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Absorptive routines and international patent performance



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Abstract Patents on an international level are essential for firm results. Accordingly, the use of external sources of knowledge acquires crucial importance to get global innovations and create competitive advantages. For that reason, the literature has highlighted the strategic role of the absorptive capacity construct.

We enrich the treatment of the absorptive capacity phases including the moderating effects between routines associated to the traditional potential-realized absorptive capacities. Taking into account external knowledge search strategies, the deeper external relationships, the better transference and appropriation of specific external knowledge. Nevertheless, when the moderating role of assimilation is included, cooperation agreements appear as the most efficient source of external knowledge. Finally, we show that technological tools let firms store and structure the information making easier its use for international patenting. This positive effect is reinforced in the presence of exploitation routines, since technological knowledge will better fit to the industry's key factors of success.

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Introduction

The economic crises that many firms have had to deal with in their domestic markets and the global nature of most industries explain the need to be internationally competitive (Yu et al., 2013). Based on this premise, some authors have defended the need to improve the management of

international patents for firm success (Mangematin et al., 2003; Al-Aali and Teece, 2013; Thomä and Bizer, 2013; Useche, 2014). Different studios have supported the use of international patents as a mechanism to promote the cross-country technology transference and exploitation in a more efficient manner (Harhoff et al., 2009; Johnstone et al., 2011; Berry, 2016). In addition, the publication of the patent only in the home-country language, without an international protection, can increase its vulnerability to imitation (Eaton and Kortum, 1999), and thus make it less valuable.

The high complexity and dynamism of industries at international level make very difficult for firms to develop the

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necessary innovations with their own resources only. Accordingly, the use of external sources of knowledge acquires crucial importance in value creation (Van den Bosch et al., 1999; Camisón and Forés, 2010; Love et al., 2014; Monteiro et al., 2016).

In this context the *absorptive capacity* construct emerges as a strategic dynamic capability to improve the innovative potential of companies (Cohen and Levinthal, 1990; Zahra and George, 2002; Xia, 2013), and their ability to adapt to context circumstances (Helfat, 1997; Zollo and Winter, 2002; Helfat and Peteraf, 2003; Reitzig and Puranam, 2009; Fisher and Oberholzer-Gee, 2013). Since the seminal work of Cohen and Levinthal (1990), a wide body of literature has been developed to get a better understanding on its internal elements as well as on its role in firm performance.

Although many contributions to the field have considered the absorptive capacity as a one-dimensional phenomenon (Tsai, 2009; De Jong and Freel, 2010; Flatten et al., 2011), in recent years such consideration has been abandoned. Some authors have adopted a multidimensional approach to the concept from an organizational routines point of view (Nelson and Winter, 1982; Jansen et al., 2005; Noblet et al., 2011). In this way, numerous works define this construct as the set of organizational routines required for recognizing, assessing, assimilating, integrating, transferring and applying the new external knowledge (Cohen and Levinthal, 1990; Zahra and George, 2002).

However, these processes have been structured in a sequential and independent manner, which makes it difficult to analyze synergies or complementarities among them (Jansen et al., 2005; Todorova and Durisin, 2007; Noblet et al., 2011). All this literature supports the general conclusion that the efforts made in any absorptive routine will improve the performance of the company. To fill this gap, in this paper we study the complementary role of the different phases of absorptive capacity. To carry on this research, we define the following research questions:

- 1) Do the assimilation routines moderate the relationship between acquisition phase and international patenting?
- 2) Do the exploitation routines moderate the relationship between transformation phase and international patenting?
- 3) Does the moderating role played by assimilation routines change according to the depth of the relationships a firm maintains with external agents?

Since resources are scarce, the first contribution of this paper is to support the making-decision process concerning their allocation along the knowledge absorptive phases. Our starting point is the well-recognized structure proposed by Zahra and George (2002), who divided absorptive capacity into two factors: *potential absorptive capacity* (PACAP) and *realized absorptive capacity* (RACAP).

We analyze in an innovative manner the moderating role that assimilation and exploitation phases play in the relationship between acquisition and transformation absorptive routines and firm innovative performance, respectively. Therefore, we followed the ideas proposed by previous authors (Schleimer and Pedersen, 2013; Ebers and Maurer, 2014), who suggested the interest of reaching a holistic approach to the absorptive process in future researches.

That is, we consider that part of the innovative potential of the company – in terms of international patenting – can be explained by the coherent effort along the different routines of the absorptive capacity.

In addition, we pay special attention to acquisition routines, analyzing different sources of external knowledge that have not received enough attention within the context of absorptive capacity. *External knowledge search strategies* framework (Laursen and Salter, 2006, 2014; Lin and Wu, 2010) studies the impact of different external sources on results. There is a large body of theoretical and empirical literature that shows the strategic role of external relationships in organizational learning, in accordance to *breadth* and *depth* of such relationships (Laursen and Salter, 2006; Hohberger et al., 2015; Zobel et al., 2017). After a proposal of knowledge acquisition strategies, we empirically test if deeper or stronger external relationships (firm acquisition/participation) are preferred options to transfer and appropriate specific and tacit knowledge, instead of cooperation agreements (Desyllas and Hughes, 2008), in which international patents are based on (Zobel et al., 2017).

Nevertheless, integrating search strategies within the absorptive capacity landscape offers new areas of debate to improve our comprehension on the role external knowledge may play in international patenting. Therefore, our second contribution has to do with the moderating role that assimilation routines may play taking into account different levels of depth among acquisition strategies.

The data used for the empirical analysis are from a sample from the *Spanish Business Strategies Survey* (SBSS, SEPI Foundation) for the years 1997–2007.

Following this introduction, the paper presents a brief definition of the concept of absorptive capacity, as well as the model for empirical verification. A description is then made of the methodology used and, finally, the main findings, conclusions and future lines of research are presented.

Literature review and research model

Absorptive capacity from an organizational routines approach

In a wide sense absorptive capacity can be defined as the firm's skill to recognize, assimilate, integrate and exploit new external knowledge (Cohen and Levinthal, 1990; Zahra and George, 2002; Noblet et al., 2011). The treatment of such absorptive capacity as a strategic variable has been very diverse in the literature, both from the point of view of its role in firm performance and from the perspective from which it has been raised its definition and measurement.

With respect to the role of absorptive capacity in firm performance, numerous scholarly works adopt a theoretical approach to defend the significance of absorptive capacity (Lane et al., 2006; Flatten et al., 2011), and reach the empirical conclusion that there is a direct relationship between that capacity and organizational performance (e.g., Jansen et al., 2005; Murovec and Prodan, 2009). Secondly, other studies consider that the potential of absorptive capacity depends on certain contingent variables, such as the context in a broad sense, so there is no conclusive results

<i>Absorptive capacity</i>			
<i>Potential absorptive capacity (PACAP)</i>		<i>Realised absorptive capacity (RACAP)</i>	
<i>Acquisition</i>	<i>Assimilation</i>	<i>Transformation</i>	<i>Exploitation</i>
Series of routines designed to screen and assess external knowledge and accumulate any of a strategic nature	Set of routines designed to facilitate the analysis and interpretation of external knowledge	Set of routines that facilitate the storage, recovery, combination and assessment of different expressions of knowledge	Set of routines used to incorporate and apply the knowledge to the processes of production and marketing
The focus of attention is the external knowledge of interest to the firm		The focus of attention is the integration of the different expressions of knowledge the firm amasses and how it uses them in its business processes	

Figure 1 Absorptive capacity: definition and key dimensions.

Source: Author's own work.

in this field (Todorova and Durisin, 2007; Escribano et al., 2009; Cepeda-Carrión et al., 2012; Xia, 2013).

Regarding the treatment of the absorptive capacity concept, numerous studies have considered absorptive capacity as one-dimensional phenomenon (Cassiman and Veugelers, 2006; Tsai, 2009; De Jong and Freel, 2010). However, this consideration is insufficient, since it does not capture the complexity of the construct (Zahra and George, 2002; Murovec and Prodan, 2009; Jiménez-Barrionuevo et al., 2011; Noblet et al., 2011). Therefore, it must be analyzed from different organizational levels and theoretical disciplines (Van den Bosch et al., 2003; Volberda et al., 2010).

This renders it essential to overcome a complacent mindset, satisfied with the mere possession of different forms of intangible assets, and so conduct a more normalized and integrated management of them (Al-Aali and Teece, 2013; Fisher III and Oberholzer-Gee, 2013). The need to consider knowledge management from a systemic approach appears reflected in numerous recent works (Huang, 2013), which leads us to reach a holistic model of the absorptive process (Schleimer and Pedersen, 2013; Ebers and Maurer, 2014). This paper considers absorptive capacity as a continuous and interrelated series of knowledge-intensive organizational routines with the aim of enabling a firm to suitably face the opportunities and threats of a dynamic and complex environment to survive in the long-term (Lane et al., 2006).

We can define routines as stable and complex patterns of collective behaviour that develop distinctive activities through the clustering of specific assets so they can respond to various external and internal stimulus (Nelson and Winter, 1982; Grant, 1991; Zollo and Winter, 2002). "Routines are a critical source of operations capabilities and subsequently investigate operations capabilities by means of their underlying routines" (Peng et al., 2008: 730).

We consider as a starting point of our model the four basic absorptive processes – acquisition, assimilation, transformation and exploitation – established by Zahra and George (2002), extending the ones proposed by Cohen and Levinthal a decade ago (1989, 1990). In a complementary way, we believe that a significant part of the innovative potential of the organization can be explained by the joint effort along the different phases of absorptive capacity.

According to the proposal made by Zahra and George (2002), we grouped routines in accordance to two main factors – PACAP and RACAP –, as it can be seen in Fig. 1. Potential absorptive capacity focuses on an analysis and understanding of external knowledge, while realized absorptive capacity places greater attention on the combination and integration of new knowledge into the pool already accumulated, as well as its inclusion in the firm's operations (Grant, 1996; Sheremata, 2000; Todorova and Durisin, 2007; Camelo-Ordaz et al., 2010; Flatten et al., 2011; Levine and Prietula, 2012; Enkel and Heil, 2014).

To get a deeper understanding on the complementarities among absorptive phases (Ebers and Maurer, 2014), in the next section we analyze the moderator effect of assimilation and exploitation phases within the context of PACAP and RACAP, respectively.

Hypotheses

The *acquisition* phase refers to a firm's skill at identifying and amassing the critical knowledge generated beyond its frontiers. When firms do not possess enough internal-based resources, the intensive use of external sources of knowledge through inter-organizational relationships of a diverse nature is recommended (Nieto and Santamaría, 2007; Lin and Wu, 2010; Makri et al., 2010). Therefore, of considerable importance in this initial process are the relations the organization maintains with different potential agents that may act as knowledge sources (Caloghirou et al., 2004; Arbussa and Coenders, 2007; Hurmelinna-Laukkanen, 2012; Hohberger et al., 2015).

Nevertheless, the Transaction Cost Theory – TCT – (Coase, 1937; Williamson, 1976, 1979) assumes that the transference of strategic knowledge across independent firms may have high costs derived from opportunism (Pisano, 1990). Then, the objective of the firm when it looks for external assets to innovate will be to minimize the associated costs to the knowledge transference process (Girma, 2005; Björkman et al., 2007). Therefore, it will be interesting to find out alternative government modes closer to hierarchy and exploit their advantages (Ahuja and Katila, 2001), as it was suggested by TCT.

The approach of *external knowledge search strategies* (Laursen and Salter, 2006, 2014; Lin and Wu, 2010; Love et al., 2014; D’Ambrosio et al., 2016; Ferreras-Méndez et al., 2016) can be useful to this objective. This framework evaluates the role of external relationships in innovative performance considering two main features of them: *breadth* and *depth* (Laursen and Salter, 2006, 2014). While breadth deals with the variety of external sources, depth is highly related to quality of such relationships, what is highly linked to the knowledge transference capacity between firms (Ahuja and Katila, 2001; Laursen and Salter, 2014; Zobel et al., 2017) and, therefore, to our research objective.

As shown in Fig. 2, we distinguish here between two alternative models of absorptive routines when accessing to new knowledge, with different levels of depth: (1) *resource-based* routines and (2) *relation-based* routines. The first one is focused on either external knowledge from agents with whom the firm maintains a greater level of independence (market) or internally developed knowledge (organic). The second one deals with the relationship through which such knowledge is obtained (cooperation agreements and mergers and acquisitions (including partial participation in companies)).

The positive effects of the market formula lie in the reduced risks and costs entailed in the in-company development of knowledge (Yeoh and Roth, 1999; Yli-Renko et al., 2001; Matusik, 2002). Nevertheless, the non-specific nature of the knowledge acquired through the markets and the temporary nature of these relationships are not suitable to obtain patents and, consequently, to appropriate benefits from innovation (Lane and Lubatkin, 1998; Lane et al., 2006; Zobel et al., 2017).

The negative effects of these processes can be mitigated through deeper external knowledge acquisition formulas that do not involve the market of resources (Miozzo et al., 2016), which can include cooperation agreements (Nieto and Santamaría, 2007; Nooteboom et al., 2007) or participation

in technology-based firms (Elango et al., 2013). A stock of shared knowledge will be generated by stable and deep relationships, whose objective is technological learning, which brings the parties to the agreement closer together (Ritala et al., 2015).

Certain works address the study of the level of interaction between acquirer and acquired firms (Desyllas and Hughes, 2008). Such is the case of the model propounded by Lane and Lubatkin (1998), in which they adapt and re-define the phenomenon under study in this paper through the expression *relative absorptive capacity*. They argue that the efficiency with which firms pursue their absorptive capacity is explained by the robustness or depth of the relationship maintained between those organizations that interact in the knowledge sharing or development process. Lane et al. (2006) contend that when these conditions are fulfilled, there will be a suitable exploratory learning process, thanks to which firms are capable of recognizing and understanding the potential value that external knowledge has for them. This exploratory learning process will play a key role in patenting (Zobel et al., 2017).

Accordingly, this paper focuses on some routines and sources of knowledge that have not received enough attention within the context of absorptive capacity, above all from an empirical perspective (George et al., 2001; Zahra and George, 2002) and whose greater efficacy, nonetheless, may be explained by the very dynamics of the relative absorptive capacity construct.

Some authors consider that “participations can overcome the problem associated to a knowledge absorption in *piecemeal strategies*, derived from in-licensing or strategic alliances” as external sources of learning (Desyllas and Hughes, 2008: 159). As a consequence, the generation of radical innovation through the participation in technology-intensive companies is an alternative efficient mechanism of government (Blonigen and Taylor, 2000; de Man and Duysters, 2005; Cloudt et al., 2006), since it supposes a

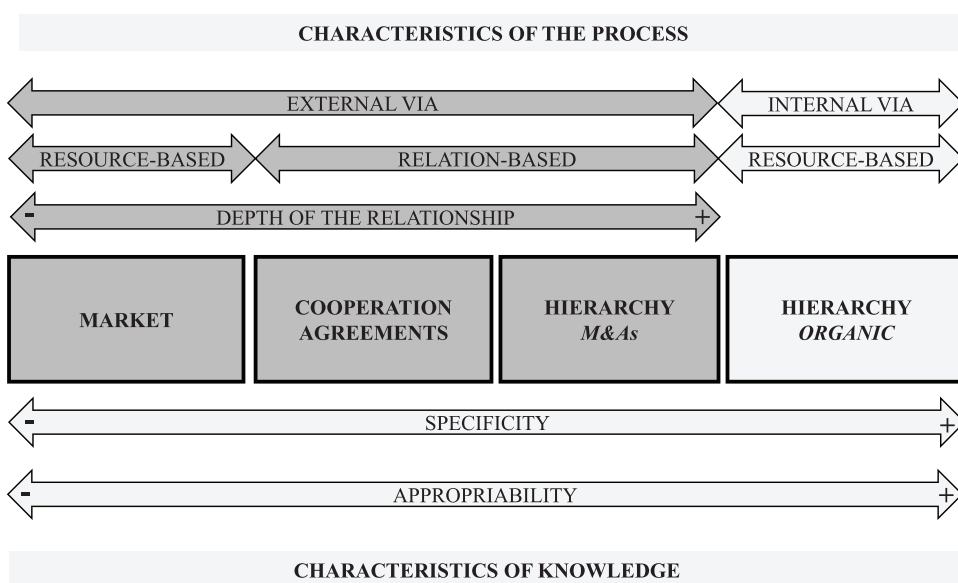


Figure 2 Modes of transaction government: characteristics of knowledge and acquisition process.

Source: Author’s own work.

remedy to the rigidity derived from the previous knowledge base (Vermeulen and Barkema, 2001; Desyllas and Hughes, 2008). Sometimes firm acquisitions or participations are the only option to get certain strategic resources in a high-technology context in a speedy way (Nadolska and Barkema, 2007; Desyllas and Hughes, 2008; Teece, 2010).

From this point of view, accumulating new technological knowledge through either firms acquisition or participation in their share capital suppose a contribution to this field by considering inter-organizational relationships a dynamic learning process (Cefis et al., 2008; McCarthy, 2011). More and more firms view such formulas as suitable mechanisms of learning and acquiring resources, competences and capabilities from knowledge sources beyond the boundaries of the firm (Veugelers and Cassiman, 1999; Ahuja and Katila, 2001; Cassiman and Veugelers, 2007).

Here we defend that robustness or depth of relations between the agents, improves firms' patent portfolio, since it encourages the transference of tacit, specific and complex knowledge (Armour and Teece, 1980; Martínez Bobillo and Tejerina Gaité, 1999; Girma, 2005; Li and Tang, 2010; Chen et al., 2011; Ferreras-Méndez et al., 2016) and, therefore, their innovation capacity (Ahuja and Katila, 2001; Björkman et al., 2007; Zobel et al., 2017). In addition, property of assets from the acquired or participated company ensures appropriability of innovative results (Kumar and Saqib, 1996).

As a consequence, we consider that the effort made in knowledge acquisition routines through participation in technology-based companies will play a decisive role in the development of international patents. Then, our first hypothesis is defined as follows:

H_{1a}. Within the context of PACAP, the acquisition routines related to participation in technology-based firms have a direct effect on international patent rate

However, it is necessary to complete the research on the effects of the relationships between the sources of knowledge with the internal mechanisms available for their absorption (Ferreras-Méndez et al., 2016). Desyllas and Hughes (2008) and Wernerfelt (2011) acknowledge that the firm's previous base of knowledge is the origin of the asymmetries in the access and use of new knowledge. Therefore, based on the PACAP-RACAP structure and according to the argument proposed in this work, we state the existence of a moderating role played by both assimilation and exploitation routines.

The *assimilation* stage encompasses the series of routines and resources that allow analysing, processing, interpreting and understanding the information obtained from external sources (Szulanski, 1996).

Zahra and George (2002) consider assimilation to be the process through which knowledge can be interpreted and understood thanks to the existing cognitive structures. Nevertheless, the more complex knowledge will demand a greater level of assimilation routines. For that reason, the role of qualified human capital is crucial along the assimilation process of specific and tacit knowledge (Minbaeva et al., 2003).

A higher educational level and academic or technical training benefit knowledge management and, consequently,

improve innovation of the organization (Nakano et al., 2013; Barba Aragón et al., 2014). Obtaining patents requires that the workers involved possess certain cognitive or psychological abilities to implement these assimilation practices, such as risk acceptance or experimentation (Agarwal-Tronetti and Shah, 2014). Some companies are "genetically" programmed to preserve their *status quo*, in which they have made remarkable investment, economic and emotional (Stringer, 2000; Wang and Noe, 2010).

According to this, formal education and training received by the human capital allows them greater empowerment, which will make them better "receptors" and "platforms" of external knowledge previously acquired, and more adept at processing it and remain vital for firm's innovation potential (Escribano et al., 2009; Grimpe and Sofka, 2009).

In conclusion, the human factor is of great relevance when the acquired knowledge is tacit and complex especially, in which international patenting are based on. Then, we propose our second hypothesis H_{1b}:

H_{1b}. Within the context of PACAP, the moderating effect of assimilation routines on international patenting will be higher as the depth of the inter-organizational relationships increases

With respect to RACAP, the *transformation* phase is defined according to the routines responsible for the opportune storage and recovery of knowledge when deemed convenient, as well as its suitable combination and the recognition of potential new uses (Jansen et al., 2005). Therefore, the organization needs to be able to provide the interested parties with accumulated expressions of knowledge, allowing access to, and efficient use of, the organizational memory through information systems and technologies or other alternative instruments (Argote and Ingram, 2000; Matusik and Heeley, 2005; Volberda et al., 2010; Zhao and Anand, 2009; Camisón and Forés, 2010).

Once the routines that involve a greater level of creativity throughout the absorptive process have concluded, the organisation's objective turns towards the design of tools that facilitate storage and the subsequent access to the new knowledge base by those involved agents, and thereby extend the learning process. This requires the design of a knowledge management policy and systems for its harnessing, standardization, storage and recovery, as well as of those means that facilitate the combination and dissemination of its different expressions (Jansen et al., 2005; Camisón and Forés, 2010; Flor-Peris et al., 2011).

Through the processes of formal arrangement and standardization, a firm develops the necessary means that enable it to achieve greater efficiency. Nevertheless, this formal arrangement may trigger greater inflexibility, which may reduce an organisation's possibilities of adjusting to and obtaining innovations that can be patented (Weigelt and Sarkar, 2012). In view of this, systems need to be introduced that allow implementing strategies for recoding and adjusting to the new knowledge that has already been assimilated. Accordingly, information and communications technologies (ICTs) provide support for the organization, localization, distribution and sharing of knowledge. Consequently, the proper use of ICT competencies is considered to be a key organizational variable, as they permit, on the one

hand, creating and maintaining competitive advantages and, on the other, generating innovations (Menor and Roth, 2007; Dibrell et al., 2008; Phang et al., 2008; Camisón and Forés, 2010) and improving the management of patents (Gassmann et al., 2012).

All this helps a firm to develop a new structure, whereby it can appropriate the external knowledge and subsequently make efficient use of the knowledge base in operations that lead to innovations (Zahra and George, 2002). In this sense, the basic purpose of transformation routines will be to provide employees with the knowledge base required for underpinning the innovation process leading to the award of patents. "Disclosure of information concerning the innovativeness and competences of a firm contained in patents is particularly important" (Useche, 2014:2). In order to attain this disclosure, technological tools allow storing and structuring the information and making it available at the right time and place, which means a significant increase in the efficiency of the management of intellectual property (Gassmann et al., 2012). This permits identifying new areas for improvement and business opportunities upon which to focus the development of future patents (Bonino et al., 2010). All these arguments encourage us to hypothesize that:

H_{2a}. Within the context of RACAP, the transformation routines have a direct effect on international patent rate

If the organizations fails to exploit properly knowledge previously transformed, they will have difficulties to materialize their efforts into concrete results that enable them occupy a position of strong competitive advantage (Todorova and Durisin, 2007). For this reason, finally, acknowledgment has been made of the key part played by the *exploitation* phase in the relationship between the transformation and international patent rate. However, this is one of the phases whose definition requires a greater effort, as the literature provides different interpretations of its specific component routines.

From a conceptual perspective, the literature does not clearly demarcate the boundary between the development of this phase and the results forthcoming from the overall process of absorbing knowledge. What's more, among those studies that define exploitation as a process, there are differences as regards the range of routines it encompasses.

We consider it pertinent here to distinguish between the exploitation phase and the outcome provided by the sum of absorptive routines. We therefore take the proposal made by Lane and Lubatkin (1998) as our reference point, as they consider that exploitation is a firm's skill in implementing and applying new knowledge, and thereby achieving its set goals.

Finally, given that the *exploitation* phase involves a series of routines directly linked to the market demand (Jansen et al., 2005), we consider the favourable effects the efforts made in these kinds of routines have on the transformed knowledge to get patents, as a result of the need to provide an original response through them to a practical problem – now or in the future (Hu, 2010; Loftus, 2012).

Note should be taken within this phase of the effort firms make to integrate different technologies that will allow redesigning the operations and positions of employment

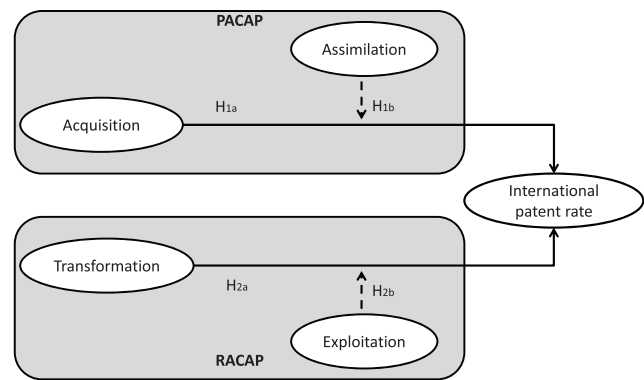


Figure 3 Model of analysis.

Source: Author's own work.

according to market needs (Nieto and Quevedo, 2005; Jansen et al., 2005; Murovec and Prodan, 2009; Flor-Peris et al., 2011). Regarding the systemization of all these processes, one may conclude that the organization has a greater potential and is better adjusted to the industry's key factors of success, forthcoming from the achievement of patents (Tu et al., 2006). Based on all the above arguments, we formulate the fourth hypothesis:

H_{2b}. Within the context of RACAP, the exploitation routines moderates the relationship between the transformation ones and international patent rate

For illustrative purposes, Fig. 3 provides a graphic depiction of the proposed analysis model.

Research method

This section describes the main methodological aspects of the empirical research conducted. Firstly, a detail is provided of the sources of information used, as well as the period under study. The next step involves presenting the metrics established for the variables included in the model, describing the psychometric analysis performed; finally, the preparation and analysis of the data is addressed, prior to the empirical verification of the hypotheses.

To test our hypotheses we used a database that involves the cohort of firms that make up the *Spanish Business Strategies Survey* (SBSS). To take into account the dynamic effect of time on variables, according to several previous studies (e.g., Archibugi et al., 2013), a three-year delay has been set between the absorptive routines and the innovative result that is open to patenting.¹ Furthermore, for independent variables we used the mean value of observations from 1997 to 2000, and, for dependent variable, we did the same calculus considering data from 2004 to 2007, considering it pertinent to limit the time horizon to this period because,

¹ The study of the effect of certain variables requires the insertion of time-delayed explanatory variables, as a period of time needs to elapse in order to analyze the relationship between cause and effect. For example, investments in R&D will lead to more significant results in the medium/long term, and not in the same year they are made.

<i>Independent variable: absorptive capacity</i>			
<i>PACAP</i>		<i>RACAP</i>	
<i>Acquisition</i>	<i>Assimilation</i>	<i>Transformation</i>	<i>Exploitation</i>
Scanning, evaluation and incorporation of external knowledge	Analysis and interpretation of external knowledge	Storage, retrieval, combination, and evaluation of opportunities of knowledge	Implementation of knowledge to operations
<i>Indicators (SBSS)</i>			
Resource-based routines - Technical and scientific information services acquisition (BUY) Relation-based routines - Technological cooperation with (COOP) : o Suppliers o Customers o Competitors o Universities and technology centers - Firm participation (PART) : o Participation in technology-based firms	ASSIMIL : - R&D employees (assistants, middle technicians and higher technicians superior)/total employees	TRANS : - Robotics - Use of CAD - ICTs, use of LAN	EXPLOIT : - Quality control systems - Flexible manufacturing systems - Marketing activities
<i>Previous studies using similar indicators</i>			
Caloghirou et al. (2004); Nieto & Quevedo (2005); Jansen et al. (2005); Arbussà & Coenders (2007); Murovec & Prodan (2009); Camisón & Forés (2010); Flor Peris et al. (2011); Fernhaber & Patel (2012); Elango et al. (2013); Miozzo et al. (2016)	Caloghirou et al. (2004); Nieto & Quevedo (2005); Jansen et al. (2005); Arbussà & Coenders (2007); Escribano et al. (2009); Grimpe & Sofka (2009); Camisón & Forés (2010); Flor Peris et al. (2011); Fernhaber & Patel (2012)	Jansen et al. (2005); Camisón & Forés (2010); Fernhaber & Patel (2012); Hurmelinna-Laukkanen (2012)	Nieto & Quevedo (2005); Jansen et al. (2005); Murovec & Prodan (2009); Camisón & Forés (2010); Flor-Peris et al. (2011); Fernhaber & Patel (2012)
<i>Dependent variable: international patents (INT_PAT)</i>			
Gambardella, (1995); Yang & Maskus (2001); Hernández Cerdán (2002); Kline (2003); Jansen <i>et al.</i> (2005)			
<i>Control variables: Size, age, industry, and R&D expenditure/sales</i>			
Damanpour (1991); Lane & Lubatkin (1998); Elenkov <i>et al.</i> (2005); Rothaermel & Alexandre (2009); Lee & Wong (2011); Lin <i>et al.</i> (2012)			

Figure 4 Absorptive capacity and international patents: measures.

Source: Author's own work.

as from 2007, the country entered a period of economic crisis that could distort the analysis of the results (Archibugi *et al.*, 2013).

Based on an analysis of the variables included in the SBSS and on the review of the prior literature (as indicated in Fig. 4), an initial selection was made of those indicators in the survey that were the most valid *theoretically* or in terms of *content* (Guion, 1980).

Dependent variable: international patents

Patenting is the result of a protracted process over time, which entails an inventive activity (not evident) that involves incurring high costs and risks, and the management of a high level of knowledge, by requiring a significant novelty for the market (Archibugi and Pianta, 1996; Reitzig and Puranam, 2009; Hu, 2010; Loftus, 2012). Therefore, patents

have been one of the indicators most often used to measure the outcome of technological activity (Kline, 2003; Jansen *et al.*, 2005; Curran and Leker, 2011).

What's more, the value of this type of knowledge also lies in other phenomena, such as, for example, the greater difficulty competitors encounter when "circling the patent" when it is of an international nature (Fischer and Leidinger, 2014). Therefore, the ownership of this kind of intellectual property rights not only enables firms to attain a position of exclusiveness, but also facilitates their sustainability and appropriability over time (Eaton and Kortum, 1999).

An essential requirement for better understanding the potential patents have involves a more thorough definition of a valid measurement indicator (Martínez, 2008; Hsieh, 2013; Tseng *et al.*, 2013; Fischer and Leidinger, 2014). The more common metrics used include the number of patents, the number or percentage of patents a firm has in the area of

technology, their citation rate in other subsequent patents or scientific papers (Griliches, 1990, Xiang et al., 2013) or their scope of application – domestic, European or international – expressed in such terms as international patents or the size of the patent *family*, according to the number of countries in which the intellectual property right is recognized (Putnam, 1996; Romero de Pablos, 2005; Martínez, 2008; Deng, 2011).

In this case, we have measured innovation performance through the number of international patents obtained by the firm from 2004 to 2007. Recent studies (i.e. Fischer and Leidinger, 2014) have developed empirical models for the variables that determine the specific value of the patents traded on organized markets, which include their international nature.

Independent variable: absorptive capacity

The difficulty in measuring and assessing a firm's intangible assets is a recurring issue in the literature (Carmeli, 2004). The intangible and complex nature of absorptive capacity makes it a phenomenon that is difficult to conceptualize and measure (Jiménez-Barrionuevo et al., 2011).

As Fig. 4 shows, the measurement of absorptive capacity in the prior literature has been considered, generally speaking, from two alternative perspectives. On the one hand, several studies propose measuring that capacity as if it were a unidimensional phenomenon, related mainly to the overall effort in R&D that a firm has made (Cohen and Levinthal, 1990; Tsai, 2001, 2009; Rothaermel and Alexandre, 2009; De Jong and Freel, 2010; Flatten et al., 2011; Lin et al., 2012; Weigelt and Sarkar, 2012). Nevertheless, following the variable's structuring around its main phases, different scholars have deemed it appropriate to detail the effort made, seeking to reflect the presence of organizational routines in each one of them. Especially illustrative in this sense are the empirical studies by Caloghirou et al. (2004), Nieto and Quevedo (2005), Jansen et al. (2005), Camisón and Forés (2010), Flor-Peris et al. (2011), and Fernhaber and Patel (2012), which establish specific measures for representing the absorption routines specific to each one of the phases (detail in Fig. 4).

As we explained in the theory section, when such knowledge is not directly available in the market, new alternatives are necessary. The rapid growth in technological knowledge, and the increasing need to integrate diverse technologies from different sources make acquisition and cooperation between firms become remarkable options for firms to create value by a synergy of complementary productive resources (Miozzo et al., 2016).

As regards the knowledge acquisition phase, and according to our classification – (1) *resource-based* routines and (2) *relation-based* routines – the measurement has been considered through the mean value of the effort developed from 1997 to 2000 in the following routines: (1) purchase of knowledge, (2) cooperation with different partners and (3) participation in high-technology firms.

Concerning the knowledge assimilation phase, we have included, as regards the overall headcount, indicators on the professional qualifications of the staff assigned to R&D duties (assistants, middle technicians and higher technicians); the references for this proposal are several prior

studies, such as those by Caloghirou et al. (2004), Arbussa and Coenders (2007), and Grimpe and Sofka (2009).

Concerning the transformation stage, in terms of its reference to information systems of use for the capture, standardization, storage, combination, disclosure and recovery of knowledge (Jansen et al., 2005; Camisón and Forés, 2010; Flor-Peris et al., 2011; Fernhaber and Patel, 2012; Hurmelinna-Laukkanen, 2012; Enkel and Heil, 2014), we have included those indicators in the survey that expressly cover the establishment of systems for the standardization and coding of processes, as well as the use of different systems and ICTs.

Finally, as regards the exploitation phase, inclusion has been made of those indicators that cater for the routines theoretically defined in section "Literature review and research model", either to facilitate the incorporation of new knowledge into the firm's operations, or to focus the processes of marketing and distribution, according to the market's uses and needs. Some of the studies that have enabled these measures to be considered valid from a *theoretical* perspective or regarding *content* are those by Nieto and Quevedo (2005), Jansen et al. (2005), Murovec and Prodan (2009), Flor-Peris et al. (2011), Fernhaber and Patel (2012) and Hurmelinna-Laukkanen (2012).

Control variables

With a view to removing any *interference* that might overshadow the analysis of the results, the control variables chosen are those corresponding to *size* (natural logarithm headcount), *age* (natural logarithm years of operation), the *industry* the firm belongs to, and *R&D expenditure/sales*.

An organization's *size* may have an impact on the innovation process (Damanpour, 1991; Elenkov et al., 2005), as it reflects its scope for allocating resources when developing new products or for dealing with uncertainty (Lee and Wong, 2011; Lin et al., 2012). An organization's *age* "modifies the context within which the innovation takes place" (Lin et al., 2012:287), as regards both the improvement in certain competencies and the obstacles it creates due to organizational inertias (Lin et al., 2012). The existence of an array of industries in the sample with different mean levels of usage of appropriability regimes requires the inclusion of the *industry* variable to control for the effects its characteristics have on innovation (Rothaermel and Alexandre, 2009). Finally, it should be noted that *R&D expenditure/sales* can increase the proportion of innovations open to patenting (Gallié and Legros, 2012), due to its impact on the commitment firms show when developing their knowledge bases (Lane and Lubatkin, 1998).

Statistical analysis

Before addressing the empirical verification of the hypotheses, we must first proceed to the preparation of the data and the prior analysis of their suitability for that verification, in this case using multiple regression techniques. As noted earlier, in the case of unidimensional dichotomous or quantitative variables (BUY, PART, ASSIMIL, INT.PAT), use was made of the arithmetic mean of the observations during the period under study, with the aim being to estimate their behaviour.

<i>COOPERATION ROUTINES</i>		<i>RACAP</i>			
		<i>TRANSFORMATION ROUTINES</i>		<i>EXPLOITATION ROUTINES</i>	
<i>COOP</i>		<i>TRANS</i>		<i>EXPLOIT</i>	
<i>Items</i>	<i>Factorial load (λ_{COOP})</i>	<i>Items</i>	<i>Factorial load (λ_{TRANS})</i>	<i>Items</i>	<i>Factorial load ($\lambda_{EXPLOIT}$)</i>
<i>Suppliers</i>	0.861	<i>CAD</i>	0.818	<i>Flexible Manufacturing</i>	0.822
<i>Customers</i>	0.859			<i>Quality</i>	0.737
<i>Competitors</i>	0.580	<i>ICTs</i>	0.632	<i>Marketing</i>	0.788
<i>Univ. And research centers</i>	0.782	<i>Robotics</i>	0.697		
Total variance	60.65%		60.76%		60.76%
Reliability (Cronbach Alpha)	0.775		0.677		0.730
KMO	0.735		0.795		0.795
Bartlett's test	0.000		0.000		0.000

Figure 5 Psychometric analysis for qualitative measures. Factorial analysis results: reliability and construct validity.

In the particular case of those phases or routines of absorptive capacity measured through a set of dichotomous variables observed during the analysis period (COOP, TRANS and EXPLOIT), the data needed to be transformed. The different observations of each dichotomous variable gathered throughout the entire period permitted their transformation into metric variables, which could be assimilated to the quantitative assessment made using Likert-type measurement scales.²

Once this transformation had been made, an exploratory factor analysis was conducted to address the study of the dimensionality of the forms of cooperation and the routines of transformation and exploitation (detail in Fig. 5). Thus, in the case of cooperation routines with different kinds of partners, the results show that these can be summarized in a single factor, which indicates the level of a firm's overall commitment to this hybrid learning formula.

As regards the phases involved in the RACAP – transformation and exploitation –, we deem it expedient to undertake a joint exploratory analysis of all the items, given the indistinct use of the metrics used for one or other phase and, specifically, the diverging treatment received by exploitation routines in prior research.

The results reveal the existence of two factors within the RACAP; on the one hand, the transformation factor, which includes the use of ICTs, as well as systems and media that contain coded knowledge. On the other hand, the exploitation factor involves the routines linked to marketing and market surveys, as well as quality control and flexibility systems, which allow adjusting to the changes in market

demand, and which, like a compass, can guide the development of patents of use for resolving real problems or unfulfilled market requirements.

We conclude this section on the research methodology by referring to Appendix A, which contains two additional figures that show, firstly, the fulfilment of the necessary conditions for using multiple regression techniques and properly interpreting the results obtained, and secondly, the correlations between the variables finally included in the model, means and standard deviations.

Empirical results

The empirical verification of the hypotheses relating absorptive capacity and international patents was undertaken using multiple linear regression models.³ The main descriptive data for the four regression models presented are shown in Fig. 6.

Models I and II contain only control variables. In the case of model I, R&D expenditure over sales, organizational size and age; with model II also including the effect of the industry to which the firm belongs (NCEA-2009). Model I shows that the predictor with the greatest relative importance, in terms of the number of international patents, is R&D expenditure over sales, and to a lesser extent, firm age. Model II shows that the variable involved in belonging to an industry is sometimes significant when explaining the number of international patents. Specifically, belonging to the chemical industry predicts a higher number of international patents. Finally, it should be noted that the effect of R&D expenditure over sales remains significant when including the industry effect.

² Whenever a firm gave a positive answer during each and every one of the exercises, the mean value of the variable would be 1, whereas if it answered negatively the resulting mean value would be 0. Depending on the number of years in which it answered positively or negatively, the value would fall somewhere between 0 and 1.

³ The statistical package used is SPSS (version 22). In the case of the regression models, the programme generated the standard model, including all the predictors.

	MODEL I		MODEL II		MODEL III		MODEL IV	
Corrected R ²	4,2%		7,1%		10%		20,4%	
Model description	Control 1		Control 2		Single absorptive routines		Joint absorptive routines	
Variable	β	Sig.	B	Sig.	β	Sig.	β	Sig.
Constant	--	0.000	--	0.001	--	0.017	--	0.215
I+D/SALES	0.861	0.000***	0.389	0.000***	0.121	0.002***	0.096	0.001***
SIZE								
AGE	0.112	0.030**						
Meat	INDUSTRY							
Food & Tobacco								
Beverages								
Textile								
Footwear								
Wood								
Paper								
Printing and publish.								
Chemical								
Rubber								
Non-metallic min.								
Ferrous & non-ferrous minerals								
Metallic products								
Farm machinery								
Office equipment								
Electrical machinery								
Motor vehicles								
Transportation								
Acquisition routines	BUY				-0.074	0.026**		
	COOP				-0.058	0.035**		
	PART (H1a)				0.039	0.084*		
Assimilation routines	ASSIMIL				0.266	0.000***		
Transformation routines	TRANS (H2a)				0.058	0.034**	0.030	0.038**
Exploitation routines	EXPLOIT							
PACAP	BUY→ASSIMIL		(H1b)				0.243	0.000***
	COOP→ASSIMIL							
	PART→ASSIMIL							
RACAP	TRANS → EXPLOIT (H2b)						0.040	0.025**
							0.219	0.000***

*** Sig. 1%.; ** Sig. 5%. ; * Sig. 10%

Figure 6 Significant results of the regressions models. ***Sig. 1%.; **Sig. 5%.; *Sig. 10%.

The inclusion of the *industry* variable increases model II's explanatory power to a modest extent, as reflected in the increase in the adjusted R². The inclusion of the effects of the absorption routines – model III – raises several issues. Firstly, there is a slight increase in the adjusted R², with the model's explanatory power over the behaviour of the dependent variable being around 10%. Secondly, belonging to the chemical industry is directly related to international patents, although its impact is lower in relative terms. Therefore, and except in the case of this sector, the industry effect is not significant when explaining a large part of the number of international patents secured.

Thirdly, several significant relationships can be identified between the absorption routines and firm performance in terms of its international patents. As regards the acquisition phase, and supporting hypothesis H_{1a}, the only routines with an individual positive effect (10% significance level) are those linked to a participation in other firms with a high technological potential, revealing the existence of a direct link between this phenomenon and the performance reflected in the number of international patents. We have therefore found evidence in support of hypothesis H_{1a}.

In the case of hypothesis H_{2a}, we find evidence to support the direct effect that transformation routines have on innovation performance. Thus, model III shows that the availability of technologies and information systems and the

existence of devices for their storage are directly associated with the obtaining of international patents.

Given the low value of the adjusted R² in the model of the individual effects of the absorption routines, we deem it expedient to conduct a joint analysis of the different absorptive phases, according to the PACAP-RACAP structure widely accepted in the literature (Zahra and George, 2002). In the full model (model IV), the level of the adjusted R² rises to around 20%.

This case reveals the explanatory power of the joint effects of the acquisition and assimilation routines. The assimilation routines moderate the relationship between the acquisition of external knowledge routines and international patent rate. In accordance to our hypothesis (H_{1b}), results show that the moderating effect of assimilation is greater in external relationships based on either cooperation or firm participation than in the ones based on markets. Nevertheless, the significance and the magnitude of the moderating impact is greater in the case of cooperation agreements. In consequence, the evidence obtained partially support our hypothesis (H_{1b}).

Finally, the maintenance of the significance of the transformation routines considered individually may explain the greater relative importance of these routines compared to those of exploitation, although the existence of moderating effect of exploitation routines in the relationship between

the transformation and international patent rate (H_{2b}), as shown by the standardized coefficient of RACAP, suggests the transformation phase has a knock-on effect.

Discussion and conclusions

The contexts firms face requires them to be internationally competitive, either to record an acceptable level of results or just simply to survive. This competitive scenario has a bearing on the significance of their performance in innovation. Besides, the maturity of domestic markets requires firms to consider international competitiveness as a strategic priority (Johnstone et al., 2011). Although international patents not always imply recognition of higher value knowledge, they shield their global exploitation in international markets. Accordingly, patents on an international level are essential for explaining firm results (Berry, 2016).

Using of external knowledge is highly recommended to reach strategic innovations necessary to be internationally competitive (Useche, 2014; Monteiro et al., 2016). Then, a better understanding about how firms identify, assimilate and exploit such external resources is of relevance for both strategy scholars and managers.

We contribute to literature on absorptive capacity in two complementary ways. On the one hand, abandoning the sequential process of absorptive processes (Todorova and Durisin, 2007; Jansen et al., 2005; Noblet et al., 2011), we propose the existence of moderating effects among absorptive routines within PACAP and RACAP, respectively. On the other hand, we enrich the treatment of the acquisition phase integrating into the analysis the alternative government models to acquire external knowledge, defined by the *search strategies* framework (Laursen and Salter, 2006, 2014). Therefore, we can analyze not only the role of different acquisition sources on international patenting, but also the specific moderating role that assimilation routines have, taking into account different levels of external relationships depth. Therefore, we have advanced in the understanding to operationalize the absorptive capacity from a holistic framework (Schleimer and Pedersen, 2013; Ebers and Maurer, 2014).

With respect to results, we can conclude the following ideas. Regarding PACAP, as we hypothesized, external sources of knowledge are vital in the absorptive process, but not all of them are equally relevant (Laursen and Salter, 2014; Hohberger et al., 2015). Deeper or stronger external relationships, like firm participation, are preferred options to transfer and appropriate specific and tacit knowledge (Desyllas and Hughes, 2008). Our results are consistent with previous studies, considering that acquisition of technology-intensive firms leads to a better transfer of knowledge and innovative performance (Girma, 2005; Elango et al., 2013).

In addition, when the moderating role of assimilation routines is included, cooperation agreements appear as the most efficient source of external knowledge (Nieto and Santamaría, 2007; Nooteboom et al., 2007), according to both significance and magnitude of their effects on international patenting. In this cases human capital is a success key factor to assimilate complex and specific knowledge from relation-based external sources (Park and Ghauri, 2011; Monteiro et al., 2016).

Considering RACAP, technological tools allow storing and structuring the information contained in firm's repositories making it available at the right time and place (Gassmann et al., 2012). Our results supported these arguments although we obtained additional evidence by including the moderator effect of exploitation in the relationship between transformation routines and international patents. So we can conclude that exploitation absorptive routines reinforce the role of ICTs oriented to knowledge transformation in innovative performance (Tu et al., 2006).

Finally, we would like to remark the higher explanatory capacity of the complete model that includes both direct and moderating effects. This fact confirms us the great relevance of interactions among absorptive routines to efficiently exploit external knowledge.

Limitations and future researches

The main limitations of this research are linked to the use of secondary information sources for measuring a highly complex organizational phenomenon, as well as to the analysis's limited time horizon. The inclusion of metrics on certain qualitative aspects of the routines, such as the purchase procedure, the characteristics of partnership agreements or affiliate companies, as well as the existence of other mechanisms for the transformation or exploitation of knowledge, would improve the treatment of the independent variable.

Accordingly, replicating the study with primary information to explore firm performance and with firms from other contexts (geographical and industrial), constitute priority lines of research. This would allow analysing other aspects that define absorption routines, such as, for example, the cognitive distance between the knowledge provider and receiver in the acquisition processes, or distinguishing between technological and social systems within the scope of knowledge transformation systems. In addition, these aspects will evolve over time. The post-acquisition period can condition the innovation output for the *acculturation process* (Berry, 1983). That is, firms experiment a cognitive convergence process after their integration (Bresman et al., 1999).

As regards the future, we also consider it important to include a firm's strategic positioning as a variable that may have a bearing on the performance of its innovation activity.

Furthermore, consideration should also be given to the existence of other results that are specific to innovation performance, besides international patents, which may be affected by the knowledge absorption process, whereby the specific effect of the absorption routines may be analyzed, depending on how radical the innovation is or its embodiment in a new product or process.

Finally, we would like to highlight the interest of further developing the joint analysis of the different absorption routines, over and above the traditional distinction between PACAP and RACAP, making it possible to identify synergies between them; for example, between the assimilation and transformation phases. The possibility of drawing a complete map of the relationships between the different absorption routines and their effects on an organisation's performance will be of great interest for making practical

recommendations designed to gain the highest possible returns from the investments made.

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Appendix A.

See Figs. A.1–A.4.

<i>PHENOMENON</i>	<i>CRITERION</i>	<i>TEST</i>
<i>RESIDUES</i>	Independence	<ul style="list-style-type: none"> • Durbin-Watson ($1.5 < DW < 2.5$) • Sample size ($N > 100$)
	Normal	
	homoscedasticity	<ul style="list-style-type: none"> • Graphic analysis: ZPRED-ZRESID
<i>DEPENDENCE RELATIONSHIP</i>	Linearity	<ul style="list-style-type: none"> • Graphic Analysis: partial regression diagram
<i>INDEPENDENT VARIABLES</i>	Non-collinearity	<ul style="list-style-type: none"> • Correlations lesser than 0.9 • Being $R^2 \neq 0, \exists \beta \neq 0$ • $-1 < \beta < 1$ • Tolerance values away 0.01 • Condition indexes > 15

Figure A.1 Multiple lineal regression conditions.

VARIABLE	N	MIN.	MAX.	MEAN	SD
LnAGE	2535	2.56	5.62	3.42	0.51
LnSIZE	2535	9.30	21.30	14.75	2.27
R&D/SALES	1727	0	18.34	0.71	1.73
BUY	1727	1	2	1.23	0.35
COOP	1727	-4.13	0.67	0	1
PART	1727	1	2	1.95	0.16
ASIMIL	1384	1	2	1.84	0.26
TRANS	1355	-2.83	1.80	0	1
EXPLOIT	1355	-3.19	1.57	0	1
INT PAT	1142	0	97	0.36	4.75

Figure A.2 Descriptive analysis.

INDUSTRY	NUMBER OF FIRMS	%
<i>Meat</i>	44	0,03
<i>Food & Tobacco</i>	158	0,10
<i>Beverages</i>	26	0,02
<i>Textile</i>	160	0,10
<i>Footwear</i>	48	0,03
<i>Wood</i>	58	0,04
<i>Paper</i>	57	0,04
<i>Printing and publishing</i>	98	0,06
<i>Chemical</i>	105	0,07
<i>Rubber</i>	102	0,06
<i>Non-metallic min.</i>	114	0,07
<i>Ferrous & non-ferrous minerals</i>	60	0,04
<i>Metallic products</i>	189	0,12
<i>Farm machinery</i>	125	0,08
<i>Office equipment</i>	21	0,01
<i>Electrical machinery</i>	102	0,06
<i>Motor vehicles</i>	91	0,06
<i>Transportation</i>	33	0,02

Figure A.3 Distribution of firms among industries.

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