (multi-response question)	---
Laursen and Salter (2004)	2,655 manufacturing firms	UK, 2000	Both, no breakdown	27% of firms. Under 2% of firms sampled indicate that such knowledge is highly important	Sources internal to the firm Suppliers Clients and customers
Cohen et al. (2002)	1,267 R&D units conducting R&D in manufacturing firms (subsidiaries of foreign MNEs excluded from the sample)	US, 1994	Only firms conducting R&D	31.6% of firms draw from universities and PROs to launch new R&D projects, and 36.3% to complete projects.	1. New projects: customers and own manufacturing operations 2. Project completion: own manufacturing operations and independent suppliers
Amara and Landry (2005)	5,455 manufacturing firms	Canada, 1999	Innovators	Between 11.3% and 18% of firms which had launched innovations new to the world market Between 4.5% and 7.0% of firms which had launched innovations merely new for the firm	Sources internal to the firm Clients 3. Trade fairs, exhibitions and professional conferences

Authors	Sample	Region/country and year	Types of firms (innovators and non-innovators)	% of firms drawing information from universities and PROs	Main sources of information
Varis and Littunen (2010)	264 SMEs	Northern Savo, Eastern Finland, 2006	Innovators and non-innovators. Innovators include only firms which have performed radical innovation or launched completely new products	Information from regional universities, PROS and vocational training centres was not significantly associated to innovation	Innovators draw mainly from freely available external sources (exhibitions, trade fairs, Internet) and from financial organisations Non-innovators draw mainly from national support organisations (e.g. Chambers of Commerce)
Rapine et al. (2009)	28,036 industrial firms (140 in Minas Gerais)	Brazil and, more specifically, Minas Gerais, 2003-2005	Brazilian sample: Innovators (both R&D performers and non-R&D performers) Minas Gerais sample: R&D performers	Brazil: 8.4% of firms, 5.4% of non-R&D performers and 27% of firms with systematic R&D activity declare that universities are an important source of information	Minas Gerais sample: 1. Company's own manufacturing operations 2. Customers 3. Fairs and exhibitions
Mention (2010)	431 service firms	Luxembourg, 2002-2004	Innovators	41% of firms which had introduced products new to the market (and 43% of those which had introduced products new to the firm)	Intra-group sources Market based sources
EUROSTAT (2001)	2nd Community Innovation Survey	European Union, 1996	Innovators	12% of high-tech firms (and 4% of low-tech firms) consider information from universities and PROs to be very important	Sources internal to the firm Clients and customers Publicly available information e.g. conferences