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The effect of external and internal factors on firms' product innovation

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Abstract

In this article we analyse the effect of factors external and internal to the firm, on product innovation novelty, and how this effect varies by industry. We estimate three econometric models to determine the individual effects of these factors, their joint explanatory power and the effects of interactions among them. The analysis is based on a sample of 6094 manufacturing firms, taken from the Spanish Survey of Technological Innovation 2000. The results indicate that the firm's technological competences, derived from in-house R&D, are the main determinant of product innovation. They also suggest that in the presence of high levels of such competences, the technological opportunities deriving from non-industry agents become less important as determinants of innovation. We show that the determinants of innovation vary depending on the industrial sector and the degree of novelty of the product developed.

Keywords: Innovation outputs; Absorptive capacity; Technological opportunities; Appropriability conditions

1. Introduction

Identification of the determinants of technological innovation in the firm is a popular topic in the empirical literature on innovation. It has been generally studied either from an industrial economy perspective or from a business management perspective.

Studies in the field of industrial economy start from the hypothesis that the level of innovation in the firm can be explained in terms of the structural characteristics of the industry in which it competes, and that it is possible to find general patterns of technological change associated with specific industries or, failing this, with broad industry categories (Souitaris, 2002a). This involves studying the effect of industry characteristics, such as market opportunities (Dougherty, 1990; Levin, 1981; Schmookler, 1966), technological opportunities (Geroski, 1990; Levin et al., 1985) and appropriability conditions (Levin et al., 1987; Mansfield, 1981, 1986). A particular focus has been on the size of the firm and the structure of the market as possible determinants of innovation. The results of these studies are ambiguous. Some validate the classical Schumpeterian hypothesis that links a monopolistic market structure and larger firm size with

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better innovative performance, while others contradict it.[1]

Studies in the field of business management focus on identifying the internal characteristics of firms that affect their innovation behaviour. Many of these investigations adopt the resource-based view (RBV), which highlights the heterogeneity of firms and the role played by internal attributes in business strategy (Wernerfelt, 1984). In this perspective, each firm possesses a unique set of resources and capacities, tangible and intangible, which have been acquired and developed over time and which, in the final instance, determine the degree of efficiency with which they perform functional activities (Dierickx and Cool, 1989; Galende and Suárez, 1999). Following this approach, researchers have evaluated a considerable number of organisational characteristics as possible determinants of innovation, which in turn have been classified within the broader category of "basic competences" (Leonard-Barton, 1992; Tidd, 2000). These basic competences include:

- Technological competences, generally measured by R&D intensity (Bhattacharya and Bloch, 2004; Love and Roper, 1999);
- Human resource competences, which include, among other things, a firm's knowledge and skills, accumulated either through the training of its workforce (Song et al., 2003) or as a result of the experience acquired over time (Hoffman et al., 1998);
- Organisational competences, which are related to administrative styles (Webster, 2004), the formalisation of internal communication systems (Rothwell, 1992; Souitaris, 2002b), and the interdependence of work teams (Cooper, 1990).

In line with this view, Cohen and Levinthal proposed the concept of absorptive capacity, defined as "the ability of a firm to recognise the value of new external information, assimilate it and apply it to commercial ends" (Cohen and Levinthal, 1990, p. 128). This concept, in common with the RBV, acknowledges that internal capacities are a key element in a firm's technological development, and highlights their dynamic and cumulative nature.

[1] Acs and Audretsch (1988), for example, in their study show that small firms are more innovation-intensive than large firms, because, among other reasons, they generally have fewer rigidities to hinder the introduction of the innovation. Also, authors such as Arrow (1962) and Lundvall and Nielsen (1999), show that faced with increased competition firms feel pressure to transform themselves and develop through innovation in order to survive.

Despite these efforts, there is no consistent body of theory related to the factors that determine the innovative performance of the firm. Some authors highlight methodological differences between studies, related to the nature of innovation (radical *vs.* incremental), the technological intensity of industrial sector (low *vs.* high tech), the characteristics of the firm (small and medium sized *vs.* big enterprise) and even geographical region, as reasons for the diversity of the results (Souitaris, 1999). In addition, the methodological difficulty involved in integrating existing theoretical perspectives has led researchers to separately analyse industry characteristics and firm's internal capacities as determinants of innovation, and to pay little attention to identifying the links between the two groups of factors (Keizer et al., 2002; Nieto and Quevedo, 2005).

Taking account of the above, we analyse the determinants of product innovation in manufacturing firms by defining a model that considers the joint effect exercised by factors external and internal to the firm on its innovative performance, and how this effect varies by industrial sector. The empirical study focuses on the determinants of product innovation in Spanish manufacturing firms, but the proposed model can be applied to other geographical contexts.

The paper is structured as follows. Section 2 provides a description of the model of analysis defined for the study. Section 3 presents the methodological aspects of the empirical study, describing the data, the measurements of the variables and the econometric specifications evaluated. Section 4 presents the results and Section 5 presents the main conclusions.

2. Model of analysis: background and hypothesis

Identification of both internal and external factors that determine innovative performance is relatively new in the firm innovation literature. Most existing studies analyse the interactions between external sources of knowledge and in-house R&D activities and several argue that the external acquisition of knowledge may stimulate rather than substitute for firms' own R&D (Arora and Gambardella, 1990; Veugelers, 1997). Cohen and Levinthal (1989, 1990) explain this relationship of complementarity in some depth, using the concept of absorptive capacity. In their research, they use absorptive capacity as a variable to explain the effect of the structural characteristics of an industry (appropriability conditions and technological opportunity) on the firm's R&D intensity. Cohen and Levinthal concluded that in-house R&D activities not only contribute to the generation of new knowledge, but also enhance the firm's ability to assimilate and exploit knowledge generated outside the firm. In other words, they increase the firm's absorptive capacity. Thus, firms operating in environments with a high level of technological opportunities (external knowledge) will have greater incentives to invest in R&D, because they will be able to make better use of these opportunities. Following the work of Cohen and Levinthal (1990), several researchers have analysed the effect of absorptive capacity on R&D intensity, looking for empirical evidence to support the existence of a positive correlation between these variables (Becker and Peters, 2000; Nieto and Quevedo, 2005; Veugelers, 1997).

However, little work has been done on the joint effect of external and internal factors on a firm's innovation outputs. Oerlemans et al. (1998) conducted an empirical investigation of the relations between the use of internal and external resources in innovation processes, using an adapted version of Håkansson's (1987) economic network model. These authors concluded that such relationships are strongly influenced by moderating variables such as sector, and type and level of innovations produced. Similarly, Freel (2003) analysed the sectoral patterns of small firm innovation, focusing on the relative importance of external linkages and internal resources on product and process innovation.

The model of analysis in the current paper is similar to the model proposed by Oerlemans et al. (1998). The underlying idea is that the innovative performance of the firm depends on external factors and on factors related to the organisation's internal competences. In view of the large number of possible variables in both groups of factors, the proposed analytical model starts with the selection of a set of characteristics which, though not an exhaustive list, includes some of the more important variables recognised in the literature. The external factors selected are *technological opportunity* and *appropriability conditions*, variables closely related to the availability of knowledge and the possibilities for its use. The internal factor selected is the firm's technological competences derived from its R&D activities (Fig. 1). This selection was made with the general objective of integrating the approaches described above, and adopting an analytical framework that conceives of the innovation process as one of continuous learning, highlighting the importance of both the external knowledge available and the learning capacity of the firm itself.

In addition we consider that the effects of external and internal factors on firm's innovative performance vary depending on the industry in which the firm operates. In other words, these effects are moderated by industry dynamics. As Oerlemans et al. (1998, p. 302) pointed out "because sectoral patterns of technological innovation are different, one may expect that firms in specific sectors use specific internal and external resources in order to innovate successfully".

In the next sections, we analyse in depth the factors selected for our model of analysis.

2.1. Technological opportunity

The concept of technological opportunity is associated with the probability that the resources dedicated to the development of innovation processes will generate real technological advances (Dosi, 1988; Nelson and Winter, 1982). The insertion of this variable in economic studies of innovation is an attempt to capture differences in the innovation behaviour of firms across different industry sectors. Despite nearly four decades of empirical analysis, it is still difficult to define the concept and to establish the measures appropriate to different types of samples (Geroski, 1990).

A method traditionally used for this variable has been to classify industries on the basis of the scientific or technological field with which they are most

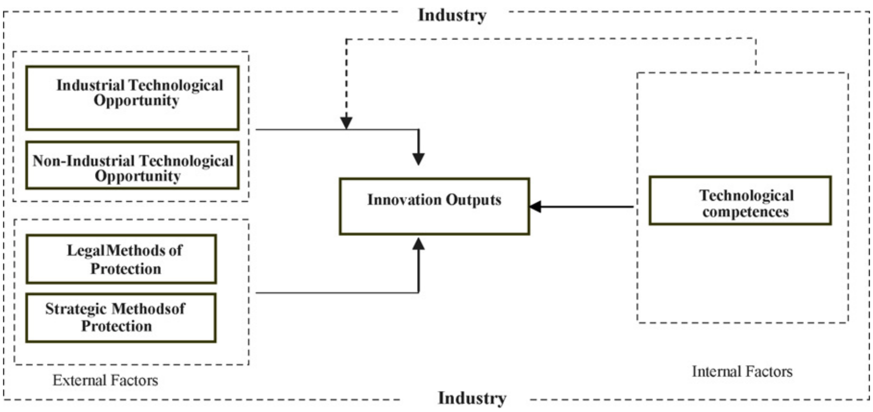

Fig. 1. Model of analysis.

closely related. Scherer (1965) proposed three industry categories (chemical, mechanical and electrical). Subsequently, some broader categories, distinguishing between industries of "high" or "low" technological opportunity (Bhattacharya and Bloch, 2004; Wilson, 1977) were established, while other authors analysed the contribution of different scientific fields to the technological advance of each industry (Cohen and Levinthal, 1989; Levin et al., 1987).

Technological opportunity has also been linked to the contribution of external sources of knowledge to the firm's innovation activities. In this context a distinction is made between industry sources, such as suppliers or competitors, and non-industry sources such as universities or public research institutes (Klevorick et al., 1995).

Independent of the measurement strategy adopted, the relationship between technological opportunity and innovation has been widely studied in the literature. Most of these studies have focussed on analysis of the effect of this variable on R&D activities (Cohen and Levinthal, 1990, 1989; Klevorick et al., 1995). Very few studies have sought to identify the relationship between technological opportunities and a firm's innovative performance. Some authors (Arvantis and Hollenstein, 1994; Becker and Peters, 2000) found indications of a negative relationship between the importance of sources of scientific knowledge and the development of new products, and associated this with the existence of an indirect effect of non-industrial technological opportunities on firm's innovation outputs contrasting with their direct and positive effect on R&D intensity.

Notwithstanding, the general premise of our analytical model is that the adaptation of external knowledge constitutes a key element in the improvement of processes and the development of new technologies, thus positing a positive relationship between technological opportunity, both industrial and non-industrial, and innovation.

2.2. Appropriability conditions

This variable represents the firm's capacity to retain the benefits derived from its inventive activities (Cohen and Levinthal, 1989). Its importance as a determinant of innovation arises from the disincentives associated with the probability that competitors will be able to access the technological knowledge incorporated in the processes or products developed by the firm at lower cost. For this reason many studies of appropriability have focussed on the effectiveness of mechanisms designed to keep the results of innovative efforts exclusive to the firm. There is a large number of studies in the literature on the value of patents as a protection mechanism, and how this varies among industries. Cohen (1995) presents a wide-ranging review of the studies on this subject, and concludes that patents are indispensable as a protection mechanism in only a few industries, for instance chemicals and pharmaceuticals, and that in mature industries, such as food processing and the production of metallic products, they are less effective.

The value of protection mechanisms not related to intellectual property rights (IPR) has also been documented. There are some studies of the implications of lead time advantage for the appropriation of an innovation (Teece, 1986), or the effectiveness of product design complexity as a barrier to imitation (Brusoni et al., 2001). In this context, Levin et al. (1987) showed that in industries other than chemicals and pharmaceuticals, the use of these latter types of strategies offered greater protection than can be obtained through patents.

There is broad consensus on the differences among industries in their use of protection mechanisms, but not on how these mechanisms act as incentives to innovative activity. The most prevalent hypothesis links a higher level of protection with greater innovative effort, insofar as spillovers are reduced and the returns to investments in R&D are increased (Spence, 1984). However, some authors (March, 1991; Teece, 1986) have suggested that an over-emphasis on protection can reduce innovative capacity, insofar as the firm concentrates its efforts on activities related to control or secrecy of the innovation and neglects the exploration of new technologies or the exchange of knowledge with other agents in the innovation system.

The effect of appropriability conditions on innovation outputs has been less well explored in the literature. The model we are proposing is based on the hypothesis that there is a relationship between these variables, and suggests that an increase in appropriability conditions associated with the effectiveness of protection mechanisms, positively affects innovation. To examine this effect in greater detail, we make a distinction between legal and strategic mechanisms. The former are related to the use of different types of IPR, such as patents, registration of utility models, and trade marks, while the latter are associated with strategies such as secrecy, complexity of product design, and lead time.

2.3. Technological competences

From the RBV, innovation is not only a product of the structural characteristics of the industry in which the firm operates; it is also a process, stemming from the strengthening of the organisation's core competences. These competences include the financial, human, physical, commercial, technological and organisational assets used by the firm to develop new or improved products and services (Galende and Suárez, 1999). Tidd (2000) classified these competences into three categories: (a) organisational competences, which include managerial systems, people's knowledge, and values and norms; (b) market competences, which capture the firm's ability to understand and exploit its markets, and (c) technological competences, derived from in-house R&D activities.

In our model we selected technological competences as an internal factor for two reasons. First, there is a wide body of empirical literature that stresses the value of R&D activities as a determinant of firm's innovative performance (Caloghirou et al., 2004; Duchesneau et al., 1979; Freel, 2003; Oerlemans et al., 1998; Reichstein and Salter, 2006). Second, technological competences can be used as an analytical link between the external sources of technological opportunity and the capacity of the firm to exploit them for innovation. In this respect, several authors have pointed out that the effect of the industry characteristics (external factors) on the firm's innovation performance is not totally exogenous, but depends on the internal capacities of the organisation. In the case of technological opportunities, for example, the extent to which firms can assimilate and exploit external knowledge depends on their scientific or technological capacities. Only firms that are in possession of a critical mass of knowledge are able to use the technological opportunities that exist around them as tools to expand their innovative capacities (Cohen and Levinthal, 1990; Harabi, 1995; Klevorick et al., 1995).

Based on the above and in line with Cohen and Levinthal (1990), we consider two possible effects of technological competences on the firm's innovative performance. The first is a direct positive effect on innovation output, insofar as a greater effort in in-house R&D activity increases the organisation's possibilities of generating new knowledge to develop new or improved products. The second is an indirect effect from increased absorptive capacity, which makes it easier for the firm to exploit externally available knowledge. This latter effect is especially relevant in the case of non-industrial technological opportunities, which, because they offer knowledge that is not immediately applicable, demand a greater assimilation and exploitation effort by the firm. We thus posit that the greater the firm's technological competences, the greater the importance of sources of scientific knowledge as determinants of innovation outputs.

3. Description of the empirical study

3.1. Data

The data for the empirical analysis are taken from the 2000 Technological Innovation in Companies Survey (TICS), carried out by Spain's National Statistical Institute. This survey is based on the Oslo Manual (OECD, 1992 (1997 revised edition)), and provides information on the innovating behaviour of Spanish firms during the period 1998–2000. Its application extends to all industrial, construction and service firms with at least 10 paid employees, distributed throughout the Spanish territory. In our study, we consider only the manufacturing firms, which yield a total sample of 6094 firms.

3.2. The variables

3.2.1. Dependent variable

The dependent variable used to measure the innovation output of the firm is *degree of innovation* (DEGINN). It can take three possible values depending on the novelty of the product innovation developed: 0, if the firm did not introduce any new or improved products into the market during the period 1998–2000; 1, if the product introduced into the market in that period was new to the firm; and 2, if the product introduced into the market was new to the market.

This variable allows us to identify the factors that are relevant for the development of new products and distinguish which among them have the greatest effect on the development of major innovations (products new to market). Few empirical studies have used indicators of this type as measures of innovation output. Some studies in the literature use the novelty of the innovation as the dependent variable in a regression model (see Amara and Landry's, 2005 study of the Canadian manufacturing industry and Oerlemans et al.'s, 1998 study of the Dutch industry.)[2]

3.2.2. Independent variables

The proposed analytical model considers three factors as possible determinants of innovation: technological

[2] Another important example is the study by Romijn and Albaladejo (2002), which uses a five-point scale to represent the degree of novelty of product innovations. However, this study does not perform regression models and uses only non-parametric statistical tests to identify the relationships between this variable and a set of possible determining factors. Reichstein and Salter (2006) used similar indicators to represent the degree of newness of both process and product innovations, but they only performed regression model about process innovation.

Table 1
Internal reliability coefficients (Cronbach's alpha) for composite variables

Variables	Number of cases	Number of elements	Cronbach's alpha
Industrial technological opportunity (ITO)	6094	4	0.822
Non-industrial technological opportunity (NITO)	6094	4	0.839
Legal methods of protection (LMP)	6094	3	0.685
Strategic methods of protection (SMP)	6094	3	0.891

opportunity, appropriability conditions and internal technological competences.

To measure technological opportunity we take account of the importance attributed by the firm to cooperation with external agents for the development of innovative activities,[3] distinguishing, as did Klevorick et al. (1995), between industry agents (customers, suppliers, competitors and firms in the same group) and non-industry agents (consultants, commercial laboratories/R&D firms, universities and public research organisations/technology centres). The degree of importance is measured on a 0–3 scale; where 0 indicates that the firm has not cooperated with the agent in question, and 3 means that the firm has cooperated and that this cooperation was very important for the development of innovative activities.

On the basis of this initial distinction, we calculated two indicators: *industrial technological opportunity* (ITO) and *non-industrial technological opportunity* (NITO), whose value corresponds to the means of the score given by the firm to the importance of cooperation with the agents from each group. The resulting variables take continuous values in the range 0–3. Bearing in mind that the final indicators are composed of several items we carried out reliability tests to determine their level of statistical validity. Table 1 presents the Cronbach's alpha coefficients obtained, which in both cases were highly reliable (higher than 0.8).

The appropriability conditions are assessed by considering the importance attributed by the firm to different mechanisms for protecting its inventions or innovations. It is measured on a scale of 1–4, where 1 equates with non-use of a mechanism, and 4 means both that a mechanism has been used and it is very important. The protection mechanisms considered are grouped into two categories: legal mechanisms (patents, registration of utility models, and trade marks)[4] and strategic mechanisms (factory secrecy, complexity of design, and lead time). As in the previous case, we constructed a composite index for each category, calculated as the mean of the scores given by the firm to each of the mechanisms in that category. The resulting variables, *legal methods of protection* (LMP) and *strategic methods of protection* (SMP) take continuous values in the range 1–4, interpreted as above for the original variables. The values of the Cronbach's alpha coefficients indicate that the composite variables used in this case are also reliable, though with a lower index for LMP (Table 1).

Technological competences are measured as R&D intensity. This variable is defined as R&D spending as a percentage of the firm's sales volume. Unfortunately, TICS does not directly enquire about this aspect, so we constructed an approximate indicator on the basis of the information available, according to the formula:

$$\mathrm{RDI} = \mathrm{TECIN} \times \left(\frac{\mathrm{INNRANK}}{\mathrm{SIZE}}\right)$$

The variable TECIN refers to the technological intensity of the firm, and is calculated as the percentage of innovation expenditure dedicated to the development of in-house R&D. The variables INNRANK and SIZE are relative indicators representing, respectively, innovation expenditure and firm's volume of sales related to the branch of economic activity to which it belongs. The values for these variables are presented in Table 2.

The size of the firm (SIZE) is also included as a control variable. With respect to this variable our aim was to determine whether the effect exercised by size varies depending on the industrial sector to which the firm belongs.[5]

[3] This technique of measurement is congruent with strategies posited in previous studies and assumes that technological opportunities are correlated with the degree to which external agents constitute important sources of information for innovation (Arvantis and Hollenstein, 1994; Becker and Dietz, 2004; Harabi, 1995).

[4] Another legal mechanism considered in TICS is Copyright. However, this mechanism was the least valued by firms and furthermore its inclusion in the variable LMP reduced the Cronbach's alpha reliability index. In view of this, and with the additional aim of establishing variables composed of an equal number of items in order to facilitate comparison between them, this mechanism was excluded from the study.

[5] The SIZE variable in this analysis is measured on an ordinal scale (range 1–4), which represents firm turnover relative to the industrial

3.3. Sectoral classification

In order to analyse the industry variations related to the effect of external and internal factors on firm's innovative performance, we classified firms into broad sectoral categories, based on the taxonomy of patterns of technological change proposed by Pavitt (1984), which distinguishes four types of firms: (a) supplier-dominated firms; (b) large-scale producers; (c) specialised suppliers; and (d) science-based firms.

Although this taxonomy leads to substantial simplifications, its applicability as a criterion for the classification of firms has been tested in several earlier studies (Arundel et al., 1995; Cesaretto and Mangano, 1992). In the specific case of the study of the determinants of innovation, Souitaris (2002a) suggests that this taxonomy is of particular value, in that it permits us to distinguish among firms of similar size, industrial sector, and types of innovation, aspects recognised in the literature as moderators of the effects of the possible determinants.

According to this taxonomy, we identified the following:

1. In the "supplier-dominated" category 2185 firms, equivalent to 35.85% of the sample. These firms mostly comprise traditional industries such as textiles, clothing and leather, furniture, wood and cork, among others.
2. In the "large-scale producers" category 2603 firms, corresponding to 42.71% of the sample and belonging mostly to the food and drinks, metallic products (excluding machinery and equipment), non-metallic mineral products, and publishing, graphic arts and reproduction sectors.
3. In the "specialised suppliers" category 526 firms, equivalent to 8.63% of the sample, from the mechanical machinery and equipment, medical, precision and optical instruments, and office machines and computers.
4. In the "science-based" category 780 firms, equivalent to 12.80% of the sample, from such industries as chemicals, pharmaceutical products, electrical machinery and material, among others.

sector in which it operates. This indicator, although not the most appropriate for testing the Schumpeterian hypothesis, is the only one we could define based on the information available. Therefore, our inclusion of this variable in the analysis is to identify any potential intersectoral differences related to the effect of firm size on innovation performance, not to test the Schumpeterian hypothesis.

Table 3 shows the distribution of firms according to these classifications. It can be seen that the sample is a fair representation of the population of manufacturing firms in Spain.

On the basis of the above classification we conducted a one-way analysis of variance (ANOVA) to determine whether there are significant differences in the innovation behaviour among the different categories of firms. In this case, the null hypothesis tested is the equality of means between the different Pavitt categories for the variable DEGINN, assessed, as indicated in Section 3.2.1, in terms of the novelty of the product innovation developed. The results of the ANOVA test (Table 4) indicate the existence of significant differences among the categories analysed. Sheffe tests show significant differences for the different combinations of categories, with the exception of "supplier-dominated" firms and "large-scale producers", which form a homogeneous sub-set. The four initial categories can thus be regrouped into three *sectoral classes*:

(a) *Sectoral class 1*: encompassing supplier-dominated firms and large-scale producers;
(b) *Sectoral class 2*: corresponding to the category of specialised suppliers;
(c) *Sector class 3*: corresponding to the category of science-based firms.

Table 5 presents the descriptive statistics for the variables analysed in each of the *sectoral classes*. In general terms, the descriptive statistics of the sample confirm some of the patterns of technological change proposed by Pavitt (1984). The firms grouped in sectoral class 3 (science-based firms) put more effort into in-house R&D activities than firms in sectoral class 1 (supplier-dominated and large-scale producers). Similarly, as the industry's technological intensity increases, the firm's innovative performance improves.[6]

With respect to appropriability conditions, science-based firms are those that attribute more importance to legal and strategic protection mechanisms. Furthermore, in line with Pavitt's observations, firms in sectoral class 1 consider strategic protection mechanisms to be more important, while specialised suppliers (sectoral class 2) value legal protection mechanisms more.

On the other hand, science-based firms attribute more importance to cooperation with scientific institutions.

[6] Innovative performance is measured by the mean value of variable DEGINN (defined in Section 3.2.1) and the percentage of firms that develop new products.

Table 2
Description of variables

Variable	Description	Scale of measurement
DEGINN	Degree of novelty of product innovations introduced in 1998–2000	0: The firm introduced no new products into the market 1: Products were introduced that were new to the firm 2: Products were introduced that were new to the market
CFIRM	Importance of cooperation with other firms of the same group in R&D activities and innovation during the period 1998–2000	0: No cooperation; 1: low; 2: medium; 3: high
CCUST	Importance of cooperation with customers in R&D activities and innovation during the period 1998–2000	0: No cooperation; 1: low; 2: medium; 3: high
CSUPP	Importance of cooperation with suppliers in R&D activities and innovation during the period 1998–2000	0: No cooperation; 1: low; 2: medium; 3: high
CCOMP	Importance of cooperation with competitors in R&D activities and innovation during the period 1998–2000	0: No cooperation; 1: low; 2: medium; 3: high
ITO	Mean value of scores given to CFIRM, CCUST, CSUPP, CCOMP	Values continuous from 0 to 3
CEXP	Importance of cooperation with experts and consultants in R&D activities and innovation during the period 1998–2000	0: No cooperation; 1: low; 2: medium; 3: high
CLAB	Importance of cooperation with laboratories and R&D firms in R&D activities and innovation during the period 1998–2000	0: No cooperation; 1: low; 2: medium; 3: high
CUNI	Importance of cooperation with universities in R&D activities and innovation during the period 1998–2000	0: No cooperation; 1: low; 2: medium; 3: high
CPRO	Importance of cooperation with public research bodies/technology centres in R&D activities and innovation during the period 1998–2000	0: No cooperation; 1: low; 2: medium; 3: high
NITO	Mean value of scores given to CEXP, CLAB, CUNI, CPRO	Continuous values from 0 to 3
PAT	Importance for protection of inventions and innovations attributed to patents	1: Not used; 2: low; 3: medium; 4: high
UTMOD	Importance for protection of inventions and innovations attributed to registration of utility models, design	1: Not used; 2: low; 3: medium; 4: high
TRMK	Importance for protection of inventions and innovations attributed to trade marks	1: Not used; 2: low; 3: medium; 4: high
COPYR	Importance for protection of inventions and innovations attributed to copyright	1: Not used; 2: low; 3: medium; 4: high
LMP	Mean value of scores given to patents, utility models and trade marks	Continuous values from 1 to 4
SECRECY	Importance for protection of inventions and innovations attributed to trade secrecy	1: Not used; 2: low; 3: medium; 4: high
COMDIS	Importance for protection of inventions and innovations attributed to complexity in design	1: Not used; 2: low; 3: medium; 4: high
LEADTIME	Importance for protection of inventions and innovations attributed to lead time over competitors	1: Not used; 2: low; 3: medium; 4: high
SMP	Mean value of scores given to trade secrecy, complexity in design and lead time	Continuous values from 1 to 4
TECIN	Technological intensity	0, if the firm spent nothing on R&D in the year 2000 1, if R&D spend/innovation spend, in the year 2000, is more than zero but less than 10% 2, if R&D spend/innovation spend, in the year 2000, is greater or equal to 10% and less than 20% 3, if R&D spend/innovation spend, in the year 2000, is greater or equal to 20% and less than 50% 4, if R&D spend/innovation spend, in the year 2000, is greater or equal to 50%

Table 2 (*Continued*)

Variable	Description	Scale of measurement
INNRANK	Innovation ranking	0, if the firm spent nothing on innovation in the year 2000 1, if innovation spend, in the year 2000, is less than or equal to quartile 1 for the innovation spend in the industry to which the firm belongs 2, if innovation spend, in the year 2000, is greater than quartile 1 but less than or equal to the median for the innovation spend in the industry to which the firm belongs 3, if innovation spend, in the year 2000, is greater than the median but less than or equal to quartile 3 for the innovation spend in the industry to which the firm belongs 4, if innovation spend, in the year 2000, is greater than quartile 3 for the innovation spend in the industry to which the firm belongs
SIZE	Size	1, if the level of sales, in the year 2000, is less than or equal to quartile 1 for the turnover in the industry to which the firm belongs 2, if the level of sales, in the year 2000, is greater than the quartile 1 but less than or equal to the median for the turnover in the industry to which the firm belongs 3, if the level of sales, in the year 2000, is greater than the median but less than or equal to quartile 3 for the turnover in the industry to which the firm belongs 4, if the level of sales, in the year 2000, is greater than the quartile 3 for the turnover in the industry to which the firm belongs
RDI	Approximate indicator of the R&D intensity calculated as TECIN × (INNRANK/SIZE)	0, if TECIN × (INNRANK/SIZE) = 0 1, if 0 < TECIN × (INNRANK/SIZE) ≤ 1 2, if 1 < TECIN × (INNRANK/SIZE) ≤ 2 3, if 2 < TECIN × (INNRANK/SIZE) ≤ 4 4, if 4 < TECIN × (INNRANK/SIZE)

Also, and counter to what one might expect, for firms in sectoral class 1, industrial technological opportunities are not the most important. In fact, for the three sectoral classes analysed, non-industrial technological opportunities have a bigger mean value than industrial technological opportunities. However, it is necessary to highlight that the mean value of the variable NITO, measured on a scale of 0–3, is not higher than 0.25, which denotes a low level of cooperation.[7] These results agree with the findings from other studies (Castro and Fernández, 2006), which show that Spanish firms do not cooperate very much with external agents, and those that do, generally cooperate with scientific institutions.

[7] The results from the Community Innovation Survey (CIS) show that cooperation between Spanish firms and universities is lower than the European average. However, industry financing of university R&D activities is similar to that for the most innovative countries.

3.4. Econometric specifications and methods of estimation

To investigate the hypotheses in this paper, we propose three econometric models. The first takes industry characteristics as the explanatory variable, i.e. technological opportunities and appropriability conditions. The second includes also internal technological competences, assessed by considering R&D intensity (RDI), and the third includes two interactive terms, calculated as the product of multiplying the RDI variable by each type of technological opportunity considered.[8]

$$\text{DEGINN} = \alpha_0 + \alpha_1\text{ITO} + \alpha_2\text{NITO} + \alpha_3\text{LMP} + \alpha_4\text{SPM} + \alpha_5\text{SIZE} \quad \text{(model 1)}$$

[8] These interactive terms indicate how the effect of technological opportunities on the degree of innovation changes when the value of the RDI variable is modified by one unit.

Table 3
Distribution of firms by economic activity and Pavitt's categories

Economic activity	Pavitt's category	No. of samples	Sample (%)	% Population
Textile	1	335	5.5	5.0
Clothing and furs	1	320	5.3	6.9
Leather and footwear	1	254	4.2	3.9
Wood and cork	1	292	4.8	5.2
Paper	1	182	3.0	2.0
Rubber and plastics	1	247	4.1	4.4
Furniture	1	320	5.3	6.8
Other products	1	199	3.3	1.8
Recycling	1	36	0.6	0.2
Supplier dominated	1	2185	35.9	36.0
Food products, beverages and tobacco	2	677	11.1	14.2
Publishing, graphic arts and reproduction	2	334	5.5	6.1
Manufacture of coke oven products, petroleum refining	2	13	0.2	0.0
Non-metallic mineral products	2	434	7.1	7.5
Iron metallurgic products	2	130	2.1	1.0
Non-iron metallurgic products	2	99	1.6	0.6
Metallic products (except machinery and equipment)	2	583	9.6	14.9
Motor vehicles	2	203	3.3	1.9
Shipbuilding	2	71	1.2	1.0
Other transport material	2	59	1.0	0.3
Scale intensive	2	2603	42.7	47.7
Mechanical machinery and equipment	3	378	6.2	7.9
Office machines and computers	3	38	0.6	0.1
Medical, precision and optical instruments	3	110	1.8	1.2
Specialised suppliers	3	526	8.6	9.2
Chemistry	4	278	4.6	2.9
Pharmaceutical products	4	117	1.9	0.6
Electrical material and machinery	4	201	3.3	2.7
Electrical components	4	83	1.4	0.4
Radio apparatus, TV and communication	4	70	1.1	0.4
Manufacture of aircraft and spacecraft	4	31	0.5	0.1
Science based	4	780	12.8	7.1

Table 4
ANOVA and Scheffé's test for the comparison of measures of degree of innovation among the different Pavitt's categories

ANOVA statistics			
F			72.612
Sig.			0.000
Pavitt's category	Sub-set for alpha = .05		
	1	2	3
Scheffé's tests			
Supplier-dominated firms (1)	0.37		
Large-scale producers (2)	0.45		
Specialised suppliers (3)		0.67	
Science-based firms (4)			0.79
Sig.	0.16	1	1

Table 5
Descriptive statistics of the sample

	Innovative performance			Technological opportunity		Appropriability conditions		R&D intensity
	% Firms with product innovations new to the market	% Firms with product innovations new to the firm	GRINPROD	ITO	NITO	LMP	SMP	RDI
Sectoral class								
Sectoral class 1	14	12	0.41	0.06	0.07	1.24	1.27	0.51
Sectoral class 2	26	16	0.67	0.09	0.10	1.44	1.39	1.15
Sectoral class 3	29	21	0.79	0.21	0.25	1.46	1.57	1.52

$$\begin{aligned}\text{DEGINN} &= \alpha_0 + \alpha_1\text{ITO} + \alpha_2\text{NITO} + \alpha_3\text{LMP} \\ &\quad + \alpha_4\text{SMP} + \alpha_5\text{RDI} + \alpha_6\text{SIZE} \quad (\text{model 2})\end{aligned}$$

$$\begin{aligned}\text{DEGINN} &= \alpha_0 + \alpha_1\text{ITO} + \alpha_2\text{NITO} + \alpha_3\text{LMP} \\ &\quad + \alpha_4\text{SMP} + \alpha_5\text{RDI} + \alpha_6\text{RDI} \times \text{ITO} \\ &\quad + \alpha_7\text{RDI} \times \text{NITO} + \alpha_8\text{SIZE} \quad (\text{model 3})\end{aligned}$$

These models are evaluated in each of the *sectoral classes* defined above with the aim of analysing the effect of industrial sector on the determinants of innovation.

Taking into account that the dependent variable (DEGINN) can take three values, the estimation technique we chose was multinomial logistical regression. This implies that the probability of occurrence for each of the categories of response ($J = 0, 1, 2$), is given by

$$P_{ij} = \frac{e^{\beta_j X_i}}{1 + \sum_{j=0}^{2} e^{\beta_j X_i}}$$

where X_i is the matrix of attributes of DEGINN and β_k is a vector of $m \times 1$ parameters. The reference category for the analysis is the one in which the firm did not introduce any new product into the market during the period 1998–2000 ($J = 0$), and in consequence the parameters estimated can be interpreted as follows:

$$\frac{P_{i1}}{P_{i0}} = \frac{e^{\beta_1 X_i}}{e^{\beta_0 X_i}} = e^{(\beta_1 - \beta_0) X_i} \quad \text{and} \quad \frac{P_{i2}}{P_{i0}} = \frac{e^{\beta_2 X_i}}{e^{\beta_0 X_i}} = e^{(\beta_2 - \beta_0) X_i}$$

which is the same as:

$$\left(\text{Ln}\frac{P_{i1}}{P_{i0}}\right) = (\beta_1 - \beta_0) X_i \quad \text{and} \quad \left(\text{Ln}\frac{P_{i2}}{P_{i0}}\right) = (\beta_2 - \beta_0) X_i$$

Consequently, the coefficients estimated by the regression model represent the marginal change in the logarithm of the *odds* of the assessment by the firm of the introduction into the market of products that are new to the firm (minor innovations) or new to the market (major innovations) over the category assessing the non-introduction of a new product, due to the marginal change in the explanatory variables.[9]

[9] We also conducted an ordered model to test the hypothesis, and the results obtained were quite similar to those derived from the multinomial logistic regression. However, we decided to use the latter technique because it allows us not only to identify the factors that are relevant for the development of new products but also to distinguish which among them have the greatest effect on the development of major innovations (products new to market).

Table 6
Results of the multinomial logistic regression analyses by sectoral classes

Variables	Model 1				Model 2				Model 3			
	New to the market/did not innovate		New to the firm/did not innovate		New to the market/did not innovate		New to the firm/did not innovate		New to the market/did not innovate		New to the firm/did not innovate	
	Coefficient (β)	Exp (β)	Coefficient (β)	Exp (β)	Coefficient (β)	Exp (β)	Coefficient (β)	Exp (β)	Coefficient (β)	Exp (β)	Coefficient (β)	Exp (β)
Sectoral class 1												
Intersection	−5.046		−4.393		−4.771		−4.081		−4.785		−4.079	
SIZE	0.373***	1.452	0.369***	1.446	0.245***	1.277	0.273***	1.313	0.230***	1.259	0.265***	1.303
ITO	1.134***	3.107	1.160***	3.191	1.1***	3.004	1.129***	3.091	0.966***	2.627	1.032***	2.805
NITO	0.732***	2.079	0.611***	1.843					1.443***	4.234	1.081***	2.948
LMP	0.844***	2.325	0.697***	2.008	0.731***	2.077	0.608***	1.837	0.742***	2.100	0.611***	1.842
SMP	0.880***	2.412	0.553***	1.738	0.605***	1.832	0.327***	1.386	0.601***	1.823	0.325***	1.384
RDI					0.926***	2.525	0.746***	2.108	0.993***	2.700	0.798***	2.221
ITO*RDI												
NITO*RDI									−0.677***	0.508	−0.564***	0.569
N (4788)	690/3502		596/3502		690/3502		596/3502		690/3502		596/3502	
Cox and Snell R^2	0.211				0.304				0.309			
Chi-squared (d.f.)	1134.492 (10)				1733.223 (10)				1769.476 (14)			
Overall % of correct predictions	76.21%				78.28%				78.20%			
Sectoral class 2												
Intersection	−4.959		−4.711		−4.944		−4.345		−4.996		−4.533	
SIZE	0.387***	1.472	0.576***	1.779	0.285**	1.330	0.456***	1.577	0.252**	1.287	0.449***	1.567
ITO	1.068	2.909	1.684**	5.388								
NITO	1.124*	3.079	0.219	1.245					3.582**	35.939	3.885**	48.660
LMP	0.984***	2.675	0.651***	1.917	0.7589***	2.136	0.454*	1.575	0.804***	2.235	0.5**	1.648
SMP	1.148***	3.151	0.786***	2.195	0.707***	2.029	0.416*	1.516	0.721***	2.056	0.461*	1.586
RDI					1.088***	2.968	0.869***	2.385	1.157***	3.183	0.975***	2.651
ITO*RDI												
NITO*RDI									−1.156***	0.315	−1.38***	0.250
N (4788)	135/306		85/306		135/306		85/306		135/306		85/306	
Cox and Snell R^2	0.330				0.478				0.493			
Chi-squared (d.f.)	210.521 (10)				342.428 (8)				357.338 (12)			
Overall % of correct predictions	70.34%				72.81%				72.81%			
Sectoral class 3												
Intersection	−4.455		−2.966		−4.606		−2.745		−4.584		−2.770	
SIZE	0.482***	1.619	0.158*	1.172	0.323***	1.382	0.042	1.043	0.303***	1.353	0.017	
ITO												1.017
NITO	0.813***	2.254	0.747***	2.111					1.525**	4.594	2.216***	9.174
LMP	0.868***	2.382	0.642***	1.901	0.607***	1.835	0.446***	1.561	0.597***	1.817	0.420**	1.522
SMP	0.817***	2.264	0.535***	1.707	0.565***	1.760	0.350**	1.420	0.553***	1.739	0.336**	1.400
RDI					0.889***	2.434	0.592***	1.808	0.929***	2.532	0.668***	1.950
ITO*RDI												

Table 6 (*Continued*)

Variables	Model 1				Model 2				Model 3			
	New to the market/did not innovate		New to the firm/did not innovate		New to the market/did not innovate		New to the firm/did not innovate		New to the market/did not innovate		New to the firm/did not innovate	
	Coefficient (β)	Exp (β)	Coefficient (β)	Exp (β)	Coefficient (β)	Exp (β)	Coefficient (β)	Exp (β)	Coefficient (β)	Exp (β)	Coefficient (β)	Exp (β)
NITO*RDI									−0.487***	0.614	−0.71***	0.492
N (4788)	229/390		161/390		229/390		161/390		229/390		161/390	
Cox and Snell R^2	0.285				0.415				0.428			
Chi-squared (d.f.)	261.296 (8)				418.138 (8)				435.776 (12)			
Overall % of correct predictions	64.36%				67.31%				67.82%			

The modelling strategy used was the method of backward elimination. With this strategy the maximum model, i.e. the one that includes all variables, is successively adjusted by eliminating the non-significant variables, as measured against a chosen level of significance. The data in the table correspond to the final reduced model, so some cells appear blank, indicating that the variable was not significant for that particular model.

* Significance at 10%.
** Significance at 5%.
*** Significance at 1%.

4. Results

Table 6 presents the results of the regression analyses for each sectoral class for each of the three models. The modelling strategy used was the method of backward elimination. Within this strategy the maximum model, i.e. the one that includes all variables, is successively adjusted by eliminating the non-significant variables, as measured against a chosen level of significance. The data presented in Table 6 correspond to the final reduced model, so some cells appear blank, indicating that the variable was not significant for that particular model.

In general terms, the econometric specifications considered have an acceptable predictive power, with an overall percentage of correct predictions in excess of 64% in all cases. The Chi-squared values for the degrees of freedom corresponding to each model suggest the rejection of the null hypothesis that all parameters, except the intersection, are equal to zero with a significance level of 1%. Furthermore, the values of the Cox and Snell R^2 are higher than 0.21, which is quite reasonable for qualitative dependent variable models (Amara and Landry, 2005). Likewise, we can see that the addition of both R&D intensity and interactive terms (RDI × ITO and RDI × NITO) increases the explained variance in all estimations. These results coincide with the findings of Oerlemans et al. (1998) and highlight that the models that include both internal and external factors explain innovative performance better than models in which only one type of factor is used.

The results from *model 1* show the effect of industry characteristics on innovation output when the firm's internal characteristics are not taken into account. The results corroborate the hypotheses with respect to the positive effect of technological opportunities on firm's innovation output. In general terms, for Spanish manufacturing firms technological opportunities constitute an important factor for the development of product innovations, whether major or minor, in comparison with the non-introduction of a new product into the market. In addition, the results indicate that the importance of such technological opportunities as determinants of innovation output varies not only with the industrial sector to which the firm belongs, but also with the degree of novelty of product innovation developed. For supplier-dominated firms and large-scale producers (sectoral class 1), both types of technological opportunities, industry and non-industry, are highly significant for the development of new products, both for the market and for the firm. For specialised suppliers (sectoral class 2), industrial technological opportunities are significant only for the development of minor innovations, while non-industrial opportunities have a significant effect only on major innovations. For science-based firms (sectoral class 3), industrial technological opportunities lose all explanatory power and only non-industrial opportunities exercise any significant influence on the firm's innovation output. In this latter case the Exp (β) indicates that an increase of one unit in the NITO index increases by 2.2 times the likelihood that firms will develop major innovations and by 2.1 times that they will develop minor innovations, as opposed to not introducing any new products into the market.

Two important points emerge from the above. First, when the firm's internal competences are not taken into account, the technological opportunities derived from scientific institutions, such as universities or public research organisations, constitute a key element in the development of products with a high degree of novelty, and furthermore represent the only source of relevant external knowledge in high technology sectors. These results, which differ from those in some studies (Arvantis and Hollenstein, 1996; Becker and Dietz, 2004), are evidence that scientific knowledge can exercise not only an indirect effect on the firm's innovation output, but also a direct effect on the development of highly novel products. Second, we find that as the technological intensity of the industry decreases, industry sources of knowledge, such as suppliers, customers and competitors, become more important. This result corresponds with the patterns of technological change proposed by Pavitt.

With respect to appropriability conditions, legal and strategic methods of protection (LMP and SMP) were highly significant and had positive coefficients, thus supporting the hypothesis that the firm's capacity to protect its technological knowledge is an important aspect in the development of new products. The estimated parameters further indicate that the intensity of the effect of protection methods is greater in the development of major innovations than minor ones. In all the estimations, the Exp (β) indicates that an increase of one unit in the variables LMP or SMP increases by more than two times the likelihood that the firm will introduce products new to the market. However, and counter to the hypothesis, the results do not support the existence of interindustry differences in the importance of the different mechanisms of protection of innovation.

The results obtained in *model 2*, which includes both external and internal factors as explanatory variables, support the hypothesis relating to the direct and positive effect of technological competences on innovation output. In all estimations, the R&D intensity was highly significant and had a positive coefficient, thus demonstrating its importance as a determinant of innovation. In this case, the Exp (β) suggests that an increment of one unit in the variable RDI increases by at least two times the likelihood of developing some type of product innovation as opposed to the likelihood of no innovation. Additionally, the effect of R&D intensity does not vary in accordance with the technological intensity of the industry and, in all sectoral classes analysed, it represents the most important factor in the firm's innovative performance. This result differs from the findings of Oerlemans et al. (1998) who found that for Dutch manufacturing industry, R&D intensity was a key factor only for the science-based and specialised supplier firms.

We also found that R&D intensity influences the effect of non-industrial technological opportunities on firm's innovation output, though in an unexpected direction. When the RDI variable is included in the analysis, non-industrial technological opportunities cease to be significant and disappear from the estimations, which suggests that in the presence of a high level of internal technological competences, the technological opportunities derived from non-industry sources, rather than acquiring greater value, as initially supposed, lose their importance as determinants of product innovation. This is confirmed in *model 3*, where the interactive term RDI $\times$ NITO is significant and has negative coefficients in all estimations, implying a decrease in the effect exercised by non-industrial technological opportunities on product innovation when the variable for R&D intensity is increased by one unit. This result is interesting because it shows that although there is a positive correlation between these variables,[10] when their interactive effect on innovation output is evaluated, rather than complementing each other they function as substitutes, with internal technological competences prevailing. This differs from what is generally posited in the literature where, at least at the conceptual level, a complementary effect between these variables is acknowledged, because a greater internal technological capacity not only promotes the use of external sources of scientific knowledge, but also facilitates their exploitation to develop innovative activities. A possible explanation for this phenomenon is that in Spain the manufacturing firms do not use cooperation with scientific agents as a mechanism to strengthen their core competences. In fact, university–industry cooperation in Spain is mainly based on low-level sci-

[10] The Pearson coefficient of correlation between the variables RDI and NITO is 0.391 and significant at the 1% level. This result indicates that the higher the internal technological competences, the greater the importance that the firm attributes to the use of non-industrial sources of knowledge for the development of innovation activities.

entific activities, such as consultancy and technical support.[11]

The previous finding suggests that, for Spanish manufacturing firms, the development of technological competences, mainly through in-house R&D activities, is the most important factor for the introduction of new products into the market. Cooperation with non-industry agents is only important when the firm does not have a high level of such competences. These results agree with previous research on the role of networking in Spanish manufacturing, which highlights the limited role of cooperation with scientific agents for business competitiveness, but differ from the results obtained in other contexts. For instance, Alvarez et al. (2005) found that the factors enhancing the competitiveness profiles of Spanish manufacturing firms are amount of resources devoted to R&D activities, hiring and training of the workforce, and the efforts made to establish cooperation with industrial organisations, rather than cooperation with scientific agents. On the other hand, Freel (2003) in his study on the sectoral patterns of small firm innovation in the United Kingdom, found that cooperation with universities constituted a key factor for product innovation, especially in the case of science-based firms.

In contrast to the previous case, the value of industrial technological opportunities as a determinant of innovation is largely independent of the firm's internal technological competences.[12] There are two possible reasons for this result. First, the knowledge generated by in-house R&D activities does not substitute for knowledge obtained from industrial agents, due to its different nature. Second, as suggested by Cohen and Levinthal (1990), the firm can access and exploit the knowledge generated by suppliers, competitors and customers easily and, therefore, does not require a high level of internal technological competences. In this sense, in the case of industrial technological opportunities, there is no substantial effect of in-house R&D on the capacity of the firm to exploit them.

Finally, in respect of the control variable, the estimations produced some interesting findings. In sectoral classes 1 and 2, the variable SIZE is highly significant and has a positive coefficient, both for major and for minor innovations, and its effect does not change when R&D intensity is considered. In sectoral class 3, on the other hand, the variable SIZE is more significant for major than for minor innovations; when R&D intensity is included its effect ceases to be important for minor innovations. These results show that the intensity of the relationship between the size of the firm and its innovative performance depends on the industrial sector in which the firm operates. In sectors of high technological intensity, size loses its importance as a determining factor, especially when the firm has a high level of technological competences.

5. Conclusions

In this paper, we sought to explore the level of complementarity between the firm's technological competences, derived from in-house R&D activities, and the technological opportunities available from cooperation with external agents, to develop new products.

The results show that the higher the firm's technological competences, the higher the level of cooperation with scientific agents. This result supports the idea that in-house R&D activities not only generate new knowledge, but also promote the use of external sources of scientific knowledge. Nevertheless, when we analysed the *joint effect* that such factors exercise on the firm's innovation output, rather than being complementary, they function as substitutes. This unexpected result leads us to an important conclusion. In the case of Spanish manufacturing firms, cooperation with scientific agents does not constitute a key factor to develop new products, especially when firms put a lot of effort into developing in-house R&D activities.

This conclusion, although it contradicts the scant empirical literature related to the joint effect of external and internal factors on firm's innovative performance, agrees with studies demonstrating the limited role of the cooperation with universities and public research organisations on the competitiveness of Spanish manufacturing firms. We consider that this is because in Spain, cooperation with scientific institutions is not used by firms as a way of expanding their core competences.

Furthermore, the results also confirm that the effect exercised by external and internal factors varies across industrial sectors. For supplier-dominated firms and large-scale producers, cooperation with industrial agents is very important for the development of new products, regardless of whether firms carry out in-house

[11] If we consider the case of universities located in the Valencian community, for instance, of the 12,121 contracts with firms during the period 1999–2004, 40% are service contracts, 39% are technological support contracts, and only 14% are R&D projects (Gutiérrez et al., 2007).

[12] Only in sectoral class 2 (specialised suppliers), do industrial technological opportunities cease to be significant for the development of minor innovations when we include RDI variable in the analysis. However, in all sectoral classes the interactive term RDI × ITO is not significant.

R&D. As the technological intensity of the sector increases, the effect of industrial technological opportunities decreases. Cooperation with industrial agents (customers, suppliers, competitors) thus constitutes a decisive factor for the development of new products in traditional industries, but is of no importance for science-based firms. Furthermore, in this sectoral category, the size of the firm loses importance as a determining factor, especially when the firm has a high level of technological competences.

These findings have important implications for the design of innovation policy in the Spanish and other similar contexts. On the one hand, these policies should strengthen the firm's technological competences, because they are the main determinant of product innovation and in addition contribute to cooperation with scientific agents. Interestingly, the results suggest that in order to promote university–industry relationships it would be more efficient to increase the firms' technological competences, than to engage in actions specifically targeted to the development of such relationships. On the other hand, government instruments to encourage relationships between innovation system actors, should consider that the effects of these relationships will vary according to the actors that take part and the industrial sectors to which the firms belong. In this sense, university policies must not only create favourable conditions for links with the productive sector, but also must define a strategy that can be adapted to the characteristics of the different industrial sectors with which the university will cooperate.

Finally, the estimations in this study show that the models that include both internal and external factors as variables of analysis, explain innovative performance better than models that include only one type of factor. This result demonstrates that firms' innovative performance cannot be explained satisfactorily by considering only the structural characteristic of the industry, and not taking account of the attributes and internal capacities of the organisation. Although important advances have been made in the fields of industrial economy and business management, our understanding of the innovation process can only be improved through more efforts directed towards integration of these perspectives. The modelling strategy adopted in this study makes some progress in this direction. Future research along these lines could aim at the estimation of models that consider a wider variety of explanatory factors, and, on the basis only of the variables used in this study, define empirical measures that would permit a more adequate operationalisation of the concepts analysed.

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