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External Knowledge Sourcing Strategies And In-House R&D Activities: Their Effects On Firms' Innovative Performance

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Abstract

This paper presents empirical evidence on the effect of external knowledge sourcing strategies on the development of both product and process innovations, and assesses the degree to which such effects are influenced by the firm's internal technological capacities. In our analysis, we consider two strategies for acquiring external knowledge (*BUYING* and *COOPERATING*) and two types of external sources (industrial agents and scientific agents). The analysis is based on a sample of 2,764 manufacturing firms, taken from the Spanish Survey of Technological Innovation 2000. Our results suggest that, rather surprisingly, with a high level of internal technological capabilities derived from in-house R&D activities, external knowledge acquisition from scientific agents loses its importance as a determinant of firm innovation output.

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1 Introduction

The role of external knowledge sources as determinants of innovation has been repeatedly emphasised in the literature from a range of theoretical approaches. According to the evolutionary theorists, for instance, innovation involves a process of continuous interactive learning between the firm and the various agents surrounding it (Lundvall ed., 1992; Edquist, 1997; Breschi and Malerba, 1997). Similarly, innovation network theorists (Håkannson, 1987; Baptista and Swan, 1998; Cooke and Morgan, 1998) maintain that firms rarely innovate on their own, and that the introduction onto the market of new products and processes largely depends on the firm's ability to build strong links with external agents. These approaches emphasise cooperation as an important knowledge-transfer mechanism, which allows the firm to learn from other organisations, thereby increasing its innovation capabilities.

There is a large body of empirical research into the relationship between firm cooperation and innovation performance. Tidd et al. (1997) examined a vast array of empirical studies and found that one of the main characteristics of innovative firms is that they often enter into cooperation agreements with other firms and with academic and research institutions. Cooperation with universities and research institutes, which recently has grown in importance, has been extensively analysed. Cooperation with these types of actors provide firms with the opportunity to develop research and development (R&D) projects in a more cost-effective and less risky manner, and enables universities to respond to the growing pressure for their research to meet the requirements of the real world.

However, cooperation is not the only mechanism for acquiring external knowledge. Firms can directly hire external R&D activities, acquire intangible knowledge in the form of patents or licences, or acquire technical knowledge embodied in machinery and equipment. Additionally, firms can indirectly acquire innovation-related information through scientific journals, from attendance at scientific fairs and congresses, affiliation to professional associations and even via the Internet. Several empirical studies have addressed the importance of these various mechanisms (Souitaris, 2001, 2002; Caloghirou et al, 2004).

Regardless of which mechanism the firm adopts, externally acquired technical knowledge has become pivotal to the firm's innovation strategy and is one of the most frequently explored areas in the literature. The studies referred to above, in general, consider that a firm’s internal technical capabilities are insufficient to cope with the challenges of the global market and ensure survival in an ever changing economy where technology shifts occur at an increasingly rapid pace.

Nevertheless, some researchers have warned about the risk of overestimating the role played by external knowledge sources, arguing that in many industries, innovation efforts are not only made by firms themselves, but are in-house generated (Nelson, 2000). The studies conducted by Oerlemans et al. (1998) in the Netherlands and Freel (2003) in the UK show that the firm’s internal resources are the main determinants of their innovation performance, and that creation of external networks has only a limited impact. Some authors have even suggested that in attempting to decentralise and outsource R&D activities firms may weaken their core competences (Coombs, 1996).

On the other hand, and from a more integrative perspective, other authors have pointed out that external and internal knowledge acquisition can be complementary in the innovation strategies of firms. They maintain that the effect of external knowledge sources on innovation performance, although important, depends on the internal capabilities of the firm. Rothwell (1992) highlights that links to external scientific and technical knowledge sources are effective only if the organisation is well prepared and open to external ideas and has skilled scientific and technical staff. In line with this thinking, Cohen and Levinthal’s (1989, 1990) concept of “absorptive capacity” has gained weight in recent years. This concept places special emphasis on the firm’s pre-existing knowledge in the tasks of identifying, assimilating and exploiting external knowledge. Based on this concept, it has been argued that not only do the internal efforts made by the firm to create new knowledge encourage the use of external knowledge sources, they also increase the firm’s ability to exploit these sources efficiently in the development of new products and processes. Thus, the greater the internal capabilities of the firm, the greater the effect of the different external knowledge acquisition strategies on innovation performance.

However, the above argument, though widespread, lacks empirically sound foundation. Most of the existing studies focus on the co-existence of internal and external knowledge sourcing activities in business strategies, and pay little attention to the analysis of the combined effects of these activities on the firm’s innovative performance[2]. Along these lines, this paper provides empirical evidence on the effect of the external knowledge sourcing strategies adopted on the development of both product and process innovation, and also assesses to what extent this effect is influenced by the firm's internal technical capabilities. Its contribution is in assessing the real value of external knowledge sources as the determinants of innovation. Additionally, our analysis examines the effects of these activities in relation to the particular industry in which the firm operates, and considers two different sectors: science-based firms and supplier-dominated firms. The present study focuses on the manufacturing industry in Spain, which is a technology follower country[3]. It is hoped that the results provided in this paper will facilitate comparisons and establish differences, in terms of innovation patterns, with technologically leading countries, which traditionally have been the focus of this type of analysis.

The paper is organised as follows: In section 2 we outline the methodological aspects of the empirical study, describing the data, the measures of the variables and the econometric specifications. Section 3 presents the results and section 4 provides the main conclusions from our study.

2 Data and methodology

2.1 Sample

The data used in the empirical analysis come from the 2000 Technological Innovation in Companies Survey (TICS) conducted by Spain's National Statistical Institute. This survey is based on the Oslo Manual (OECD, 1992, 1997), and provides information on the innovative behaviour of Spanish firms during the period 1998-2000. The original sample comprises both manufacturing and service companies employing a minimum of

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[2] Thus, while Arora and Gambardella (1994) demonstrate that a firm's internal know-how encourages the use of external know-how, Veugelers (1997) found evidence of an inverse relationship, i.e., that external knowledge acquisition, under certain conditions, encourages internal R&D activities. Neither of these studies, however, addresses the joint effect of these activities on innovation outcome.

[3] Spain has some of the lowest science and technology (S&T) indicator scores in the EU. Total expenditure on R&D in relation to GDP is half of the EU average and the productive sector is characterised by a concentration of low-technology traditional sectors and medium and small enterprises, with a low R&D expenditure (Castro y Fernández, 2006).

10 staff; our study includes only the manufacturing companies, which total 6 094 firms across 29 different industries[4].

Several studies in the field of industrial economics have shown that the effect of both internal and external knowledge sources upon innovation can also be determined by industrial dynamics, which should not be overlooked (Malerba, 2005). In order to control for these potential variations, in this paper we adopt the taxonomy proposed by Pavitt (1984) of patterns of technological change, which classifies firms into four different categories: supplier-dominated, scale intensive, specialised supplier and science-based firms.

Although adoption of this taxonomy can lead to certain simplifications, its applicability as a criterion for the classification of firms has been tested in several studies (Arundel et al., 1995; Cesaretto and Mangano, 1992). In the particular case of this paper, this taxonomy is extremely valuable as it classifies firms in terms of the technological knowledge sources they use to develop their innovation activities. Thus, Pavitt (1984), for instance, suggests that in supplier-dominated firms (textile, clothing and fur, furniture, etc.) the technological knowledge is mainly embodied in the machinery, equipment and capital assets produced by other sectors, while in science-based firms (pharmaceutics, electronic components, spacecraft) the main sources of knowledge are the firms' internal R&D activities and scientific research carried out by universities and public research institutions. This paper focuses on these two sectoral categories as they are the ones that display more heterogeneous innovation patterns, and are the categories of firms in which the industry dynamics associated with the use of external and internal knowledge sources are more clearly distinguishable.

We have selected a total sample of 2764 firms from the spectrum of manufacturing companies, falling within the categories of supplier-dominated and science-based industries. The distribution of the final sample analysed is shown in table 1.

[4] This is not to say that service firms (as users of technology developed in other sectors) have a passive attitude to the innovation process; it means only that, as the nature of the innovative processes vary substantially from manufacturing to service firms (Hoffman et al., 1998) , we do not consider it appropriate to analyse them jointly.

Table 1 Distribution of the sample by economic activity and industry classification

Pavitt´s Category	Economic Activity	No. of firms in sample	% sample	% population
Supplier dominated firms	TEXTILE	335	15,3%	13,8%
	CLOTHING AND FURS	320	14,6%	19,0%
	LEATHER AND FOOTWEAR	254	11,6%	10,7%
	WOOD AND CORK	292	13,4%	14,4%
	PAPER	182	8,3%	5,5%
	RUBBER AND PLASTICS	247	11,3%	12,3%
	FURNITURE	320	14,6%	18,9%
	OTHER PRODUCTS	199	9,1%	4,9%
	RECYCLING	36	1,6%	0,5%
	Total	**2185**	**79,1%**	**89,0%**
Science-based Firms	CHEMISTRY	278	48,0%	66,4%
	PHARMACEUTICAL PRODUCTS	117	20,2%	13,2%
	ELECTRICAL COMPONENTS	83	14,3%	10,1%
	RADIO APPARATUS, TV AND COMMUNICATION	70	12,1%	8,6%
	MANUFACTURE OF AIRCRAFT AND SPACECRAFT	31	5,4%	1,8%
	Total	**579**	**20,9%**	**11,0%**
		2764		

Consistent with the population distribution, the group with the largest representation in the sample is supplier-dominated firms (79.1%). Within this group, the textile industry has the highest participation, although there is no one particular economic activity that is more markedly concentrated than the rest. In the science-based group, however, the chemical industry accounts for 48% of the sample. Generally speaking, the distribution of the sample sectors in each of the two categories is similar to the distribution of the population in those categories.

2.2 Dependent variables

According to Oerlemans et al. (1998), the effects of internal and external resources on the firm's innovation outcome vary based not only on the industry in which the firm operates, but also on the type of innovation developed. Nevertheless, the literature on the sources and determinants of technological change has traditionally focused on the study of product innovation, while process innovations have been somewhat neglected (Reichstein and Salter, 2006). In order to redress the balance, in our analysis we distinguish between two dichotomous variables, one related to product innovation (PRODIN), and the other to process innovation (PROCIN). These variables are based directly on the responses to two questions in the survey, which explored whether the firm had introduced new or significantly improved products or processes during the period 1998-2000.

2.3 Explanatory variables

The first group of explanatory variables we studied relates to the different external knowledge acquisition strategies. Following Veugelers (1997), we distinguish between purchased knowledge (*BUY* strategy) and knowledge acquired through cooperation (*COOPERATION* strategy). Within the *BUY* strategy, we further distinguish between external R&D acquisition *(ERD)*, acquisition of technology embodied in machinery and equipment (*EQ*), and the acquisition of intangible technology in the form of patents, trademarks, software and the like *(TECNO)*. These variables are measured on an ordinal scale (within the range 0-4), which rates the firm's expenditure in those activities in the year 2000 in relation to its turnover in the same year[5]. Generally speaking, R&D-activity outsourcing has been associated mostly with product innovation, particularly in the case of science-based firms, and technological knowledge embodied in machinery and equipment has been assumed traditionally to be related process innovation, and particularly for supplier-dominated firms (Von Hippel, 1988). The effect of intangible technology acquisition has been relatively less explored in the literature, although it is likely that there is a positive relationship between this variable and the innovative performance of the firm.

Strictly speaking, cooperation is a more "hybrid" mode of knowledge acquisition, building as it does on both externally supplied knowledge and the internal capacities of the firm. To evaluate the effect of cooperation on innovation performance, we drew on the responses to the TICS questions about firm cooperation with various external agents for R&D and innovation during the period 1998-2000. Based on previous classifications relating to the nature of external knowledge sources (Klevorick et al., 1995), we constructed two variables—*CI* and *CNI*—with the aim of reducing the number of variables in the regression analysis. The first relates to cooperation with industrial agents

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[5] We chose this measuring technique because it not only indicates whether the firm has used the different external knowledge acquisition modalities included in the analysis; it also provides indications of the intensity of use for each mode. However, as the database does not provide direct information on the percentage of investment in these activities related to the firm's turnover, we calculated an approximate indicator based on a set of ordinal variables referring to total expenditure on innovation in relation to the firm's turnover and to innovation activities (external R&D, machinery and intangible technology) expenditure in relation to total innovation expenditure.

(clients, suppliers, competitors, and sister companies) and the second relates to cooperation with scientific agents or with agents not part of the industry chain (consultants, commercial laboratories/R&D firms, universities and public research institutions). These variables are measured on an ordinal scale (in the range 0-4) according to the number of collaborative agents in each category. The Cronbach alpha coefficients reveal that the two variables can be considered measures of one single unidimensional latent construct (*CI* alpha of 0.88 and *CNI* alpha of 0.92), thereby indicating that both have a good degree of reliability[6].

The effect of cooperation with external agents on the innovation performance of firms has been extensively examined in the literature. On the one hand, these studies identified sectoral variations associated with greater relative importance of cooperation with scientific agents for science-based firms, and greater relative importance of cooperation with industrial agents for supplier-dominated firms (Freel, 2003; Oerlemenas, 1998). On the other hand, although universities and R&D institutes have traditionally been recognised as key actors in new product development, the role they play in process innovation is far from clear (MacPherson, 1997; Reichstein and Salter, 2006).

Compared to the use of *BUY* strategies for the acquisition of knowledge, cooperation has some benefits arising out of the scale economies and reduction of costs and uncertainties associated with the innovative activities (Becker and Peters, 1998; Robertson and Langlois, 1995). However, the transaction costs (coordination, management and control of the activities carried out by the different parties) are higher (Arrow, 1962; Williamson, 1989).

The second group of explanatory variables relates to the firm's internal technological capabilities. Specifically, we included two variables traditionally considered to be indicators of the efforts made by firms to create and assimilate new knowledge. The first variable refers to the effort expended on internal R&D activities (*IRD*) and the second to efforts made to train staff directly involved in the development of innovations *(TRAINING).* These variables are measured on an ordinal scale (range 0-4), which represents the firm's expenditure in those activities during the year 2000 in relation to its

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[6] Cronbach alpha coefficients measure the level of reliability among a given number of variables. Although it is not a statistical test in the strict sense, it can be considered a measure of consistency that indicates to what extent a set of variables represents the same construct (Hair et al., 1998).

turnover for that year[7]. Both internal R&D activities and training efforts increase the existing organisational knowledge base and the ability of the firm to economically utilise this knowledge (Caloghirou et al, 2004). While related empirical studies have demonstrated the importance of internal R&D as a determinant of firm's innovative performance, they are inconclusive as to the influence of investments in staff training on new process development or new product launch.

At the same time, various authors have suggested that the effect of external knowledge sources on the firm's innovation performance is not completely exogenous, but depends on the internal capacities of the organisation. Thus, Harabi (1995) and Klevorick et al. (1995), for instance, uphold that only those firms with a critical mass of knowledge are able to use the knowledge that exists in their environment to expand their own innovation capabilities. In line with this view Cohen and Levinthal (1989, 1990) pointed to the two faces of R&D in terms of the different effects of internal R&D activities on the firm's innovation performance. There is a direct and positive effect, since these activities engender new knowledge which can be used for the development of new or enhanced products and/or processes. In addition there is an indirect effect, resulting from the increase in the firm's absorptive capacity, which facilitates the acquisition and exploitation of external knowledge. This latter effect is particularly relevant when the knowledge is of a scientific or technological nature, because its absorption and utilisation will require greater efforts on the part of the firm. This applies to knowledge acquired through cooperation with scientific agents or R&D outsourcing.

Thus, higher investment in internal R&D is not only likely to increase the potential to generate both product and process innovations, but is also likely to emphasise the role of external scientific and technological knowledge sources as determinants of innovation. This implies that the greater the firm's internal capacities, the greater the effect external knowledge source is likely to have on the firm's innovative performance.

We also included as a control variable a measure for firm size *(SIZE).* Although the importance of size as a determinant of innovation has been extensively analysed, it is difficult to determine *a priori* its real influence. The Schumpeterian hypothesis holds that, as large firms own the necessary resources (infrastructure, financial resources,

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[7] These variables were built in a similar way to the variables used to evaluate the different types of purchased knowledge.

production and marketing capabilities, R&D) to cope with the risks associated with innovation processes, they are more likely than their smaller counterparts to engage in innovative activities. Some recent empirical works have found evidence to support this hypothesis (Freel, 2003; Reichstein and Salter, 2006). Other studies, however, have yielded contradictory results. Acs and Audretsch's (1988) work, for instance, shows that small and medium enterprises (less than 250 employees) are more innovation-intensive than larger firms due, amongst other reasons, to their lower degree of rigidity when faced with innovations (Caloghirou *et al.*, 2004; Cohen, 1995).

The *SIZE* variable in this analysis is measured on an ordinal scale (range 1-4), which represents firm turnover relative to the industrial 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[8]. 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.

2.4 Econometric specifications and estimation methods

To meet the objective outlined in Section 1, we defined the following econometric models:

$$INNOV_i^d = \alpha_0 + \alpha_1 ERD_i + \alpha_2 EQ_i + \alpha_3 TECNO_i + \alpha_4 CI_i + \alpha_5 CNI_i + \alpha_6 SIZE_i \quad \textbf{(mod. 1)}$$

$$INNOV_i^d = \alpha_0 + \alpha_1 ERD_i + \alpha_2 EQ_i + \alpha_3 TECNO_i + \alpha_4 CI_i + \alpha_5 CNI_i + \alpha_6 IRD_i + \alpha_7 TRAINING_i + \alpha_8 SIZE_i \quad \textbf{(mod. 2)}$$

$$INNOV_i^d = \alpha_0 + \alpha_1 ERD_i + \alpha_2 EQ_i + \alpha_3 TECNO_i + \alpha_4 CI_i + \alpha_5 CNI_i + \alpha_6 IRD_i + \alpha_7 TRAINING_i + \alpha_8 SIZE_i + \alpha_9 IRD_i * ERD_i + \alpha_{10} IRD_i * CI_i + \alpha_{11} IRD_i * CNI_i \quad \textbf{(mod. 3)}$$

where *i* = 1,...,N (number of occurrences); d = *PRODIN*, *PROCIN*.

In the first model, we analyse the effect of external knowledge sources on the firm's innovation performance, regardless of its internal technological capabilities. In the second model, we include *IRD* and *TRAINING* as additional explanatory variables in

[8] Log specification is acknowledged by the literature as being the most appropriate technique for measuring firm size and testing the Schumpeterian hypothesis (see Kamien and Schwartz, 1982; Cohen, 1995).

order to determine to what extent internal capabilities influence the innovation outcome and ascertain their impact on the effects of external knowledge sources. Model 3 includes three interactive terms, derived from product of multiplying the *IRD* variable (moderating variable) by the E*RD, CI*, *CNI* variables (moderated variables), in order to explore this aspect further[9].

The joint estimation of these models allows us to identify the effect of external knowledge acquisition upon the firm's innovative performance, and to confirm whether internal R&D efforts increase the importance of such a strategy.

The above three models were estimated for each of the two sectoral classes analysed, employing "new or significantly improved product introduction (PRODIN)", and "new or significantly improved process introduction (PROCIN)" as dependent variables. This yielded 12 logistic equations, which, based on the dichotomy of the dependent variables, were estimated using binary logistic regression.

3 Results

3.1 Descriptive statistics

Tables 2 and 3 present the basic statistics for the variables used in the regression analysis along with their correlation coefficients.

[9] These interactive terms indicate how the effect of external knowledge sources on the innovation outcome varies when the *IRD* variable is modified by 1 unit.

Table 2 Descriptive statistics and Spearman's correlation coefficients (supplier-dominated firms)

	Mean	SD	PRODIN	PROCIN	ERD	EQ	TECNO	CI	CNI	IRD
PRODIN	0,242	0,428								
PROCIN	0,254	0,435	,461(**)							
ERD	0,130	0,568	,303(**)	,275(**)						
EQ	0,685	1,365	,458(**)	,644(**)	,237(**)					
TECNO	0,033	0,212	,112(**)	,163(**)	,115(**)	,185(**)				
CI	0,063	0,426	,252(**)	,140(**)	,275(**)	,093(**)	0,039			
C-Other firms	*0,019*	*0,137*								
C-Clients	*0,011*	*0,106*								
C-Suppliers	*0,021*	*0,144*								
C-Competitors	*0,011*	*0,104*								
CNI	0,061	0,424	,236(**)	,162(**)	,252(**)	,110(**)	0,007	,619(**)		
C-Experts and Consultants	*0,014*	*0,116*								
C-Labs and R&D firms	*0,012*	*0,108*								
C-Universities	*0,018*	*0,134*								
C-Public Research Institutes and Technology Centres	*0,017*	*0,131*								
IRD	0,443	1,093	,572(**)	,424(**)	,337(**)	,313(**)	,061(**)	,283(**)	,294(**)	
TRAINING	0,118	0,463	,322(**)	,364(**)	,197(**)	,346(**)	,104(**)	,125(**)	,158(**)	,360(**)

**Correlation is significant at the 0.01 level (bilateral).

Table 3 Descriptive statistics and Spearman's correlation coefficients (science-based firms)

	Mean	SD	PRODIN	PROCIN	ERD	EQ	TECNO	CI	CNI	IRD
PRODIN	0,527	0,500								
PROCIN	0,418	0,494	,389(**)							
ERD	0,387	0,920	,293(**)	,267(**)						
EQ	0,819	1,364	,309(**)	,453(**)	,221(**)					
TECNO	0,064	0,329	0,075	,206(**)	0,026	,128(**)				
CI	0,461	1,151	,312(**)	,350(**)	,416(**)	,176(**)	0,041			
C-Other firms	*0,130*	*0,336*								
C-Clients	*0,112*	*0,316*								
C-Suppliers	*0,119*	*0,324*								
C-Competitors	*0,100*	*0,300*								
CNI	0,553	1,230	,350(**)	,314(**)	,453(**)	,176(**)	-0,003	,784(**)		
C-Experts and Consultants	*0,114*	*0,318*								
C-Labs and R&D firms	*0,116*	*0,320*								
C-Universities	*0,171*	*0,377*								
C-Public Research Institutes and Technology Centres	*0,152*	*0,359*								
IRD	1,679	1,729	,574(**)	,374(**)	,339(**)	,234(**)	0,03	,386(**)	,423(**)	
TRAINING	0,219	0,596	,249(**)	,191(**)	,125(**)	,331(**)	,099(*)	,112(**)	,088(*)	,204(**)

**Correlation is significant at the 0.01 level (bilateral).
*Correlation is significant at the 0.05 level (bilateral).

In line with Pavitt's (1984) findings, science-based firms show a better innovation performance than supplier-dominated firms, and supplier-dominated firms innovate more in processes while science-based firms innovate more in products.

The descriptive statistics also show some differences in terms of the use of knowledge sources. Thus, supplier-dominated firms mostly invest in the acquisition of knowledge embodied in machinery and equipment, while science-based firms devote most of their efforts to generating internal R&D. Furthermore, science-based firms cooperate more than supplier-dominated firms with external agents, although in general the level of cooperation is still below the European average[10]. Even though cooperation with scientific agents is the most frequent form of collaboration for science-based firms, surprisingly, cooperation with industrial agents is not proportionately greater in the case of supplier-dominated firms. These results coincide with those found by other authors (Castro and Fernández, 2006), and demonstrate that Spanish firms in general engage in low levels of cooperation and that those that do collaborate are more likely to choose scientific institutions as cooperation partners.

On the other hand, although the correlation matrix shows significant and positive correlations among nearly all the variables analysed, in only some cases do the estimated coefficients show a values that point to high or moderate association[11]. In the two sectoral categories analysed, internal R&D activities show strong correlation with product innovation and moderate correlation with process innovation. This variable is also positively related to external knowledge sources, and especially to the acquisition of external R&D and cooperation with scientific agents in the case of science-based firms. The latter may be an indication of the twofold effect of R&D, in that the greater the effort put into such activities, the greater is the firm's ability to identify and use external knowledge sources.

The correlation coefficients for product and process innovations indicate moderate levels of positive correlation. This is in keeping with Martínez-Ros's (2000) findings, which indicate a strong complementarity between product and process innovation in Spanish manufacturing firms, and is also consistent with Pisano's (1997) arguments on the interdependence of the two types of innovation.

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[10] According to Eurostat data based on the Community Innovation Survey (CIS3).

[11] According to Hopkins (2000), a correlation coefficient lower than 0.30, albeit significant, has such a small effect that it can be considered as indicating little or no correlation. In the range 0.30 to 0.50 correlation can be considered moderate, and in the range 0.50 to 0.7 the correlation is high. Coefficients higher than 0.70 indicate a high level of association between the variables.

3.2 Regression analysis

The results of the regression analysis are presented in tables 4 and 5. Table 4 shows the estimations for the supplier-dominated firm category, and table 5 presents the estimations for the science-based firm category.

Table 4 Determinants of innovation performance of supplier-dominated firms, results of the regression analysis.

	Variables	Model 1			Model 2			Model 3		
		B	Sig.	Exp B	B	Sig.	Exp B	B	Sig.	Exp B
Product innovation	SIZE	0,564	0,000	1,757	0,430	0,000	1,537	0,410	0,000	1,507
	ERD	0,473	0,000	1,605	0,174	0,110	1,190	0,426	0,002	1,531
	EQ	0,588	0,000	1,800	0,541	0,000	1,718	0,539	0,000	1,714
	TECNO	0,393	0,086	1,482	0,391	0,111	1,478	0,419	0,087	1,520
	CI	1,024	0,001	2,783	0,917	0,009	2,503	1,097	0,072	2,995
	CNI	0,343	0,210	1,409	-0,079	0,800	0,924	1,503	0,008	4,496
	IRD				0,851	0,000	2,342	0,968	0,000	2,632
	TRAINING				0,422	0,001	1,525	0,423	0,001	1,526
	IRD*ERD							-0,222	0,001	0,801
	IRD*CI							-0,021	0,920	0,979
	IRD*CNI							-0,656	0,001	0,519
	Constant	-3,377	0,000	0,034	-3,464	0,000	0,031	-3,471	0,000	0,031
	R^2 *Cox & snell*	0,234			0,328713935			0,338822774		
Process innovation	SIZE	0,511	0,000	1,668	0,405	0,000	1,499	0,386	0,000	1,471
	ERD	0,448	0,000	1,565	0,235	0,028	1,265	0,360	0,019	1,434
	EQ	0,981	0,000	2,668	0,927	0,000	2,527	0,926	0,000	2,525
	TECNO	0,693	0,016	2,000	0,651	0,027	1,917	0,661	0,025	1,936
	CI	0,226	0,306	1,254	0,073	0,746	1,076	0,207	0,631	1,230
	CNI	0,086	0,702	1,090	-0,061	0,792	0,941	0,856	0,056	2,354
	IRD				0,506	0,000	1,659	0,571	0,000	1,770
	TRAINING				0,790	0,000	2,203	0,766	0,000	2,151
	IRD*ERD							-0,104	0,122	0,901
	IRD*CI							-0,027	0,860	0,973
	IRD*CNI							-0,348	0,035	0,706
	Constant	-3,479	0,000	0,031	-3,518	0,000	0,030	-3,505	0,000	0,030
	R^2 *Cox & snell*	0,331			0,371673222			0,375569991		

Table 5 Determinants of innovative performance of science-based firms, results of the regression analysis.

	Variables	Modelo1			Modelo2			Modelo3		
		B	Sig.	Exp B	B	Sig.	Exp B	B	Sig.	Exp B
Product innovation	SIZE	0,301	0,000	1,351	0,136	0,181	1,146	0,137	0,188	1,147
	ERD	0,313	0,009	1,367	0,124	0,345	1,132	0,413	0,077	1,511
	EQ	0,360	0,000	1,434	0,312	0,000	1,366	0,307	0,000	1,359
	TECNO	0,427	0,187	1,533	0,496	0,137	1,641	0,442	0,197	1,555
	CI	-0,194	0,388	0,824	-0,188	0,450	0,828	0,196	0,730	1,217
	CNI	0,637	0,003	1,891	0,337	0,164	1,401	0,702	0,197	2,018
	IRD				0,704	0,000	2,022	0,799	0,000	2,223
	TRAINING				0,291	0,145	1,338	0,245	0,233	1,278
	IRD*ERD							-0,143	0,077	0,866
	IRD*CI							-0,116	0,511	0,890
	IRD*CNI							-0,126	0,453	0,881
	Constant	-1,251	0,000	0,286	-1,801	0,000	0,165	-1,914	0,000	0,147
	R^2 Cox & snell	0,184787606			0,348895172			0,36192521		
Process innovation	SIZE	0,393	0,000	1,481	0,315	0,002	1,371	0,312	0,003	1,367
	ERD	0,166	0,137	1,181	0,078	0,500	1,081	0,629	0,013	1,876
	EQ	0,714	0,000	2,042	0,684	0,000	1,983	0,698	0,000	2,010
	TECNO	1,576	0,004	4,837	1,535	0,005	4,642	1,523	0,003	4,588
	CI	0,442	0,024	1,556	0,483	0,015	1,621	-0,223	0,714	0,800
	CNI	0,062	0,726	1,064	-0,114	0,532	0,892	0,777	0,178	2,175
	IRD				0,345	0,000	1,413	0,447	0,000	1,564
	TRAINING				0,102	0,566	1,107	0,005	0,977	1,005
	IRD*ERD							-0,221	0,008	0,802
	IRD*CI							0,213	0,231	1,238
	IRD*CNI							-0,266	0,109	0,766
	Constant	-2,279	0,000	0,102	-2,620	0,000	0,073	-2,784	0,000	0,062
	R^2 Cox & snell	0,295142785			0,329806698			0,347517265		

In general, it can be said that the econometric specifications have acceptable predictive power, with an overall percentage of accurate predictions higher than 64% in all cases. Chi-square values for each model's degrees of freedom seem to point to a rejection of the null hypothesis that all parameters, except the intersection, are equal to zero with a significance level of 1%. Additionally, Cox and Snell's R^2 values are higher than 0.23 in all cases but one, being within the reasonable limits for models with qualitative dependent variables (Amara & Landry 2005).

3.2.1 The effect of external knowledge acquisition

The results of the *model 1* estimation indicate that the effect of the different modalities of external knowledge acquisition on the firm's innovation performance varies depending on industry sector and type of innovation.

For firms in the supplier-dominated category, the three *BUY* strategies studied show a positive effect on development of both product and process innovations. In addition, acquisition of technological knowledge embodied in machinery and equipment (*EQ)* has the greatest impact on innovation performance, while cooperation with external agents is shown to be of minor importance. Confirming the findings in the literature, cooperation with scientific agents (*CNI)* is shown to be not relevant for either type of innovation, and also, contrary to expectations, industry cooperation *(CI)* was found to be not significant for process innovation.

This latter result shows that in Spain, in contrast to other countries, the establishment of cooperation agreements between firms in the traditional manufacturing sectors and industrial agents does not enhance firms' production processes[12]. A likely explanation for this result is the low technological levels of the firms in these sectors, for which process innovations mainly consist of minor incremental improvements achieved through the purchase of new machinery and equipment, with the supplier's role being reduced to the provision of this equipment. Nonetheless, cooperation with industry agents was shown to be the greatest influence in product innovations. In this case, the knowledge obtained from suppliers, clients and other firms seems to be a key input in the development of new or improved products.

The analysis of the behaviour of science-based firms reveals that the effect of external knowledge sources varies significantly depending on the type of innovation developed. The acquisition of external R&D *(ERD)* has a significant influence only on product innovation, while the acquisition of intangible technology *(TECNO)* significantly affects only process innovation. Machinery and equipment acquisition *(EQ)* is the only *BUY* strategy that is shown to have a positive and significant effect on both innovation types, although, in contrast to the case of traditional firms, it is not the variable that has the greatest influence for either type of innovation.

In science-based firms, cooperation with external agents is a more relevant determinant of innovation. Whilst cooperation with industry agents has a significant and positive influence on process innovation, cooperation with scientific agents has the greatest effect on product innovation. These results are in keeping with the literature, and show

[12] In the United Kingdom, for instance, Freel (2003) found that for supplier-dominated firms the establishment of links with suppliers is an important factor for both product and process innovation.

that the more technology-intensive the industry, the more important will be the knowledge from scientific agents for new product development.

For the control variable, model 1 estimations show that size *(SIZE)* has a positive and significant effect in the two sectoral categories analysed, and for both innovation types. However, bearing in mind how this variable was operationalised (see footnote 6), we cannot conclude that these results confirm the classic Schumpeterian hypothesis.

3.2.2 External knowledge acquisition and its interaction with the firm's internal capabilities

Model 2 estimations show the effects of the different modalities of external knowledge acquisition on a firm's innovation performance, taking the firm's internal capabilities as additional explanatory variables.

First, our results highlight the importance of the firm's internal capabilities as determinants of technological innovation. The *IRD* variable exerts a significant and positive effect in all estimations, showing that for Spanish firms internal R&D efforts not only favour the development of new products, they also are an important factor in the upgrading of the productive processes[13]. Expenditure on personnel training *(TRAINING)* has a significant effect on both types of innovation, but only in the case of supplier-dominated firms. This result is interesting insofar as it shows that although science-based firms invest more than supplier-dominated firms in staff training, the influence of this activity is significant only for the latter category of firms[14].

Second, it is important to note that the firm's internal capabilities are shown to influence the effect of external knowledge acquisition on the firm's innovative performance. Also noteworthy is the fact that when we include in-house R&D in our analysis of product innovations, some of the variables associated with external knowledge acquisition lose their importance. Thus, for instance, R&D outsourcing is not significant in either of the two sectors analysed. This also applies to the acquisition of intangible technology in the

[13] In this case again, our results differ from those found by Freel (2003) for the United Kingdom where firms' internal R&D expenses were found not to be associated with process innovation for either science-based or supplier-dominated firms.

14 If we consider that most of the work force in science-based firms have higher education degrees, we could say that the higher the skill level of the staff, the lower will be the effects of training on innovation performance.

case of supplier-dominated firms, and to non-industry cooperation for science-based firms. It should also be noted that the above variables represent for the most part scientific knowledge sources. In this sense, the results suggest that, rather surprisingly, with a high level of internal technological capabilities derived from in-house R&D activities, external knowledge acquisition loses its importance as a determinant of firm innovation output. The model 3 estimations confirm the above, provided that the interactive terms ERD*IRD and CNI*IRD have a negative sign and, in some cases, are significant at 1%.

Although the empirical support for the argument is small, it is generally assumed that internal R&D efforts increase the firm's absorption capacity, thereby promoting the use of external scientific knowledge sources and streamlining its exploitation for innovation development. Peters and Becker (1999), for instance, demonstrated that in the case of the German automotive industry, R&D agreements with universities only had a significant effect on innovation outcomes when considering absorption capacity (R&D laboratories). Our results, however, indicate that although the *IRD* variable is positively correlated to the *ERD* and *CNI* variables, if we analyse their joint effects on the firm's innovation output, they do not behave in a complementary way. We can infer, therefore, that although internal R&D activities are associated with a greater use of external scientific knowledge sources (through purchase or cooperation), they do not seem to promote their utilisation for innovation development. This result suggests that the indirect effect of R&D that arises out of the increase in absorption capacity is limited. Following the conceptual framework proposed by Zahra and George (2002), we could say that in the context analysed in the current study, internal R&D efforts are associated with the firm's potential absorption capacity (acquisition and assimilation of external knowledge), but not with the actual absorption capacity realised (transformation and utilisation of external knowledge).

The above results may be related to characteristics inherent in the context analysed. According to Molero and Buesa (1996), in Spain, most firms—including innovative ones—are at a lower technological level than their international competitors, and therefore it is to be expected that a high percentage of the product innovation introduced in the marketplace consists of small incremental improvements. Along these lines, some authors (Acosta and Coronado, 2002) have proved that the low scientific level of the innovations performed by Spanish firms is related to improvements building mainly on these organisations' accumulated know how. In this framework, firms do not use cooperation with scientific agents as a mechanism to strengthen their innovative competences, which limits the effect of scientific knowledge sources on technological innovation. The proof of this can be seen in the quality of the services provided by universities to firms, which mainly consists of occasional activities, with little scientific content, such as consultancy or technological support[15].

The above shows that the innovative performance of Spanish manufacturing firms, especially in terms of new products introduced in the marketplace, is mainly determined by the firm's internal technological capabilities. These results are consistent with the findings from other studies that show that the value of external factors in innovation processes may have been overestimated by the network approach (Sternberg, 2000; Oerlemans et al., 1998), and point to an estimation of the importance of cooperation in conditional terms. As Freel (2003, p 762.) puts it: "*certain types of cooperation are associated with specific types of innovation, involving certain firms, in certain sectors*", to which we would add an additional rider: and certain levels of internal technological capabilities.

Also worth noting is that both machinery and equipment acquisition and cooperation with industrial agents have the same influence in model 2 as in model 1, proving that, unlike scientific knowledge sources, the effect of industrial knowledge sources on innovation performance is largely dependent on the firm's internal technological capabilities. This is to be expected if we bear in mind that the knowledge generated by in-house R&D activities, in principle, is different in nature from that generated through the purchase of machinery or cooperation with industrial agents. Additionally, as suggested by Cohen and Levinthal (1990), the firm can fairly easily access and exploit the knowledge generated by suppliers, competitors and customers and, therefore, does not require a high level of internal technological competences.

Last, but not least, it should be noted that in model 2, the *SIZE* variable loses significance for product innovation by science-based firms. Again, although these

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[15] For instance, if we consider the case of the universities located in the Autonomous Community of Valencia, out of the 12,121 contracts entered into between the universities and private businesses in the period 1999-2004, 40% consisted in the provision of services, 40% were technological support and only 14% were R&D agreements (Gutierrez et al., 2007).

results do not allow us to confirm the Schumpeterian hypothesis, they indicate that the effect of size on innovation performance may vary depending on the type of innovation, the industry sector and the internal technological capabilities of the firm.

4 Conclusions

The importance of external knowledge sourcing in the firm's innovative strategy is a subject that has been extensively addressed in the recent literature. On the one hand, it has been established that firms are not self-sufficient with regard to technological resources and that they therefore need to combine their capabilities with the capabilities that exist in other companies and institutions. On the other hand, it has been pointed out that the availability of external knowledge, instead of discouraging expenditure on internal R&D, could promote the development of inhouse capabilities and even complement them and improve innovative performance. This paper has addressed those relationships and, unlike previous studies, it not only examines the coexistence of external and internal knowledge acquisition in business strategies, but also studies their joint effect on the development of both product and process innovations. We distinguished in our analysis between external scientific and industrial knowledge sources, and took account of the possible moderating effect of industry dynamics. We included two sectoral categories: supplier-dominated firms and science-based firms.

The effects of the different external knowledge sources on the firm's innovation performance are partly consistent with the existing literature. Along this line, it is all the more surprising that cooperation with industrial agents for process innovation in the case of supplier-dominated firms is not significant, but it is important for science-based firms. Although suppliers are not the only group of industrial agents considered in the analysis, this result indicates that their importance as a knowledge source for the improvement of production processes in traditional industry firms is limited to the supply of machinery and equipment.

With regard to the relationships between external knowledge sourcing and internal R&D activities, our study provides no indications of support for the complementarity hypothesis. More importantly, our analysis reveals that depending on the type of innovation developed and the nature of the external knowledge, the effect of external knowledge sources on the firm's innovation performance may decrease as the firm's

R&D efforts increase. Thus, the greater the firm's internal technological capability, the less important is the acquisition of external R&D and cooperation with scientific agents in determining product innovation. This is true for science-based firms also, despite the fact that the literature generally assumes that for such firms new product development exceeds the limits set by their internal capabilities. However, when external knowledge is acquired from industrial sources, be it through purchase or cooperation, the effect on innovation performance does not depend on the development of internal R&D activities.

In general, the results obtained support the idea that innovation is a process that largely builds on the firm's internal capabilities, and warn against the risk of overrating external knowledge sourcing. In this regard, neither R&D outsourcing nor cooperation with scientific agents seem to play a key role in expanding the core competences of the firm, let alone replacing internal R&D efforts as determinants of innovative performance. In contrast to the general trend in innovation policies, which stress and promote cooperation between universities and firms, our results show that the networks that have the greatest effect on innovation performance are those established among industrial actors along the value chain.

However, we cannot generalise or extend the above statements to other contexts than the manufacturing industry in a technology follower country; some of the patterns identified in this study differ from those found in previous research conducted in countries with higher levels of scientific and technological development. Policy makers in technologically backward countries should note this and avoid defining innovation promotion mechanisms that respond to the dynamics of developed countries. Our results suggest that, rather than promoting the establishment of relationships with scientific agents, innovation policies in Spain should focus on strengthening the technological capabilities of firms as these capabilities have the greatest influence on innovation, and on increasing firms' human capital, encouraging the spread of new technologies, and focusing on the implementation of innovation networks of firms. University policies, on the other hand, rather than indiscriminately promoting the commercialisation of their knowledge and technological capabilities, should define strategies that take account of the requirements of the sectors and firms being targeted.

Finally, we should emphasise that, given the lack of empirical studies on this topic, our results provide some suggestions about the importance of external knowledge acquisition on innovation performance, bearing in mind both the characteristics of the firm and the specificities of the context. Analysis of the complementarity of firms' innovation strategies constitutes an interesting area for future empirical research.

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