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An Analytical Model Of Absorptive Capacity

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Abstract

This article presents a new model for analyzing determinants of absorptive capacity in companies and shows how can be operacionalized. We propose that absorptive capacity is not only determined by R&D activities but also by a set of internal factors, which we group into three basic categories: organizational knowledge, formalization, and social integration mechanisms. We pilot our model on a sample of 84 small and medium-sized enterprises (SMEs) located in the province of Valencia, Spain. The results of our pilot study suggest that the model specification is useful to explain the determinants of firm's absorptive capacity. In addition, our findings show that the determinants of absorptive capacity differ with respect to the applicability of knowledge absorbed and that R&D activities have two different effects. Greater investment in R&D promotes the exploitation of external knowledge, regardless of its nature, while sustained R&D activities over time are a decisive factor for the exploitation of scientific knowledge.

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1. Introduction

The concept of absorptive capacity has been used recently to explain a diversity of phenomena, ranging from technology transfer among nations (Mower and Oxley, 1995) to the efficiency of strategic international alliances (Lane and Lubatkin, 1998; Lane et al., 2001). It has been widely used at the organizational level to analyze innovation processes and the effect of organizational learning on the creation of sustainable competitive advantage. However, despite its increasing use, the lack of a widely accepted measure combined with other factors, has prevented the creation of a consistent body of theoretical knowledge on absorptive capacity, its determinants, components, and results.

The concept of absorptive capacity first emerged as significant in the 1980s, in the field of organizational learning. Studies at that time highlighted the fundamental role that the acquisition and application of new knowledge played in business competitiveness. Kedia and Bhagat (1998) used the term in the context of technology transfer among nations, and related it to firms' receptiveness to technological change. Cohen and Levinthal, however, were the first authors to offer a broad definition of the concept and to build a general theoretical framework around its characteristics in business applications. They defined absorptive capacity as: "the ability of a firm to recognise the value of new external information, assimilate it and apply it to commercial ends" (Cohen and Levinthal, 1990: 128).

Their definition encompasses a number of important aspects. First, the multidimensional nature of the concept, which involves three basic capacities in relation to new knowledge: a) recognition of its value; b) its assimilation; and c) its application for commercial ends. Second, the relationship between a firm's absorptive capacity and its prior related knowledge, which includes both basic skills and a common language. This means that absorptive capacity has a cumulative character in the sense that its development in the present will permit its more efficient accumulation in the future. These aspects of absorptive capacity imply that its development is path or history-dependent.

In addition, Cohen and Levinthal distinguished between absorptive capacity at individual level and absorptive capacity at organizational level, and highlighted the role

of the firm's internal mechanisms in fostering communication and relationships among its members as a distinctive organizational aspect of absorptive capacity. In their analytical model, these authors use absorptive capacity as a variable to explain the effect of appropriability conditions and technological opportunity on R&D intensity. In this sense, Cohen and Levinthal used absorptive capacity as a conceptual tool to determine the incentives for R&D investment, but did not establish a means of measuring this directly. Neither did they conduct an empirical study of the impact of the factors that they defined as determinants of absorptive capacity.

Since Cohen and Levinthal's seminal work, many empirical and theoretical studies have explored the concept of absorptive capacity from the perspective of different analytical units and modelling strategies (Newey and Shulman, 2004). Of particular interest are those by Van den Bosch et al. (1999) and Zahra and George (2002), which take the firm as the basic unit of analysis.

The main contribution of Van den Bosch et al. (1999) was to suggest that the firm's knowledge environment could influence the development of its absorptive capacity. The authors established that the cyclical process through which absorptive capacity stimulates learning was regulated by the firm's competitive setting. Depending on the nature of this setting (stable, turbulent, etc.), firms adopted different forms of organization and emphasized different mechanisms to accumulate knowledge. While Van den Bosch et al. defended the thesis that prior knowledge was the main antecedent of absorptive capacity, they also established that its impact on this capacity was determined by a set of mechanisms associated with organizational forms (functional, divisional, or matrix), and by what they called "combinative capabilities", which represent the way in which companies acquire and apply knowledge[1].

Zahra and George (2002) conducted a review and reconceptualization of absorptive capacity. Their theories differed from the traditional views of Cohen and Levinthal in at least two respects. First, Zahra and George defined absorptive capacity as a dynamic capacity embedded in a firm's routines and processes, which promotes organizational change and evolution. And second, they established that absorptive capacity had four dimensions, which they grouped into two main categories: potential capacities (knowledge acquisition and assimilation) and realized capacities (transformation and

exploitation of knowledge). Using the above concepts, Zahra and George (2002) developed an extended model of absorptive capacity, which highlighted new determinants and new results regarding the development of corporate competitiveness. They maintain that prior knowledge, which is equivalent to a firm's experience, is important for developing absorptive capacity, but they stress that other factors, such as external knowledge sources and complementary external knowledge, are equally important.

Although we have focused on the above studies because of their importance in defining the conceptual elements in the development of absorptive capacity theory, a considerable number of other studies, particularly in the field of industrial economy, have used absorptive capacity to analyze business efforts in the area of R&D (Stock et al., 2001; Veugelers, 1997). However, as mentioned earlier, there is a lack of consensus on the appropriate operationalization of this variable, which makes it difficult to compare the results produced to date.

Generally speaking, the studies conducted so far have revolved around Cohen and Levinthal's (1989, 1990) theories and explored in further detail two aspects identified by these authors: the "path-dependent" nature of absorptive capacity, and its organizational dimension. The effect of external knowledge on the development of absorptive capacity has received little attention. Even Cohen and Levinthal (1989) did not include this aspect in their analytical model, although they did theorize that the characteristics of technological knowledge (applicability and complexity) influenced a firm's facility to learn. The conceptual models developed to date have analyzed how different factors have influenced the development of a firm's absorptive capacity, but do not take account of the nature of the knowledge being absorbed, which, in our opinion, is a key part of the analytical process.

In this paper we present a new model to analyze the determinants of absorptive capacity at organizational level, based on the above factors. The remainder of the paper is structured as follows. In section 2 we present the proposed model. In section 3 we describe the empirical study carried out with the aim of offering preliminary evidence on the applicability of the proposed model. In section 4 we outline the most relevant

findings and finally, in section 5, we present our conclusions and propose avenues for future research.

2. An analytical model of absorptive capacity

We formulated a new model that analyzes the determinants of firms' absorptive capacity, with a view to providing a clearer insight into how the role of internal factors varies according to the characteristics of the scientific-technological knowledge that is relevant to the organization. Figure 1 offers a schematic view of this model.

[Insert Fig 1 about here]

The model comprises two main blocks: one showing the different dimensions or components of absorptive capacity; the other showing the determinants of this capacity. We designed the first block based on the approach adopted by Zahra and George (2002) relative to the multidimensional nature of absorptive capacity and its division into two components: potential absorptive capacities (PACAP) and realized absorptive capacities (RACAP). We chose to use this distinction because we believe that it provides conceptual elements that are important for analyzing the role played by the different determinants in the model.

PACAP and RACAP can be considered as two separate, yet complementary states of absorptive capacity. As Zahra and George (2002) suggest, firms cannot exploit external knowledge if they have not previously acquired and integrated this knowledge into their organizational processes. However, the acquisition of knowledge does not necessarily imply a capacity for transforming and exploiting it. For example, a firm can have a high level of PACAP, but a low capacity for exploiting external knowledge through the development of new products or processes. This does not mean that PACAP are not important. Indeed, in highly dynamic environments, they make it easier for firms to adapt to changes, explore new paths, and even reshape their knowledge base.

The distinction between PACAP and RACAP highlights two important aspects. First, the complex nature of absorptive capacity and the difficulty of defining a direct global measurement system; second, the diverse nature, even though interrelated, of the components of this capacity, which can modify the effect of the different determinants depending on which component is being analyzed. In other words, while certain

organizational characteristics can have a positive effect on the development of a firm's PACAP, they may have a negative, or no effect whatsoever, on its RACAP. In this respect, Van den Bosch et al. (1999) demonstrated how the effects of organizational forms and combinative capabilities on the development of absorptive capacity vary depending on the three dimensions of knowledge absorption that they identified: efficiency, scope, and flexibility[2].

The second block in the model shows the various internal factors of a firm that we consider to be the main determinants of absorptive capacity: organizational knowledge, formalization, and social integration mechanisms.

Organizational knowledge embraces the set of skills, knowledge, and experience that a firm possesses, and is determined by the firm's prior knowledge base, the individual skills of its employees, and its R&D activities.

A firm's prior knowledge base is made up of a series of elements related to shared language, organizational memory (Walsh and Ungson, 1991), and internalized experiences (Tripsas and Gavetti, 2000). These elements, which are often tacit, influence the firm's valuation of the knowledge available in the environment, and are what makes absorptive capacity "path dependent" insofar as they determine which paths should be explored during the knowledge acquisition process and also regulate the evolution of subsequent stages.

Individual skills refer to the level of education and training of the workforce, and the experience acquired in a given knowledge field over time. It is widely accepted that highly educated and technically qualified staff are more receptive to assimilating and transforming available external knowledge (Vinding, 2000). In other words, companies whose employees are highly educated and trained will have higher levels of absorptive capacity.

R&D activities have traditionally been considered a determinant of absorptive capacity. A firm's ability to exploit external knowledge is often a subproduct of its R&D activities (Cohen and Levinthal, 1990). These activities not only contribute to the development of innovations, but also increase the firm's knowledge stock. The literature has analyzed the effects of a firm's internal R&D activities on the exploitation of external knowledge sources and while some studies have highlighted the

complementary nature of these variables, others have found that they can actually replace each other. What is certain, however, is that a firm's R&D activities strengthen its technological trajectory in a given knowledge field, and make it more receptive to the relevant external knowledge (Veugelers, 1997; Coombs and Bierly, 2006).

Formalization and **social integration mechanisms** are organizational parameters that can influence knowledge transfer among individuals and between the different functional areas of a firm. These parameters jointly illustrate the relational dimensions of a firm and represent distinctive organizational aspects that determine the efficiency with which companies assimilate external ideas (Lenox and King, 2004; Zander and Kogut, 1995).

Formalization refers to the extent to which procedures, rules, and instructions govern organizational processes, or in other words, it reflects the degree to which behaviours are programmed by formal explicit rules (Khandwalla, 1977). The main virtue of formalization is that it reduces the need for inter-unit communication and coordination and creates an organizational memory that allows the firm to act in routine situations (Van den Bosch et al., 1999). Nonetheless, a high level of formalization will have a negative influence on the flexibility of the firm and the spontaneity of its workers to respond in crisis situations, and this tends to reduce creative input and discourage innovation. In this sense, formalization has a dual influence on absorptive capacity. On the one hand, it increases the efficiency of knowledge acquisition by laying down general guidelines tailored to the needs of the firm; on the other hand, it hinders the transformation and exploitation of knowledge, insofar as these are highly cognitive dimensions in which rigid structures are a serious impediment.

Social integration mechanisms, on the other hand, are practices that reduce the barriers to information exchange within an organization (Zahra and George, 2002). These mechanisms enhance the absorption of knowledge by encouraging interaction between the different members of a group, and thus are most effective in activities that require a considerable cognitive level, such as transformation and exploitation. Social integration mechanisms facilitate the distribution of knowledge within an organization and, at the same time, make the combination of this knowledge with existing skills and experience much easier. They can be formal or informal mechanisms, depending on their degree of

systematization, but they are generally associated with practices such as job rotation, quality circles, and problem solving methodology. Cohen and Levinthal (1990) suggested that job rotation increases the effectiveness of knowledge absorption as it promotes the complementarity of experience in the firm. The creation of quality circles, the use of problem solving methodologies, and other management practices that promote employee participation also facilitate the exchange, transformation, and exploitation of knowledge.

It should be stressed that the above factors are not independent of one another. They are in fact interrelated, and in some cases, even complementary. R&D activities are clearly related to the workforce's level of education and training as their performances requires capable individuals. Likewise, organizational knowledge is linked to the firm's management practices (formalization and social integration mechanisms) insofar as these determine the nature of the learning processes. Level of formalization, for example, is an important factor for the combination of explicit knowledge, while social integration mechanisms facilitate the externalization of tacit knowledge (Nonaka, 1994). Management practices regulate the development of a firm's internal knowledge and give it distinctive characteristics that distinguish organizational knowledge from the individual knowledge of its workers. Furthermore, both formalization and social integration mechanisms are the result of a firm's accumulated experience and the knowledge residing in the individuals that make up the firm. In other words, both factors are dependent on the trajectory of the firm.

Formalization and social integration mechanisms are also inter-related. A high level of formalization can have a negative influence on a firm's social integration mechanisms in that it reduces the need for communication among individuals, and particularly so if the firm is operating in a stable and homogenous environment involving a few product-market combinations with relatively long life cycles (Van den Bosch et al., 1999).

We have included an additional and equally important element in our model**: the applicability of relevant knowledge available in the environment**[3]. The inclusion of this element in our analytical model is consistent with the contributions of several authors, particularly in the field of technology transfer, who consider it to be a key variable for the success of this process (Chen, 2004; Kogut, 1998; Lam, 1997; Zander

and Kogut, 1995). Also, Mangematin and Nesta (1999) pointed out that a firm with a higher level of absorptive capacity is more able to use fundamental knowledge than a firm with lower absorptive capacities.

In our model, applicability refers to the degree to which the external knowledge is targeted to the firm's particular needs. This attribute is related to what Cohen and Levinthal (1989) call "ease of learning". The more applicable the external knowledge, the easier it is for the firm to acquire and exploit it, because, for example, less scientific and technological expertise will be required. In practice, this type of knowledge is mostly obtained from industry sources such as suppliers or customers. If the firm belongs to an industry in which technological change primarily depends on knowledge generated by the above-mentioned sources, R&D activities and formalization will not play a decisive role in the absorption of this type of knowledge.

In contrast, when external knowledge is not immediately applicable, it is more difficult to acquire and exploit, even though the firm might recognize that it has value. When this type of knowledge is relevant, the firm needs to develop the competences that will allow it to access the knowledge and exploit it efficiently. Sources of this type of knowledge include universities, public research institutes, and technology institutes. In these cases, the capacity of the firm to absorb this type of knowledge will be more dependent on its R&D efforts, both in the short term, and also within a longer timeframe, to provide a solid foundation for its future technological trajectory. Similarly, formalization will be more important in this context as the firm needs to have certain procedures and instruments in place to facilitate communication with institutions, which tend to use a different language and adopt a different working culture. It is in this context that the level of education of the workforce becomes a decisive factor. The more of the firm's employees that have higher education qualifications, the easier it will be for the firm to associate with universities and access their knowledge bases.

Based on the above, we can distinguish between two types of absorptive capacity, which, for simplicity, we will call scientific absorptive capacity and industrial absorptive capacity. The former is a firm's ability to absorb scientific/technological knowledge from universities, technology institutes, and public and private research centres; the latter is its ability to assimilate and exploit knowledge from actors in the

industry chain. The factors that determine the development of these types of absorptive capacities are different although in certain sectors they may be complementary. In other words, if a firm belongs to an industry in which both scientific and industrial knowledge are important for driving technological change, then logically the firm needs to be able to develop both types of capacities. It is also likely that a firm with a good level of scientific absorptive capacity will be better able to exploit the knowledge from other industry agents.

In brief, the determinants of a firm's absorptive capacity can be classified into three groups: organizational knowledge, formalization, and social integration mechanisms. Organizational knowledge has a positive effect on all components of absorptive capacity while the effects of formalization and social integration mechanisms are different on different components. Formalization, for example, has a positive effect on knowledge acquisition (PACAP), while social integration mechanisms have a similar positive effect on transformation and exploitation (RACAP). Likewise, depending on the applicability of the external knowledge, the firm develops two types of absorptive capacity: scientific and industrial. Organizational knowledge and formalization are more important for the first than for the second.

The previous assumptions are the cornerstones of the proposed model and produce the following hypotheses:

Hypothesis 1. Organizational knowledge is positively related to the firm's capacity to acquire and to exploit the relevant external knowledge (PACAP and RACAP).

Hypothesis 2. Formalization is positively related to the firm's capacity to acquire the relevant external knowledge (PACAP).

Hypothesis 3. Social integration mechanisms are positively related to the firm's capacity to exploit the relevant external knowledge (RACAP).

Hypothesis 4. Organizational knowledge and formalization are related more to scientific absorptive capacity than to industrial absorptive capacity.

3 Data and methodology

3.1 Data

The data in the empirical analysis are from a survey carried out on small and medium manufacturing firms (SMEs)[4] from two industrial estates in the province of Valencia (Spain). The survey questionnaire was addressed to managers and senior personnel in the engineering and R&D departments. The survey included questions related to the level of human resource training, the degree of assimilation and dissemination of technology, and various innovation inputs and outputs. The questionnaire was administered by e-mail and followed up by phone calls and personal visits. Data were collected from a total of 84 firms, which represent 15.6% of the total population chosen (Table 1).

[Insert Table 1 about here]

3.2 Variables

In order to examine the relationship between absorptive capacity and the determining factors in our analytical model, we first defined a set of variables that would allow us to measure the study aspects.

As we have already mentioned, there is no a widely accepted measure of absorptive capacity. The majority of research has worked with proxy variables relating to the firm's efforts in innovation activities, such as R&D intensity (Stock et al., 2001), number of patents held by the company (Nicholls-Nixon, 1993), or even the existence of a formally established R&D department in the firm (Veugelers, 1997). In terms of our analytical model, none of these measures is adequate to estimate the firm's absorptive capacity, first, because none of them captures the multidimensionality of the concept and also because they are strongly correlated with organizational knowledge, which for us is a determinant of absorptive capacity.

Thus, we propose two measures of a firm's absorptive capacity: the first refers only to the business capacity to acquire external knowledge (PACAP), and the second refers to the business capacity to exploit it (RACAP).

To measure PACAP, we take into account the acquisition of external knowledge through different mechanisms. Specifically we consider subscriptions to journals, attendance at scientific events (conferences, congresses), and attendance at science fairs or exhibitions[5]. The resulting variable can take the value 0 to 3, depending on the use made of these three mechanisms as sources of external knowledge.

The RACAP is assessed by considering the firm's use of external agents as knowledge sources for the development of innovative activities. We asked about which of following agents were seen as important sources of knowledge to develop current or future innovation projects: universities, technology institutes, suppliers, and customers. We built a variable on the basis of the agents used by the firm. This variable can take the value 0 to 4. This measurement technique is congruent with the strategies adopted by Schmidt (2005), who built a measure of absorptive capacity using questions related to the external impulses used by firms to develop innovative products and processes.

To measure *organizational knowledge* we defined four variables related to the three elements covered by this determinant - individual skills, organizational experience and R&D activities. These variables are:

- *Level of education of the workforce (LE)*. This variable provides a representative measure of employee skills and is calculated as the number of employees with higher education degrees as a share of total employees.
- *Mean of seniority of workers (MS)*. This variable provides an approximate measure of the accumulated experience of the firm, and is calculated as the worker's the mean number of years of employment in the firm.
- Development of R&D activities, evaluated using two variables: *R&D intensity (RDI)* and *R&D department* (RDD). The first is a measure of R&D expenditure as a percentage of the firm's volume sales in the year prior to the survey. The second is a dummy variable, which takes the value 1 if the firm has an R&D department, and 0 otherwise. R&D department gives an idea of the continuity of the firm's R&D activities and assesses the "path dependent" character of its absorptive capacity.

To measure formalization we looked at the firm's management practices related to the development of procedures or rules to govern its organizational processes. Specifically, we have looked at whether the firm operated a technology watch system, provided training programmes for its personnel, and had ISO 9000 certification. The resulting variable (designated as FORM) can take the value 0 to 3 depending on the number of management techniques used by the firm.

Social integration mechanisms was evaluated through a compound variable (designated as SIM), defined by the total number of management techniques used by the organization to promote employee participation. This variable takes the value 0 to 3 depending on its use of quality circles, job rotation and problem solving methodology.
In order to distinguish between scientific and industrial absorptive capacity, we considered the nature of the external sources used by the firms both to acquire knowledge and to carry out innovation activities. Following the assumptions in our analytical model, we decided that knowledge obtained from journals or attendance at scientific events, along with knowledge derived from universities and technology institutes, was less applicable than the knowledge derived from customers, suppliers and attendance at fairs or exhibitions. On the basis of this initial distinction, we calculated four indicators that represent different types of absorptive capacity:

- Scientific potential absorptive capacity (SCPACAP). This variable can take the value 0 to 2, depending on the use by the firm of the following mechanisms as external knowledge sources: journals and attendance at scientific events.
- Industrial potential absorptive capacity (INPACAP). This is a dummy variable, which takes the value 1 if the firm uses the attendance at fairs or exhibitions as source of external knowledge, and 0 otherwise.
- Scientific realized absorptive capacity (SCRACAP). This variable takes the value 0 to 2, depending on the firm's use of universities and technology institutes as knowledge sources for innovation activities.
- Industry realized absorptive capacity (INRACAP). This variable takes the value 0 to 2, depending on use of customers and suppliers as knowledge sources to develop innovation activities

3.3 Quantitative analysis and methodological limitations

The main methodological limitation of the empirical test is the size of the sample (84 firms). This number of observations in combination with the number of variables in our analysis did not enable the use of econometric techniques to identify causality links. Consequently, we decided to base the test on "indicative" correlation coefficients. This technique allows identification of statistically significant relationships between the

determinant factors and the variables related to absorptive capacity. Even though this is not the most rigorous method of testing, we think that it helps in the achievement of our aim to carry out an exploratory test related to the applicability of the model proposed. Therefore, this paper's empirical work is an exploratory test of the proposition of determinants factors of firm's absorptive capacity, offering some hints on what these different determinants might be. It is not an absolute and final test of our model.

4. Results

Table 2 presents the descriptive statistics for the variables used in our empirical analysis. The mean seniority of workers of the sample was approximately 11 years; and only 12% of the employees had higher education degrees. Twenty-three firms in our sample (27%) had R&D departments and average R&D expenditure in total turnover is 0.5%.

[Insert table 2 about here]

In spite of the small size of the firms in our sample, their use of social integration mechanisms was quite high: most used at least two mechanisms out of the three considered in the analysis. In contrast, the mean value of formalization was 1.33.

In terms of absorptive capacity, the firms possess a higher level of PACAP (2.46) than RACAP (1.69). In other words, the capacity of firms to acquire relevant external knowledge exceeds their capacity to exploit it through development of innovation activities. Likewise, their capacity to acquire and to exploit industrial knowledge is greater than their capacity to acquire and to exploit scientific knowledge[6]. This result was to be expected because most firms were in traditional, low technology-intensive sectors.

The variables related to absorptive capacity were linked to the determinant factors by means of simple Spearman rank correlations[7]. The results are highlighted in Table 3.

[Insert table 3 about here]

In accordance both with the literature and the proposed model, the firm's absorptive capacity is associated with the organization's prior knowledge. The share of workers

with higher education degrees, and R&D intensity are positively correlated with both potential absorptive capacity (PACAP) and realized absorptive capacity (RACAP). These results represent evidence in favour of the first hypothesis and also show that organizational knowledge gained both through education of personnel or development of R&D activities, positively influence the firm's absorptive capacity. However, in contrast to expectations, neither mean seniority nor the existence of an R&D department was significant in our analysis.

Degree of formalization was positively associated with the firm's capacity to acquire relevant external knowledge (PACAP). This result, in conformity with hypothesis 2, shows that the identification and acquisition of external knowledge by firms is eased by the existence of norms and explicit procedures (e.g. if the firm has a technology watch system).

Table 3 shows that social integration mechanisms (SIM) are positively related to PACAP, but do not have a significant relationship with RACAP. At first this result would seem to run counter to our third hypothesis. However, when we analyze the relations between the variable SIM and the variables related to the different types of absorptive capacity, we find a significant and positive relationship with SCRACAP. This suggests that the effect of SIM on the firm's capacity to exploit external knowledge is only significant when the knowledge is scientific in character, which represents partial evidence in favour of our third hypothesis. One explanation for this finding may be that knowledge obtained from industry sources is generally easy to understand and assimilate as it is embedded in specific products or technologies that respond to practical needs. The firm does not need special mechanisms to facilitate the transfer of internal knowledge in this case, whereas the transfer of scientific knowledge requires efforts by the firm for it to be incorporated into its products and processes.

Underlying the above results is the existence of differences in the influence exercised by the determinant factors on each component of absorptive capacity (PACAP and RACAP), as proposed by Zahra and George (2002). This result highlights the multidimensional character of absorptive capacity and the fact that each of its components can be affected by different organizational characteristics.

The last of our hypotheses relates to the fact that the influence exercised by the determinant factors varies with the type of absorptive capacity developed by the firm (scientific or industrial). Table 3 shows that the level of education of the workforce is positively associated with the firm's capacity to acquire and to exploit scientific knowledge (SCPACAP, SCRACAP), but not with the firm's capacity to acquire and to exploit industrial knowledge (INPACAP, INRACAP). R&D intensity, on the other hand, is positively correlated with the firm's capacity to *exploit* any type of knowledge, but with its capacity to *acquire* scientific knowledge. These results indicate that if the external knowledge is immediately applicable, in other words it stems from industrial sources, the firm does not require a high level of internal knowledge to be able to absorb it. However, the less applicable the external knowledge, the more that specific capacities, resulting from better educated personnel and development of R&D activities, will be necessary for its acquisition by the firm.

Also, R&D department (RDD) is positively correlated with the firm's capacity to exploit scientific knowledge (SCRACAP). If we take the variable *R&D Department* as a proxy for the continuity of a firm's R&D activities, and ultimately, of its accumulated experience in a given technological trajectory, this finding illustrates that the capacity to exploit scientific knowledge is determined not only by the firm's short-term efforts, but also, and more importantly, by its possession of certain skills in a specific research field.

The effect of formalization appears to be similar. This variable is positively correlated with the firm's capacity to acquire and to exploit scientific knowledge, but it is not significantly related to the firm's capacity to acquire and to exploit industrial knowledge. In keeping with our analytical model, the absorption of scientific knowledge is favoured by the existence of norms and procedures that facilitate both its identification, and access to its sources.

These results represent evidence in favour of our fourth hypothesis, and also show that if the firm operates in an industry where the relevant external knowledge is scientific in character, the degree of formalization and the prior knowledge of the company are key factors required for the acquisition and efficient use of this knowledge.

5. Conclusions

We have described a model that analyzes the different determinants of firms' absorptive capacity. The model was built around theories proposed by several authors in the field, but also incorporates a number of innovative elements. This model is in line with existing theories in that it considers the multidimensional nature of absorptive capacity and defines organizational dimension and path dependency as its main characteristics.

Using this as our starting point, we distinguished two components of absorptive capacity: potential absorptive capacity (PACAP) and realized absorptive capacity (RACAP). We also defined three groups of determining factors: organizational knowledge, formalization, and social integration mechanisms. Although within each group we included several variables, these should not be considered to be exhaustive. Our objective was to construct a general framework within which the roles of different types of factors could be interpreted.

Our hypotheses suggested that the determinant factors would have varying influences on each of the components of absorptive capacity. Our results show that organizational knowledge is positively associated with both PACAP and RACAP, but that formalization and social integration mechanisms are associated only with the PACAP. These results highlight the importance of the theoretical distinction between PACAP and RACAP, and also indicate that different management practices are necessary to nurture and reap the benefits of these two components of absorptive capacity.

A central aspect of our model is the identification of two types of absorptive capacity, based on the applicability of the external knowledge. Our results confirm the importance of this distinction in analyzing the influence of the different determinant factors. For example, the acquisition and exploitation of scientific knowledge requires greater capacities that the acquisition and exploitation of industrial knowledge. In this sense, the firm's internal knowledge, gained through education of personnel or as a by-product of R&D activities, is a key factor in the absorption of external knowledge from scientific sources, but is less significant when the knowledge comes from industry agents. Similarly, the degree of formalization is more strongly correlated with the absorption of scientific knowledge than with the absorption of industrial knowledge. Depending on the industry sector to which the firm belongs, a particular type of

absorptive capacity will be required, and a greater focus on some determinant factors than others.

We have extended Cohen and Levinthal's theories by demonstrating that R&D activities have two effects on absorptive capacity: a short-term effect, which is directly linked to R&D investment and has a positive influence on all types of absorptive capacity, and a cumulative (non-immediate) effect related to R&D activities sustained over time, which contributes to the acquisition of solid experience in a given technological trajectory and is particularly relevant for the absorption of scientific knowledge.

In summary, this paper illustrates the complexity and problems associated with measuring the absorptive capacity. This construct not only has different components, but also different 'shades' depending on the nature of the external knowledge being absorbed. The implication for researchers is clear: use a simple indicator, for example R&D expenditure, is not always the best proxy to test empirically firm's absorptive capacity. In this sense, future research is needed to address both the specific operationalization of the different dimensions that absorptive capacity comprises and distinguish the types of knowledge to be acquired. The variables presented in this paper are first proxies and that can be used as the starting point for subsequent work.

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Tables

Table 1. Characteristics of population and sample

Number of Firms				
Industrial estate	Sample	Sample (%)	Population	Sample/Population %
1	61	71.26	328	18.6
2	23	28.74	209	11
Total	*84*	*100*	*537*	*15.6*

Table 2. Descriptive statistics of the sample*

	Minimum	Maximum	Mean	S.D.
Level of education (LE)	0	83	12,60	14,35
Mean seniority (MS)	1	32	10,95	6,44
R&D Department (RDD)	0	1	0,27	0,45
R&D Intensity (RDI)	0	6	0,51	0,99
Formalization (FORM)	0	3	1,33	0,99
Social integration mechanisms (SIM)	0	3	2,04	0,87
PACAP	0	3	2,46	0,67
RACAP	0	4	1,69	1,29
SCPACAP	0	2	1,49	0,65
INPACAP	0	1	0,98	0,15
SCRACAP	0	2	0,61	0,76
INRACAP	0	2	1,10	0,88

*84 Observations

Table 3. Correlations between determinants factors and absorptive capacity variables [a].

Determinant factors		PACAP	RACAP	SCPACAP	INPACAP	SCRACAP	INRACAP
Organizational Knowledge	Level of education (LE)	0,324(**)	,262(*)	0,286(**)	0,199	0,331(**)	0,128
		(-0,003)	(0,027)	(0,008)	(0,07)	(0,003)	(0,28)
	Mean seniority (MS)	0,064	0,055	0,083	-0,141	0,094	-0,048
		(0,563)	(0,647)	(0,452)	(0,201)	(0,412)	(0,688)
	R&D Department (RDD)	0,128	0,123	0,11	0,096	0,261(*)	-0,076
		(0,245)	(0,306)	(0,318)	(0,386)	(0,02)	(0,525)
	R&D Intensity (RDI)	0,232(*)	0,465(**)	0,216*	0,139	0,398(**)	0,307(**)
		(0,034)	(0)	(0,05)	(0,207)	(0)	(0,008)
	Formalization (FORM)	,291(**)	0,186	0,285(**)	0,054	0,350(**)	-0,052
		(0,007)	(0,12)	(0,009)	(0,627)	(0,002)	(0,665)
	Social Integration Mechanisms (SIM)	0,261(*)	0,175	0,215(*)	0,237(*)	0,265(*)	0,027
		(0,017)	(0,144)	(0,049)	(0,03)	(0,018)	(0,82)

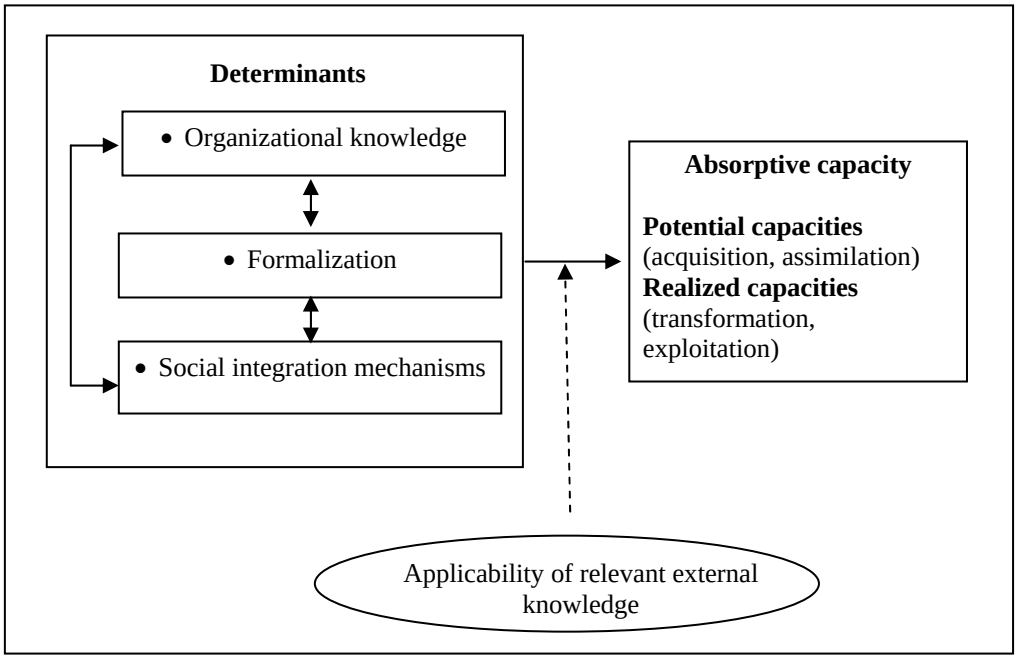
[a] Spearman correlation coefficients. *P*- values in parentheses

** Significance at the 0.01 level (bilateral).

* Significance at the 0.05 level (bilateral).

Figures

Figure 1. Absorptive capacity model



Notes

[1] Van den Bosch et al. (1999) distinguished three types of combinative capabilities: system capabilities, coordination capabilities, and socialization capabilities.

[2] Efficiency refers to how well firms identify and exploit knowledge from the perspective of economies of scale. Scope denotes the depth of the knowledge that a firm absorbs, while flexibility refers to the degree to which it can access a much more varied type of knowledge and reconfigure existing knowledge. Van den Bosch et al. (1999) suggested that organizational characteristics do not affect these dimensions equally, and posited that although they may have a positive influence on absorptive capacity efficiency, they might have the opposite effect on scope and flexibility.

[3] Relevant external knowledge offers to the added value for the organization of the development of new processes or products, but is also related to the prior knowledge existing in the firm. This definition is congruent with the concept of "knowledge relatedness" (Breschi et al., 2003), which has been identified as a key factor in firm's technological diversification.

[4] We consider as SMEs those companies with more than 10 employees and no more than 249 employees

[5] The firms were asked to indicated whether the above mechanisms were their usual sources of external knowledge.

[6] The mean value of INRACAP (1.10) is greater than the mean value of SCRACAP (0.61). Also the variable INPACAP has a mean value of 0.98 on a scale from 0 to 1, while the mean value of SCPACAP is 1.49 on a scale from 0 to 2.

[7] We decided to use non-parametric statistics because most of the variables were ordinals.