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Absorptive capacity, technological opportunity, knowledge spillovers, and innovative effort

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Abstract

This paper analyses the influence of two variables related with industrial structure (technological opportunity and knowledge spillovers) and one management variable (absorptive capacity) on the innovative efforts developed by firms. These relationships are investigated in a total of 406 Spanish manufacturing companies with an established degree of innovative activity. In addition the nature of the variable 'absorptive capacity' is considered and an index is suggested that would render this concept operational through analysis of the factors defining it and by which the process of building it up is influenced. As a result of this study it is demonstrated that the absorptive capacity variable determines innovative effort to a greater extent than the two structural variables. It is also shown that absorptive capacity has a moderating effect on the relationship between technological opportunity and innovative effort being this one of the most remarkable results obtained from the work.

Keywords: Absorptive capacity; Technological opportunity; Knowledge spillovers; Innovation; R&D; Spain

1. Introduction

Carrying out innovative activities provides an inexhaustible source of competitive advantages. Firms, being conscious of this, strive to innovate by generating the technological knowledge necessary for developing new products and production processes or improving those already in existence. However, the intensity of this effort to innovate varies from one company to another. Such variations have been explained both through analysis of the structure of the industry within which they compete (external factors) and on the basis of their strategy and organization (internal factors).

A large number of research projects undertaken in the area of Industrial Economics, have studied the influence structural factors exerts over the innovation strategies of companies.[2] From this point of view there have been analyses of the extent to which the degree of concentration of an industry (Scherer, 1965; Levin et al., 1985), the stimulus of demand (Schmookler, 1966; Scherer, 1982), the existence of technological opportunities (Geroski, 1990; Klevorick et al., 1995), suitability for appropriation (Levin et al., 1987) or the existence of spillovers (Jaffe, 1986; Levin and Reiss, 1988) can shape the innovative behaviour of a business.

Other work has emphasized the part played by factors that are internal, and thus controllable by the firm, when it is taking decisions about the effort it should put into innovation. Hence, analyses have been performed of the influence on innovative behaviour of businesses, arising from a great number of company variables. These have included size (Cohen and Klepper, 1996), mechanisms for coordination between departments (Gupta et al., 1985), human resources procedures (Balkin and Gómez-Mejía, 1984), capacity for self-financing (Grabowski, 1968), the type of diversification strategy adopted (Scott and Pascoe, 1987), and the nature of firms' competences (Henderson and Cockburn, 1994) to name but a few.

The differing approaches to research and the difficulty of carrying out empirical studies keeping both groups of factors, structural and managerial, in view, have together led researchers to consider the effects of the two types

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[2] Excellent reviews have been published of the principal empirical studies carried out in this field, such as those by Kamien and Schwartz (1982), Baldwin and Scott (1987) and Cohen (1995).

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separately. This situation has yielded only skewed appreciations and partial explanations for the elements shaping the process of innovation in firms. However, it would seem to be of value to study the links between the two categories of factors, as this would permit an answer to be provided for various questions relating to the ways in which structural and managerial variables interact with each other and to which of them have the greatest influence on innovative behaviour in organizations.

Recently some work has focused on this aspect and has made an effort to analyse jointly the effects of both groups of variables (Veugelers, 1997; Galende and Suárez, 1999; Becker and Peters, 2000). In this wein, the present paper considers the relative weight of each of the two different groups of variables in determining innovative behaviour within companies. For this purpose, starting with a review of the literature, a specific analytic model made up of variables belonging to both groups was developed.

As industry structure related aspects, two variables were chosen. These were technological opportunity and spillovers. The reason, why these were the selected variables, was that of both them are closely linked to the fields of knowledge in which the business operates. This point means that an analysis of the relationships between structural variables and firms innovative behaviour could be enriched with the inclusion of some internal variable embodying the learning capacity with which firms face the opportunities that the close environment provides. With this aim the variable *absorption capacity* was selected, this being a variable that represents the linkage between know-how generated outside the firm and the knowledge obtained internally. The resultant model is shown in Fig. 1.

This paper has been organized as follows: Section 1 considers the characteristics of each of the variables involved in the model and suggests what relationships it seems likely would exist between them. Section 2 describes the sample, defines the measurements employed to make each of the variables usable and specifies the econometric models being checked. Section 3 presents the principal results obtained, while Section 4 sums up the main conclusions that may be drawn.

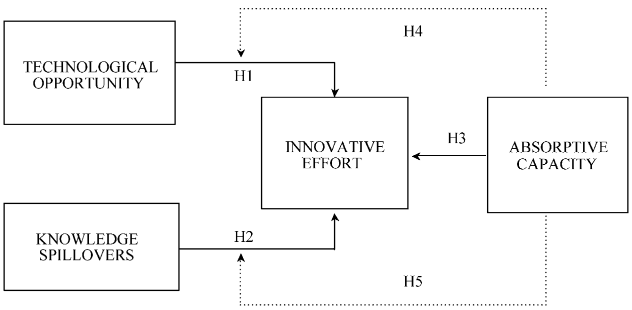

Fig. 1. The model.

2. Review of the literature and drawing up of hypotheses

2.1. Innovative effort

Effort to innovate is the dependent variable in the model. It reflects the volume of resources that a company dedicates to carrying out innovative activities over a given period of time. In empirical testing, the concept of effort to innovate is usually brought into play through the use both of absolute measurements (spending on Research and Development [R&D], number of employees working in R&D, number of hours given over to R&D), and of relative measurements (spending on R&D/volume of sales, spending on R&D/number of employees). All of these have in common the fact that they indicate the input to the process of innovation within the firm in the shape of R&D activities.

These measurements, despite their extensive use, tend to underestimate the real effort put into innovation by a firm. In fact, identifying innovative effort exclusively with the undertaking of R&D activities, with *learning before doing*, as Pisano (1997) puts it, involves ignoring the potential for innovation from the other sources of learning that are latent within companies, such as (1) through practice, *learning by doing*, which arises spontaneously as productive activities take place (Arrow, 1962); (2) through use, *learning by using*, which comes from observation of the different ways in which clients use the firm's products (Rosenberg, 1982); (3) from mistakes, *learning by failing*, derived from analysis of erroneous decisions adopted by upper management (Maidique and Zirguer, 1985). These three sorts of incremental learning generate a continuous flow of new technological know-how which the firm 'unconsciously' transforms into innovations that may have a great competitive impact (Rosenberg, 1996). It seems obvious that resources channelled by a firm into taking advantage of such sources of learning, constitute an important element within its effort to innovate.

However, despite these limitations, in this study it was decided to remain the ratio between spending on R&D and the volume of sales as a measure of innovation effort. This consistency with the majority of the empirical work hitherto undertaken (see Cohen, 1995) allows the authors to compare these results with previous work. In addition, the main sectors of industry represented in the sample used in this research are based on sciences such as chemicals, electricity or electronics, and such a measure has been shown to be appropriate in such sectors (Patel and Pavitt, 1995, p. 20). Furthermore, we are interested in representing the firm's propensity to innovate, and the effort made in order to finance R&D activities can be a good indicator for this tendency.

In this paper, while it is recognized that there are limitations in seeing a firm's innovative effort in terms exclusively of the R&D activities that it carries out, it has been decided to use as a measure of such effort the ratio between spending on R&D and the volume of sales. This solution is consistent with the majority of the empirical work hitherto undertaken (see Cohen, 1995) and has the advantage of permitting comparison of results. Similarly, it has been pointed out that this measure is the most appropriate for estimations of effort to innovate in sectors based on science like chemicals or electricity and electronics (Patel and Pavitt, 1995, p. 20), and these are precisely the sectors best represented in the sample used for this research.

2.2. Technological opportunity

It has been noticed that technological advances are easier to achieve in some industries than in others. This is largely due to the fact that the scientific and technological know-how relevant for each industry advance at different paces and with varying degrees of difficulty (Klevorick et al., 1995). The concept used in the literature to reflect the possibilities for technological progress in different industries is technological opportunity. This variable thus indicates how easy, in terms of time and costs, it is to bring about innovations in a given field of knowledge (and hence a given industry). The degree of technological opportunity depends on the nature of the technological fields themselves, on the path they have followed in the past, on how long they have been in existence and their closeness to basic science (Nelson and Winter, 1982). This variable, in combination with others, has been used to explain differences between industries observed empirically in the rates of technical progress, total productivity of factors and economic growth (Harabi, 1995, p. 67).

This paper analyses the relationship between this variable and the effort put into innovation by a firm. There is a large body of empirical evidence about the stimulus given to undertaking innovative activities arising from the presence of technological opportunities (see Table 1). Most of the work done up to the moment points out the existence of a positive linkage between the level of technological opportunity facing a firm and the efforts it makes to innovate (Scherer, 1965; Levin et al., 1985; Jaffe, 1986, 1988, 1989; Geroski, 1990; Klevorick et al., 1995). Technological opportunity exercises a crucial influence over the type and variety of the technological results attained by firms. This is especially so with regard to the level of expenditure on R&D and to the proportion of sales relating to new or improved products. Adaptation of know-how drawn from the stock of technological opportunities broadens the firm's capacities and so increases the probability of gaining success in innovating. Improvements in production arising from making use of technological opportunities lead to the achievement of more efficient production processes, greater technological knowledge and learning on the part of R&D staff. Thus, it may be considered that the greater the technological opportunity, the bigger the incentive for firms to invest in R&D, since the likelihood of obtaining positive results is greater while the effort needed to achieve them is lessened. Hence, the first hypothesis to be tested is the following:

Hypothesis 1. Firms operating in technological and scientific environments with a high level of technological opportunities put more effort into innovation.

2.3. Knowledge spillovers

Furthermore, the difficulties faced by companies in appropriating or adopting fully the results of their efforts to innovate, give rise to a mass of know-how which other organizations can make use of without having to make any outlay whatsoever for using them. This accumulation of public knowledge constitutes what has come to be called in the literature spillovers. To some extent, the existence of spillovers in an industry shows a close negative relationship with another structural variable: the conditions for apropriability. In effect, the more difficulty firms have in appropriating the new technological knowledge that they generate, the larger will be the stock of spillovers present in the industry in which they are competing (Spence, 1984). The presence of external items in a given environment will thus depend upon the specific characteristics of the knowledge in use within it, which will make it harder or easier to establish ownership rights over it, and upon the conditions for appropriating it that prevail (Zander and Kogut, 1995).

The majority of the empirical work done (see Table 2) has pointed to the fact that the existence of knowledge spillovers, while accelerating technological advances in the industry, and so increasing social returns, also has the effect of being a disincentive to private investment in R&D. This means that it reduces the level of effort companies put into innovation (Spence, 1984; Bernstein and Nadiri, 1989). This disincentive effect has been explained as triggered by two motives. On the one hand, innovative companies will limit their new investments in R&D if they see a decreased likelihood of being able to make exclusive use of the results of their efforts (Spence, 1984). On the other, imitator firms (absorbers of know-how) if they can use the stock of public technological knowledge, will do so to the detriment of any R&D activities of their own, as long as the knowledge generated by competitors can be seen as a substitute for, and not a complement to, that generated internally (Henderson and Cockburn, 1996; Levin and Reiss, 1988). The size of this disincentive effect will depend on the level and nature of the knowledge spillovers existing in any given technological environment, and on the intensity of the competition present among companies. On the basis of this reasoning, and in the light of the fact that this paper analyzes decisions to invest in R&D at a microeconomic or company level, the second hypothesis is formulated as follows:

Hypothesis 2. Firms operating in technological and scientific environments with a high level of spillovers put less effort into innovation.

Table 1
Research on the relationship between technological opportunity and innovative effort

Author	Sample	Dependent variable	Independent variable	Results
Scherer (1965)	Four hundred and forty eight largest manufacturing businesses in the USA (Fortune 500 list)	Innovative output measured in terms of number of patents obtained	Size of firm Diversification index Technological opportunity Market concentration Profits between 1955 and 1960	Technological opportunity is the principal factor responsible for differences between industries in innovative output
Levin and Reiss (1984)	Twenty manufacturing industries in the USA	Index of concentration R&D Investment Investment in advertising	Technological opportunity Appropriability Sector demand	Technological opportunity and the extent of appropriability are of weight in determining dependent variables
Pakes and Schankerman (1984)	Four hundred and forty three major manufacturing firms responsible in 1963 for 48% of all investment in industrial R&D in the USA	R&D spending	Technological opportunity Appropriability Sector demand	Technological opportunity and the extent of appropriability explain the majority of the variance observed in investment in R&D (in intra-industry analysis) Sector demand is more explantory (inter-industry analysis)
Scott (1984)	Three thousand three hundred and eighty eight business units from 437 companies in the USA	R&D spending Market value of the firm Total factor productivity	Value of non-price competitiveness Technological opportunity Entry conditions Ability to compete R&D financed by the Government	The effects of variables, at both business and sector level, including technological opportunity, explain a large proportion of the variability in the intensity of R&D R&D financed by the Government does not drive out private investment on it
Levin et al. (1985)	Six hundred and fifty R&D directors representing 130 business lines in the USA	R&D spending/sales	Technological opportunity Degree of concentration Appropriability	Technological opportunity and the extent of appropriability are highly significant in determining the dependent variable
Jaffe (1986, 1988, 1989)	Five hundred manufacturing firms spending on R&D and having obtained at least 10 patents between 1969 and 1979 in the USA	R&D spending	Spillovers Technological opportunity Other industrial factors	Technological opportunity is highly significant
Cohen et al. (1987)	Two hundred and forty four business units in 345 companies in the USA	R&D Intensity	Size of firm and of business unit Technological opportunity Appropriability	The size of the firm has minimum effect on the firm's R&D intensity when sector variables are taken into account Sector variables explain 50% of the variance in the dependent variable The size of the business unit, while not affecting the firm's intensity of R&D, does affect the probability a firm will decide to undertake such activities
Geroski (1990)	Four thousand three hundred and seventy eight significant innovations produced and used in the UK between 1945 and 1983	R&D spend/Sales	Technological opportunity Degree of concentration Profit after innovation	Variations in explain at least 60% of the variations in the level of innovation
Paricio (1993)	Forty one industries in Spain 1987–1989	R&D spending (both internal expenditure and outlays on acquiring technology from external sources)	Technological opportunity Appropriability Demand Market structure	Technological opportunity is a major factor in explaining differences between industries in R&D activities

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Table 1 (*continued*)

Author	Sample	Dependent variable	Independent variable	Results
Klevorick et al. (1995)	Six hundred and fifty R&D directors representing 130 business lines in the USA	R&D spending	Technological opportunity measured through contributions to the pool from various sources	R&D intensity is closely related to the technological opportunity represented by the strength of the connections of the given industry to various fields of science and the relevance of knowledge generated by universities
Harabi (1995)	Three hundred and fifty eight R&D directors in Switzerland in 1988	Technological progress	Contribution of several sources of knowledge to that technological progress: competitors, suppliers, public bodies, and so forth	The sources of knowledge contributing most to technological progress are those belonging to the industry, competitors, users and suppliers of materials and equipment Organizations not belonging to the industry (universities, state laboratories, independent inventors), make a minimal contribution Basic science also contributes to progress, but selectively (education and learning in areas like physics, chemistry, electrical engineering, materials science, and similar are considered highly relevant) University research makes a positive contribution only in specific fields (computing, materials science, and some others)
Veugelers (1997)	Two hundred and ninety firms with R&D expenditure in the Netherlands between 1992 and 1993	Spend on R&D financed internally by the firms in 1993	Size of firm Internationalization Degree of diversification Technological opportunity Government support R&D contracts placed externally Co-operation on R&D Existence of an R&D department Technology purchases	Technological opportunity is of relevance in determining the dependent variable
Cincera (1997)	One hundred and eighty one multinationals manufacturing businesses belonging to 15 industries with R&D expenditure between 1983 and 1991	Number of applications for patents	Present and past levels of R&D spending Spillovers Technological opportunities Geographical opportunities	Variables representing technological and geographical opportunities are highly significant, hence innovative behaviour varies considerably between countries and sectors

2.4. Absorptive capacity

In accordance with the two previous hypotheses, the existence of certain industry structure related conditions involving technological opportunity and spillovers, will influence the level of the efforts put into innovation by a company, the former in a positive way, the latter negatively. Nonetheless, according to the model being proposed, internal characteristics of the firm itself should affect the intensity of this innovative effort. The company's capacity to absorb, defined as its ability to identify, assimilate and apply for commercial purposes know-how generated outside itself (Cohen and Levinthal, 1989, 1990), has in this way been considered one of the most relevant business characteristic in determining this effort (Veugelers, 1997).

As pointed out by Cohen and Levinthal (1990, p. 128), capacity to evaluate and use external know-how is largely a function of prior related knowledge. At its lowest level, they see this prior knowledge as including basic abilities or even just shared language, but it can also refer to awareness of the most recent technological or scientific advances in a given field. These authors note that such prior knowledge arises as a by-product of carrying out own R&D activities.

Table 3 brings together details of practically all the research undertaken to date on the variable of absorptive capacity. In this work it has been recognized that this capacity has a positive effect on the productivity of

Table 2
Reseach on the relationship between spillovers and innovative effort

Author	Sample	Dependent variables	Independent variables	Results
Spence (1984)	Theoretical study	Firm's net profits	Production costs dependent on the accumulated stock of technological knowledge. This, in its turn, depends on the firm's R&D spending and on the knowledge it can gain from external sources (spillovers)	Firms in environments with considerable spillovers have only very weak incentives to invest in R&D
Jaffe (1986, 1988, 1989)	Five hundred manufacturing firms with R&D spending and obtaining at least 10 patents between 1969 and 1979 in the USA	Patents awarded Profits Firm's market value Firm's gross income	Investment in R&D Spillovers stock Technological opportunity Capital stock Market share	The stock of spillovers is significant in explaining the variance in the dependent variables
Bernstein (1988)	Firms from 8 industries (food, paper, metals, machinery, aircraft, electricity, chemicals) in Canada between 1978 and 1981	Costs and production structure of an industry	Knowledge Spillovers between and within industries Output Price of factors	Spillovers bring about a reduction in production costs in an industry Spillovers alter the structure of production (modify the proportion of factors)
Bernstein and Nadiri (1988)	Five hi-tech industries (chemicals, non-electric machinery, electrical products, transport equipment and scientific instruments) between 1958 and 1981in the USA	Variable cost	Output Physical capital Workforce Own R&D capital Other industries' R&D capital	Variable costs are reduced as a result of spillovers s Both work and the demand for materials are reduced as a response to spillovers
Levin and Reiss (1988)	Business units of manufacturing firms in the USA	R&D spending Degree of market concentration	Spillovers	There are significant variations in the level of spillovers generated in different industries and in their level of productivity
Bernstein (1989)	Firms from 9 Canadian industries between 1963 and 1983	Production cost	Output of the firms Price of factors Own R&D capital stock Other industries' R&D capital	All these industries are influenced by R&D spillovers to different degrees The effect of external factors on costs depends on the particular source of de R&D spillovers
Bernstein and Nadiri (1989)	Forty eight firms belonging to 4 industries (chemicals, oil, machinery and instruments) in the USA	Output of the firm	Physical capital Variable factors Own R&D capital Spillovers	The cost to firms receiving spillovers is reduced as knowledge spreads The demand for factors changes in response to Knowledge spillovers
Jaffe (1989)	Twenty nine States in the USA (the unit of analysis was a State)	Number of patents obtained by firms from a State in a given area of technology and period of time	Investment in R&D for an industry by a State in a specific area of technology Investment in R&D by universities in a State in a specific area of technology A variable "C" measuring the geographical coincidence between university and industrial R&D activity in a State	Knowledge spillovers from universities are relevant to the determination of the number of patents obtained by firms Geographical proximity of firms and universities working in a given area of technology increases the effect of spillovers
Henderson and Cockburn (1996)	Ten major pharmaceutical firms	Number of major patents obtained by the firm ("major" being understood as registered in at least two of the three principal economic zones, Japan, United States and Europe)	R&D spending of each investment programme Size of total R&D effort made by the firm Presence of economies of scale Degree of dispersion of technological interests Stock of prior knowledge Spillovers	Spillovers are significant when explaining the results of research by firms

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Table 2 (*continued*)

Author	Sample	Dependent variables	Independent variables	Results
Nadiri and Mamuneas (1994)	Twelve manufacturing industries in the USA	Cost structure of the industry Productivity	Prices of variable factors Quantity of output Infrastructures financed by the Government R&D financed by the Government	There are significant effects on productivity brought about by R&D capital. Costs are reduced, productivity increases and the demand for factors is also affected
Mamuneas and Nadiri (1996)	Twelve manufacturing industries in the USA	Cost structure of the industry	Prices of traditional factors Capital stock financed by the industry Capital stock financed by the State and developed by the industry Capital stock financed by the State and developed in other institutions like universities and independent laboratories	R&D financed by the Government and by an industry are replacements for each other in industries with little intensity of R&D and are weakly replacive in industries with intensive R&D R&D financed by the Government and developed within an industry has a greater effect on cost savings than R&D financed by the Government but developed outside the industry R&D financed by the Government has the effect of reducing costs while also reducing private investment in research. Tax incentives stimulate investment in R&D
Mamuneas (1999)	Firms belonging to 6 industries (chemicals, metals, non-electrical machinery, electrical products, transport equipment, scientific instruments) in the USA	Total output of the industry	Variable factors Physical capital R&D capital Investments in physical and R&D capital R&D capital financed by the Government	There are positive spillovers associated with public investment in R&D

innovative activities (Cohen and Levinthal, 1990; Cockburn and Henderson, 1998) and improves the efficiency of the process of development of new products (Atuahene-Gima, 1992; Stock et al., 2001). The various categories of knowledge to which a company can gain access as a function of the nature of its absorption capacity what its absorption capacity is have been identified (Mangematin and Nesta, 1999; Lane and Lubatkin, 1998). It has also been verified that this variable constitutes a factor for success in processes of technological knowledge transfer within organizations (Szulanski, 1996). Above all, the part it plays in the setting up of technological cooperation agreements has been analyzed as being an element explaining their success (Mowery et al., 1996; Koza and Lewin, 1998; Kumar and Nti, 1998; Lane and Lubatkin, 1998; Shenkar and Li, 1999).

There are only a few empirical studies of the relationship between the variables absorption capacity and innovative effort effort to innovate (see Table 3), although there is evidence that they are positively correlated (Cohen and Levinthal, 1989, 1990; Veugelers, 1997; Becker and Peters, 2000). Emphasis has been laid on the fact that a company's absorptive capacity in the present depends on the efforts it has made to innovate in the past (Cohen and Levinthal, 1990, p. 136). In this sense, it is clear that there is a dynamic relationship which follows a route subject to historic conditioning factors or path dependency (Arthur, 1989). This means that firms which have a record of innovating in the past will put more effort into innovation in the present and this in its turn may be expected to give rise to fresh innovations and normally to a greater innovative effort in the future (Grabowski, 1968).

In brief, companies which have successfully accumulated a certain capacity for absorption in the past will have a greater propensity to innovate in the present. This is so because they will be especially well placed to take advantage of all possible sources of know-how, whether internal or external. Consequently, the third hypothesis to be tested in this paper is the following:

Hypothesis 3. Companies with a greater absorptive capacity put more effort into innovation.

2.5. *The moderating effect of absorptive capacity*

Now that the three independent variables of the model have been defined, along with the expected relationships

Table 3
Research on the variable absorptive capacity

Author	Sample	Measure	Basic relationship	Results
Cohen and Levinthal (1989, 1990)	Thousand three hundred and two business units in 297 industrial companies in the USA	Impact on R&D expenditure of certain characteristics of the learning environment	Relates R&D spending/sales with absorptive capacity	Factors affecting ease of learning impact on the R&D spending as a proportion of sales, hence absorptive capacity exists and is relevant
Atuahene-Gima (1992)	Theoretical analysis		Relates adoption of internal technology licences to absorptive capacity.and to internal capacity to develop new products	The existence of absorptive capacity is a basic condition for adoption of internal technology licences
Nicholls-Nixon (1993)	Multinational pharmaceutical companies	Patents. Development of new products. Reputation	Relates absorptive capacity to the advantage taken (level of learning) of research alliances	Companies with greater absorptive capacity invest more in R&D, co-operate more on R&D and get more out of alliances
Mowery, Oxley and Silverman (1996)	Bilateral alliances established between 1985 and 1986 in which one of the firms is from the USA	Patents of Firm A cited in patents of Firm B/Total citations presents in Firm B's patents before the agreement	Relates overlaps in the technological interests of those co-operating to several variables such as nationality of participants, structure of the agreement, investment on R&D and Absorptive Capacity	Absorptive capacity is important in allowing the co-operating parties to get technological capabilities out of an agreement
Szulanski (1996)	One hundred and twenty two transfers of 38 management practices involving 8 originating firms	Set of items rated on a scale from 1 to 5	Analyzes factors hindering knowledge transfer between different organizational units of a single firm and groups them in four sets: characteristics of the knowledge, characteristics of the context, characteristics of provider and characteristics of the receiver (Absorptive Capacity seen as part of last)	Absorptive capacity of the receiver is one of the principal factors explaining rigidities in companies (*firm stickiness*) over transfer of knowledge between their organizational units
Veugelers (1997)	Two hundred and ninety firms with outlays on R&D in the Netherlands between 1992 and 1993	Links with basic research. Presence of an R&D department. Number of Ph.D.s in the R&D area	Relates R&D spending to absorptive capacity	Co-operation on R&D has positive effects on investment in own R&D only if there is absorptive capacity
Luo (1997)	Joint ventures established in China between local firms and multinationals between 1988 and 1991	Technology staff/Total staff	Impact of given characteristics of local firms (absorptive capacity, market strength, size, etc.) on the success of co-operation agreements	The absorptive capacity of the local associate is vital for good running of any joint venture
Cockburn and Henderson (1998)	Ten large pharmaceutical firms	Total publications per dollar spent on R&D per year	Examines the relationship between public R&D, private R&D and absorptive capacity	Only firms with absorptive capacity. are able to have access to or connect with basic research carried out by public laboratories The degree to which private companies tap into the work of public laboratories is correlated to their absorptive capacity
Koza and Lewin (1998)	Theoretical analysis		Relates the aims of alliances (exploratory/exploitation) to the form of the co-operation agreement (absorptive capacity of participants, systems of control and identification)	
Kumar and Nti (1998)	Theoretical analysis		Relates the stability and evolution of an alliance to conflicts relating to the ability of those co-operating to attain their learning objectives (linked to their absorptive capacity)	

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Table 3 (*continued*)

Author	Sample	Measure	Basic relationship	Results
Lane and Lubatking (1998)	International co-operation agreements for R&D set up between pharmaceuticals firms involved in developing therapeutic products between 1985 and 1993	Overlap of product characteristics. Formalization of management practices. Degree of centralization of decision-taking. Similarities in pay and benefit packages	Relates absorptive capacity with success within the firms in the alliance (in learning organizational skills)	The factors determining success in the relationship are the following: (1) relevance of the learning firm's basic knowledge to the teaching firm's, (2) similarity in pay and benefits practices, (3) similarity in areas of research, (4) similarity between organizational structures
Shenkar and Li (1999)	Ninety Chinese firms seeking partners for co-operation agreements	Knowledge brought by local associate (Binary variables according to whether or not the local contact brings various specific types of knowledge)	Relates the type of associate that the local firm will seek to the knowledge that it possesses; a partner complementing knowledge it already has or aiding it to expand this knowledge	Firms seek knowledge in areas complementary to their own rather than in their own area of specialization
Mangematin and Nesta (1999)	Four hundred R&D contracts drawn up between the French National Centre for Scientific Research and firms located in the area of Grenoble	R&D Spending. Number of researchers. Number of R&D laboratories. Permanence of R&D activity. Relations with public research institutes. Number of publications, of patents	Analyzes the relationship among three features: the tacit or codified nature of knowledge, its basic or applied status and the firms absorptive capacity	The presence of considerable absorptive capacity inhibits co-operation on R&D. Moreover, given this circumstance it is possible to absorb all sorts of knowledge, both basic and, through a whole range of vehicles (doctoral students, machinery, scientific staff). There is also a diversification of the mechanisms by which such an absorption can occur
Becker and Peters (2000)	Two thousand and nine hundred innovative manufacturing firms (data from the Mannheim Innovation Panel [MIP] gathered in Germany in 1993)	Existence of permanent R&D departments. R&D activities carried out continuously	The relation between the level of technological opportunity in a sector and innovative activity by firms (investments made and results obtained) and how this relationship is influenced by the presence of Absorptive Capacity	Regressions not including absorptive capacity indicate that sources linked to scientific knowledge have a very strong influence on the innovative activity of German manufacturing companies. When Absorptive Capacity is included there is an increased probability that the firm will carry out R&D actions. There is a positive relation between Absorptive Capacity and output of innovations
Stock, et al., (2001)	Firms that between 1976 and 1993 developed modems and brought them onto the market	R&D Spending/Sales	The relationship between absorptive capacity in a company and its efficiency in the process of developing new products	The relationship between absorptive capacity and efficiency in developing new products is not linear. An inverted U curve is found, suggesting diminishing returns for absorptive capacity

between them and the dependent variable, innovatory effort, it would seem necessary to gain a deeper awareness of the possible links among them.

A start will be made by analyzing the moderating influence of absorptive capacity over the relationship between technological opportunity and innovative effort. As Teece's work suggest and this article points out in Hypothesis 1, firms operating in environments with a high level of technological opportunities will have greater incentives to invest in R&D. However, the structural variable technological opportunity is not totally exogenous, but rather its impact on innovative efforts will depend on the internal characteristics of the company (Teece et al., 1997, p. 523).

In fact, the existence of technological opportunities in a given sector does not affect all the firms operating in it with the same intensity. The extent to which they make use of these opportunities will depend for the most part on the knowledge and capacities each business has at its disposal. Only firms having accumulated a critical mass of know-how and in possession of a certain capacity for absorption, will be able to take advantage of the pool of technological opportunities (Klevorick et al., 1995). In contrast, businesses not attaining the minimum critical mass of knowledge will not be able to enjoy the advantages of belonging to an environment of great technological opportunity.

In other words, the relationship posited between the variables technological opportunity and innovative effort will be moderated by the variable firm's absorptive capacity of the firm. The presence of absorptive capacity is necessary for the effect of technological opportunity on efforts to innovate to be of any weight. All the above leads to a need to look at the following hypothesis:

Hypothesis 4. Absorptive capacity exercises moderating effect over the impact of technological opportunity on firm's innovative effort.

A similar reasoning may be applied here as with respect to the relationship predicted in Hypothesis 2 between externalities and effort to innovate. Harabi (1995) points out that access by a firm to knowledge generated outside it, is in no way cost-free. Such access to know-how is possible only on condition that there has previously been generated within the firm a mass of knowledge permitting the company to understand, evaluate, assimilate and use what is on offer in its environment. Gaining such a capacity to absorb is a by-product of the firm's internal R&D activities (Cohen and Levinthal, 1989). So, it is necessary to take into account that the creation of absorptive capacity is not costless given that firms have to assume the costs associated with those R&D activities.

This view leads to a modification in the supposition of a negative relationship, as noted above, between knowledge spillovers and effort to innovate. In reality, the fact that know-how is not completely protected by its generator does not automatically imply that it will be imitated (Evenson and Kislev, 1973). Imitation will take place only if there are businesses in the environment capable of absorbing this knowledge; if not, the innovating firm will not suffer any risk to its ability to obtain adequate recompense for its efforts and, in consequence, the disincentive effect noted above will not necessarily exist.

Moreover, these considerations lead to the establishment of a distinction between investment in R&D made with the aim of creating new products and services (innovation) and that made with a view to gaining access to knowledge developed by other (imitation). In situations where the environment offers opportunities for access to valid know-how, firms might reduce their R&D for innovation, but increase what they do with an eye to improving their ability to imitate. This means that a desire to generate absorption capacity can outweigh the effect of disincentive to invest in R&D that was predicted when knowledge spillovers were present. This reasoning leads to the formulation of the following hypothesis:

Hypothesis 5. Absorptive capacity exercises a moderating effect upon the impact of the stock of spillovers on firm's innovative effort.

3. Methodology and description of the empirical study

3.1. The sample

With the aim of testing the predictions made, we carried out a survey between the Spanish industrial firms that had demonstrated some innovation activity. The sample was obtained from the database of the CDTI in which information is held relating to all the businesses which have received financing from this body. The CDTI or Centre for the Development of Industrial Technology is a public organisation depending on the Spanish Ministry of Science and Technology, involved in the promotion of innovation and the technological development of Spanish companies. In this way, the use of CDTI database gave us a guarantee that the companies included in the survey really were involved in the development of innovative activities.

After elimination of service-sector firms and filtering of the data, a population of 2030 firms was established. These were sent a questionnaire directed to the R&D manager, in those firms where that existed, or to the CEO in other case. This questionnaire included items intended to measure the firm's absorptive capacity (Appendix A). The process of gathering information ended in March 2001. By that date 406 questionnaires had been received, but of these only 401 were considered valid, so that the actual sample represented 19.75% of the total potential population. In Table 4 it may be observed how the distribution of responses is strongly concentrated in sectors based on science.

3.2. Measurements of innovative behaviour and of the structural variables

3.2.1. Innovative effort (IE)

The dependent variable in the model, innovative behaviour by the firm, is to be measured, as noted above, in terms of effort to innovate (IE).

IE = Spending on R&D/Volume of sales

3.2.2. Technological opportunity (TO)

To bring in the variable technological opportunity, in accordance with the recommendation made by Geroski (1990), preference was given to an indirect measurement of this variable, with no attempt to identify all the sources of technological opportunity one by one in such a way as to measure them individually. With this in mind, all the firms in the sample were grouped in accordance with their membership of the various groupings used by the CNAE at a two-digit level, so that the degree of technological

Table 4
Distribution of firms in the sample by CNAE* code

CNAE code	Sectors	No. of firms	% of total
15	Food and drink	33	8.12
17	Textiles	12	2.95
18	Clothing and furs	1	0.24
19	Leather and footwear	6	1.47
20	Wood and cork, excluding furniture manufacture	5	1.23
21	Papermaking	4	0.98
22	Publishing and printing	4	0.98
23	Oil refining and fuels	1	0.24
24	Chemicals	78	19.21
25	Rubber and plastics	25	6.15
26	Other mineral products	17	4.18
27	Metals	16	3.94
28	Manufacturing of metal products other than machinery and equipment	19	4.67
29	Machinery and mechanical equipment construction	72	17.73
30	Office machinery and computer manufacturing	4	0.98
31	Manufacturing of electrical machinery and equipment	18	4.43
32	Manufacturing of electronic material and radio, television and communications equipment	20	4.92
33	Manufacture of precision medical and surgical instruments, optical material and clockmaking	30	7.38
34	Motor vehicle manufacturing	11	2.70
35	Other vehicle manufacturing	9	2.21
36	Furniture manufacturing and other manufacturing industries	10	2.46
37	Recycling	6	1.47
–	Not specified	5	1.23
Total number of firms		406	≈ 100

CNAE, The Spanish National Classification of Economic Activities.

opportunity from which they benefit could then be estimated.[3] The supposition underlying this procedure is that firms belonging to the same group are involved in very similar industrial activities and so their research interests should be much alike. This would cause their technologies, being related to areas of science very close one to another, to be subjected to the same possibilities for advances, that is, to have the same technological opportunity conditions.

On the basis of this assumption, and with the aim of discovering whether there indeed is a significant difference in the average effort to innovate among the firms belonging to the various CNAE groups, an analysis of the differences in averages was performed (one factor ANOVA). The results of this check confirm that the innovatory behaviour of firms belonging to different groups is not homogeneous. Consideration of the graph showing the averages (Fig. 2) shows the existence of two clearly differentiated groups. The first includes those sectors which present an above-average innovative effort (17, 18, 24, 29, 31, 32, 33, 35, 36, 37) and the second those whose innovative efforts fall below this parameter (15, 20, 23, 30, 34). From this information an artificial variable (TO) was created, adopting a value of 1 for firms belonging to the first group (high level of technological opportunity) and of 0 for those in the second (low level of technological opportunity). This variable was to be used in later analyses.

3.2.3. Knowledge spillovers (SP)

Knowledge spillovers, as in other work on the subject (Berstein, 1988, 1989; Bernstein and Nadiri, 1988), were measured on the basis of the total R&D spending in the industry. This assumes that any firm has the same possibilities of gaining access to the stock of spillovers in the industry in which it operates. Data for spending on R&D

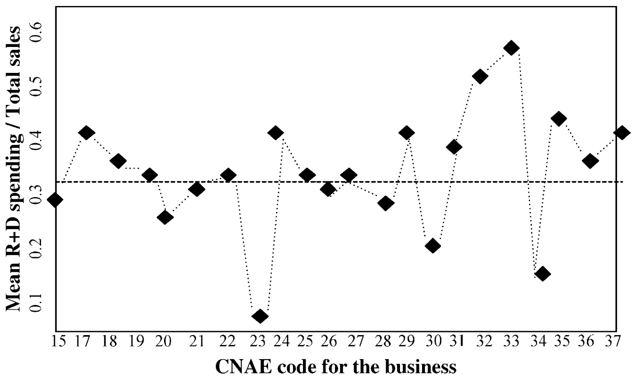

Fig. 2. Technological opportunity means by CNAE code.

[3] This approach is similar to that used in other work in which industries have been grouped by sector of activity using the SIC code (Cincera, 1997) as a function of the scientific and technological field (chemicals, machinery, electricity, biology) to which they are closest (Scherer, 1965) or according to whether they are in sectors of low, middling or high technology (Paricio, 1993).

in each sector were drawn from statistics on research and development activities (INE [Spanish National Institute of Statistics], 2001). These data refer to the sector as a whole and so include investment in R&D by the firm under study. Hence, in order to estimate the net stock of spillovers to which the firm has access, the amount of investment in R&D by the firm itself was deducted from the figure obtained from the INE. In other words, the following formula was used:

$$\mathrm{SP}_i = \sum_{\substack{j=1 \\ j\neq i}}^{n} \mathrm{RD}_j - \mathrm{RD}_i$$

where: SP_i is the level of spillovers enjoyed by firm i; RD_j is the investment in R&D by firm j; and RD_i is the investment in R&D by firm i.

3.3. Index of absorptive capacity

Unlike what happens with the structural variables, there is no standard measurement permitting operational use of the variable absorptive capacity. As is indicated in Table 3 the majority of research has worked with proxy variables relating to the results of the effort put into innovation in the past. Measures such as the number of patents or technical publications produced by the company have been used (Nicholls-Nixon, 1993; Mowery et al., 1996; Cockburn and Henderson, 1998). Use has also been made of the ratio between spending on R&D and sales (Stock et al., 2001), or the mere fact that there is a formally established R&D department in the company (Veugelers, 1997; Becker and Peters, 2000). These measures have as their main drawback their strong correlation with the variable innovative effort and are of limited use here, since for this analysis it is essential to separate these two concepts.

As an alternative, in this paper a measure for the variable has been built on the basis of identification of the principal factors having an influence, whether positive or negative, over accumulation of this capacity.[4] A first approximation to the selection of the factors that may be considered relevant for measuring the absorptive capacity is made by Cohen and Levinthal (1990) when they point out that in order to grasp what the sources of firm's absorptive capacity are, one should concentrate on the 'way the communications between the firm and the external environment' are organized, and also on the 'nature of the know-how and experience within the organization' (p. 544). They see the trade-off between internal and external components (the latter being openings to the exterior) in the absorptive capacity as requiring attention to be directed onto how the relationship between 'shared knowledge and range of knowledge' among individuals affects the development of organizational absorptive capacity. They note that while some overlapping of knowledge among individuals is necessary for internal communication, benefits are also to be obteined from the 'diversity of knowledge' between individuals (p. 545).

Furthermore, Fiol and Lyles (1985), pp. 804–805) highlight the importance of a firm's strategic positioning as an element determining its ability to learn, stating that the 'organization's strategic posture' determines in part its capacity for learning. Strategy fixes the aims and objectives and the range of actions available for developing them. Hence, strategy influences learning by setting limits on the decision making process, and a context for perception and interpretation of the environment.

In this way, and taking into account the suggestions of these authors, an attempt has been made to measure each of the groups of factors they note: (1) communication with the outside environment, (2) level of know-how and experience in the organization, (3) diversity and overlaps in the knowledge structure and (4) strategic positioning. With this in view, the indicators which appear in the questionnaire reproduced in Appendix A were used. The information collected about each of these indicators was related to a variable representing the success achieved in innovating, measured on the basis of the percentage new products constitute of the total sales by the company. An analysis of the difference in mean, (one factor ANOVA) between the various levels of each indicator is carried out. This is intended to check if the different levels for each of the indicators also determine different degrees of success in innovation.

The influence of all those variables for which a significant difference of averages was found (Table 5) is aggregated into an indicator defines as the sum of the effects of each of the factors on the dependent variable, innovatory success. The underlying assumption in this operation is that those factors proving to have a positive influence over success in innovating, do so because they affect the firm's absorption capacity and, through that, the company's commitment to R&D activities. Hence, the index offers a measurement of the theoretical or potential absorptive capacity of each company.

3.4. Statistical tools

The statistical tool used to check hypotheses 1–3, which consider the relationships, direct and individual, between each of the independent variables and the target variable, effort to innovate, was univariate regression. The equations for the regression are those shown below:

$$\mathrm{IE} = \beta_1 + \beta_2\ \mathrm{TO} \quad (1)$$

$$\mathrm{IE} = \beta_1 + \beta_2\ \mathrm{SP} \quad (2)$$

$$\mathrm{IE} = \beta_1 + \beta_2\ \mathrm{AC} \quad (3)$$

[4] In other research, such as that done by Szulanski (1996), Lane and Lubatking (1998) and Mangematin and Nesta (1999) absorptive capacity has also been measured by a set of factors.

Table 5
Measures of absorptive capacity

Significant factors	Spearman's rho
Awareness of competitors' technologies	0.152**
Awareness of customer needs	0.184***
Staff skills	0.173***
Investment in training	0.138**
Capacity for technological development	0.107**
Capacity to adapt technologies from other sources	0.156**
Range of staff training	0.131***
High level of technological specialization	−0.225***
Effort put into development of new products	0.335***
Effort put into cost reduction	−0.135**
Noteworthy economies of scale	−0.196***

Notes: *** significant at 1%; ** significant at 5%.

where IE represents companies' innovative effort and TO, SP and AC represent, respectively, the variables technological opportunity, spillovers and absorptive capacity.

To check hypotheses 4 and 5, which predict the existence of interaction effects among the independent variables, the technique of multiple regression was used. Nevertheless, in this case, and with an eye to detecting the effects of interaction, the analysis was carried out in three phases:

In the first phase two regression Eqs. (4) and (5) are used, in which innovative effort appears as the dependent variable and as independent variables there are technological opportunity and absorptive capacity in the forth, and the second of these variables together with the variable spillovers in the fith. The purpose of this analysis is to determine the joint explanatory power of the two pairs of variables mentioned.

$$\mathrm{IE} = \beta_1 + \beta_2\,\mathrm{TO} + \beta_3\mathrm{AC} \tag{4}$$

$$\mathrm{IE} = \beta_1 + \beta_2\,\mathrm{SP} + \beta_3\,\mathrm{AC} \tag{5}$$

Secondly, multiple regression analysis is reapplied to estimate, in this case, two fresh regression Eqs. (6) and (7) in which the dependent and independent variables are the same and are combined in the same way, but into which a further independent term is introduced, the effect of interaction. This term is calculated as the product obtained by multiplying the moderating variable by the variable moderated (absorptive capacity multiplied by the variables technological opportunity and spillovers, respectively[5]).

$$\mathrm{IE} = \beta_1 + \beta_2\,\mathrm{TO} + \beta_3\,\mathrm{AC} + \beta_4(\mathrm{TO{\cdot}AC}) \tag{6}$$

$$\mathrm{IE} = \beta_1 + \beta_2\,\mathrm{SP} + \beta_3\,\mathrm{AC} + \beta_4(\mathrm{SP{\cdot}AC}) \tag{7}$$

[5] It should be pointed out that the interpretation of beta coefficients in moderated relationships is somewhat different from those not moderated. The beta coefficient corresponding to each variable indicates the effect of that variable on the dependent variable when the remaining independent variables are equal to zero. The beta coefficient of the interaction factor indicates a unit change in the effect of one of the independent variables on the criterion variable when the value of the moderating variable changes by one unit.

Finally, multiple linear regression analysis is applied to estimating a model in which the dependent variable is innovative effort and the independent variables are the two structural variables (technological opportunity and spillovers), the managerial variable, (absorptive capacity) and the two interaction factors (technological opportunity with absorptive capacity and spillovers with absorptive capacity (Eq. (8)).

$$\mathrm{IE} = \beta_1 + \beta_2\,\mathrm{TO} + \beta_3\,\mathrm{SP} + \beta_4\,\mathrm{AC} + \beta_5(\mathrm{SP{\cdot}AC}) + \beta_6(\mathrm{TO{\cdot}AC}) \tag{8}$$

4. Results

Table 6 shows the results from the analyses of regression mentioned above. The variables with greatest explanatory power are technological opportunity and absorptive capacity, this latter variable being the one that by itself explains the greatest proportion of the variance in the criterion variable. These results demonstrate the existence of a significant and positive relationship between each of these two variables and the dependent variable. Hence, hypotheses 2 and 3 of the model may be not rejected. The influence of the variable spillovers may be considered almost residual but still significant, since it is able to explain a percentage of only around 2% of the variance of the dependent variable. The direction of this relationship with the criterion variable is negative, so that Hypothesis 2 cannot be rejected as borne out.

Consideration of the outcomes of Eqs. (4) and (5) highlights the variable absorptive capacity as that having the greatest explanatory power. With reference to the variable technological opportunity, there is confirmation of the existence of a significant and positive relationship between it and the criterion variable. The variable spillovers, by contrast, appears as of no significance, which is not strange in view of the weak relationship previously found between this and the dependent variable.

The findings of Eq. (6) indicate that when the effects of the moderating variable (TO·AC) are taken into account, technological opportunity ceases to be significant. This moderation factor, which would show the changes in the effect of technological opportunity on innovative effort when the capacity for absorption is modified in a unit, appears significant and with a negative sign. This confirms that in the presence of absorptive capacity, the effect of technological opportunity on innovative effort is reduced, the learning capacity of the firm prevailing in the determining of this effort. In other words, where the capacity for absorption is greater, innovative effort made by a company will be independent of the industrial conditions related to technological opportunity.

These results make it plain that there does effectively exist a moderation effect from the variable absorptive

Table 6
Results of regression analyses

Independent bariables	1	2	3	4	5	6	7	8
TO	0.315***			0.185**		–		–
	(−5.616)			(−2.300)		(1.035)		(1.187)
SP		0.144**			–		–	−0.163**
		(-2.466)			(−1.918)		(−1.918)	(−2.161)
AC			0.359***	0.297***	0.359***	0.455***	0.359***	0.439***
			(4.666)	(3.683)	(4.666)	(5.459)	(4.666)	(5.309)
TO–AC						0.225***		0.237***
						(−2.695)		(−2.874)
SP–AC							–	–
							(−1.577)	(0.677)
R^2	0.099	0.021	0.129	0.159	0.129	0.170	0.129	0.196

Notes: (1) Under the values for the beta coefficients of regression values of *t* are given in brackets; (2) variables for which no beta coefficient of regression is shown did not reach a significant value and are thus excluded; (3) ***significant at 1%; ** significant at 5%.

capacity, and so hypothesis H_4 cannot be rejected as borne out. Nonetheless, it must be admitted that the direction of this moderating effect is the opposite of what was initially expected.

The spillovers variable, in contrast, is in no way modified by the presence of absorptive capacity. This lack of significance remains and is not modified at all by the effect of the opportunity that is implied by the existence of know-how freely available for any company with the capacity to absorb this knowledge. These results require it to be accepted that there is no effect of moderation by absorption capacity on the relationship between spillovers and effort to innovate, and so, that hypothesis H_5 of the model can be rejected.

Finally, regression Eq. (8) is calculated. It may be observed how the level of explanation provided by the target variable increases to 19.6%. The variable absorptive capacity retains the greatest weight in the equation, as against the other variables. Knowledge spillovers appears as significant, with the negative sign noted in the univariate model, while technological opportunity ceases to be significant as a consequence of the action of the moderating variable. This, as mentioned above, causes a situation in which the higher the level of absorptive capacity, the lower the influence of this variable over innovative effort. The factor of interaction between the variables spillovers and absorptive capacity was not of significance in this regression either, which confirms that an effect of moderation by the managerial variable is non-existent.

5. Conclusions

As was envisaged in the theoretical model and on the same lines indicated by the majority of the publications reviewed, a positive relationship proved to exist between technological opportunity and innovative effort. This means that in those science-related research environments presenting the biggest potential for advances, company commitment to innovation is greater.

With reference to the relationship envisaged between the level of externalities and innovative effort, it is noticeable that the effect of disincentive for R&D investment by innovating firms (or the effect of replacing internal R&D with external R&D in firms adopting these innovations) is indeed greater than the incentive effect arising from companies' desire to increase their absorptive capacity when faced with the existence of a larger amount of 'freely available' knowledge. Nonetheless, although a statistically significant relationship was found, the explanatory power of this variable can be considered residual.

On the other hand, analysis of the data permits the conclusion that there exists a positive and significant relationship between the variables absorptive capacity and innovative effort. Those firms presenting a higher level of the first variable are able to use knowledge generated by other companies and so should have a greater ability to obtain profits (since their starting point is more favourable). In the same way it may be noted that this variable is the one with the greatest explanatory power. This leads to acceptance of the view that variables of business managerial type, in particular absorptive capacity, are more important in determining the effort put into innovation by companies, than the structural conditions to which the latter are subject.

In respect of moderation relationships it was possible to note that there is no moderating action in the case of the variable knowledge spillovers. For technological opportunity, while there is such an effect, it has a negative sign, that is, higher levels of absorptive capacity will lead companies to put more effort into innovation, relying on their own resources and to some extent doing without the greater or smaller range of opportunities offered by the environment.

Finally, and with reference to the nature itself of the variable absorptive capacity, a first approximation has been made to determine the factors contributing to its acquisition

(Table 5), and this has permitted the establishment of an index for measuring it.

Appendix A. Questionnaire format

Part I: General details of the firm

1. Name of firm and of person responding to the questionnaire
2. Size: volume of sales, number of staff
3. Research and development effort: average annual expenditure on R&D over the last 5 years
4. Contribution to sales by R&D: The percentage of sales represented by new products developed in the last 5 years.

Part II: measures of the firm's absorptive capacity

1. Links between the firm and the surrounding environment: Indicate level of agreement with the following statements (on a scale from 1 to 5):
   - The firm's own staff systematically undertake technological awareness surveys
   - The firm conducts frequent market research so as to be aware of customer needs
   - Licensing is a method we often use to obtain technology
   - We have developed new products and/or processes in collaboration with other firms
   - The R&D budget is spent on subcontracted research teams from outside the firm
   - The firm is well aware of the technologies being developed by competitors
   - The firm has become a technology supplier to other firms in its sector
   - The firm normally goes to other bodies (consultants, universities) to find out about fresh opportunities for introducing new products
2. Level of knowledge and experience of the organization: Indicate level of agreement with the following statements (on a scale from 1 to 5):
   - Most of our staff are highly skilled and qualified
   - We invest a great deal in training
   - We innovate by improving competitors' products and processes
   - Most of the time we are ahead of our competitors in developing and launching new products
   - We have the capacity to adapt others' technologies
   - We innovate as the result of R&D carried out within our own firm
   - The firm has a capacity for technological development allowing us to introduce onto the market innovations which are completely novel on a worldwide scale
   - We have considerable capacity for technological development
3. Diversity and overlapping of knowledge structures: Indicate level of agreement with the following statements (on a scale from 1 to 5):
   - The firm's production activities are concentrated in one single locality
   - The firm's organization includes a large number of managerial posts
   - In comparison with other firms, ours has a large number of sections within each management level
   - The level of co-ordination between the various activities carried out in our firm is very high
   - The firm has staff with a wide range of training and educational backgrounds
   - Payment for R&D employees in the firm is linked to the contribution they make to innovation
   - The firm specializes in a small number of technologies
   - Development projects for new products are carried out by multidisciplinary teams
4. Strategic posture: Assess the importance of each of the following factors for defining your firm's strategy (on a scale from 1 to 5):
   - Achieving maximum product quality
   - Efforts aimed at developing new products
   - Improving existing products
   - Efforts to maintain and improve the firm's brand image
   - Efforts aimed at reducing costs
   - Price is a fundamental factor
   - Market share
   - Major economies of scale

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