Absorptive capacity, innovation networks and products: SME in the Basque Country

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Abstract: Innovation networks and knowledge clusterisation depends to a great extent on the capacity of companies to acquire and assimilate external knowledge. The capacity of business to absorb scientific knowledge is associated with the disciplinary profile of its human resources. To explore the relationship between disciplinary absorption capacity, networks and innovation products, we suggest the concept of critical mass in science and technology-oriented human resources and compare two types of companies distinguished by differences in the profile of their critical masses. The results show that a relation does exist between the discipline-related makeup of the critical mass, the types of products obtained and the types of partners in innovation networks.

Keywords: absorptive capacity; critical mass; Basque Country; innovation networks; regional development.

Reference to this paper should be made as follows: Castro Spila, J., Rocca, L., Ibarra, A., Pradales, I., Pérez Vega, N. and Méndez de Castro, C. (2010) 'Absorptive capacity, innovation networks and products: SME in the Basque Country', *Int. J. Innovation and Regional Development*, Vol. 2, No. 3, pp.182–197.

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1 Introduction

Small and medium enterprises (SME) are considered to be increasingly important in regional development. Regional policies seek to promote and facilitate innovation capability at SME, while improving cooperation levels between them, in a bid to develop interactive learning processes between firms and regions (Hoffman et al., 1998; Nauwelaers and Wintjes, 2000). The development of such interactive learning processes depends, however, on the nature and characteristics of regional innovation networks and on the capacity of firms to absorb knowledge (Abreu et al., 2008; Benz and Furst, 2002).

Absorptive capacity is defined as '*an ability to recognise the value of new information, assimilate it, and apply it to commercial ends*' [Cohen and Levinthal, (1990), p.128]. The concept attempts to pinpoint the dynamics of learning by interaction deriving from the process of assimilation and exploitation of external knowledge acquired through alliances between organisations (Lane and Lubatkin, 1998). In a relatively recent paper, Zahra and George (2002) provided an integrated overview of the concept of absorptive capacity by differentiating two key factors: *potential absorptive capacity*, which refers to the skills firms exhibit in acquiring and assimilating knowledge, and *realised absorptive capacity*, referring to the skills shown by firms in transforming and commercially exploiting the knowledge assimilated (Zahra and George, 2002).

In the present paper, we explore the concept of *disciplinary absorptive capacity* to show the connection between the disciplinary profile of businesses, their products and the innovation networks they are involved in. Disciplinary absorptive capacity is defined as the skill shown by companies in acquiring and assimilating external scientific knowledge used to solve innovation-oriented problems (Lim, 2008). In our view, the notion of the critical mass of Human Resources for Science and Technology (HRST) is particularly important to disciplinary absorptive capacity, as qualified or skilled staffs are in a position to acquire, assimilate and exploit knowledge (Abreu et al., 2008; Castro Spila et al., 2008).

Our work revolves around the following issue: what influence does the disciplinary profile of HRST have on the composition and shaping of innovation networks and the products obtained by businesses in their innovation processes? To answer this question, we provide empirical evidence on the role of disciplinary absorptive capacity in two types of SME in the Basque Country (Spain), differentiated by the disciplinary profile of the critical mass of their HRST. The first type of firm (E1) has a critical mass comprising 100% of their HRST being associated with engineering and technology. The second type of company (E2) has a critical mass comprising HRST that may be from the areas of engineering and technology or the exact and natural sciences. Our results show there is a relation between the disciplinary makeup of the critical mass, the types of products obtained and the types of partners found for cooperation in innovation networks.

The paper's main contribution is to improve our understanding of the concept of absorptive capacity by establishing the importance of the critical mass of HRST and their disciplinary profiles. Critical mass and its composition is a key factor in characterising innovation capabilities at companies, the types of products they obtain (innovations, patents, publications) and the types of partners they bond with in the innovation networks in which they are involved.

The work done has been divided into three sections. The first section provides an analytical framework on absorptive capacity, the second expounds the nature and characteristics of the Basque region of Spain as the study's context, the methodology and the results obtained and the third contains our conclusions and some implications.

2 Absorptive capacity

2.1 The concept of absorptive capacity

In a seminal paper, Cohen and Levinthal defined absorptive capacity as the '*an ability to recognise the value of new information, assimilate it, and apply it to commercial ends*' [Cohen and Levinthal, (1990), p.128]. From their viewpoint, the capacity to absorb knowledge is a relational concept that refers back to the notion of interaction between internal and external features of companies in the development of internal innovation capabilities. The concept attempts to pinpoint two types of related processes:

a internal knowledge interactions within firms, whose practices and dynamics are part and parcel of organisational routine

b the external interactions of firms that permit them to attract knowledge available in the organisational environment and use a number of assimilation mechanisms to integrate such knowledge into the innovation processes.

This absorptive capacity always expresses an innovation-oriented learning process by interaction (Cohen and Levinthal, 1990; Lane and Lubatkin, 1998; Nooteboom, 2000; Zahra and George, 2002).

But as well as being relational, absorptive capacity is also accumulative (Cohen and Levinthal, 1990; Van den Bosch et al., 2003; Zahra and George, 2002). Indeed, prior knowledge permits the *assimilation and exploitation* of new knowledge to the extent that a portion of the knowledge pre-existing in a firm is one step this side of the new knowledge and acts as a bridge between the knowledge accumulated and assimilated and the different, as yet unassimilated knowledge, facilitating its creative use. Without accumulated knowledge it is not possible to interpret and evaluate what is different and original in the new knowledge. So '*absorptive capacity accumulated over a period of time permits more efficient accumulation in the following period*' [Cohen and Levinthal, (1990), p.136].

In this way Cohen and Levinthal conceptualised the relational and interactive nature of absorptive capacity in the notions of *assimilation* and *exploitation* of new knowledge deriving from the existence of prior knowledge (Cohen and Levinthal, 1990; Van den Bosch et al., 2003; Zahra and George, 2002). However, the ability of *assimilating* and *exploiting* knowledge require different competencies. In the first case, we are dealing with learning capacities that enable new knowledge to be captured and fixed (*assimilation*); and the second case has to do with competencies or capacities for problem solving facilitating creative solutions to new or unexpected problems and to take commercial advantage of them (*exploitation*).

How to observe, empirically, the absorptive capacity in the firms? Cohen and Levinthal considered a decisive factor in absorptive capacity was associated with the R&D effort [Cohen and Levinthal, (1990), p.138]. Besides producing new knowledge for innovation and increasing a firm's competitive levels, R&D is also responsible for generating incentives for learning at the organisational level and encouraging interactions with other companies and organisations (Abreu et al., 2008; Cohen and Levinthal, 1990; Schmidt, 2005). The R&D effort made by the firms is a proxy indicator of absorptive capacity. However, subsequent studies have shown that R&D expenditure, while an important feature of innovative companies is ambiguous and less decisive than Cohen and Levinthal thought as a proxy indicator of absorptive capacity (Schmidt, 2005). Authors like Lane and Lubatkin (1998), Van den Bosch et al. (2003) and Schmidt (2005) offer empirical evidence for the argument that R&D expenditure is less important in company absorptive capacity, underscoring other factors like the degree of integration of knowledge in organisational routine and the role of human resources in the dynamics of innovation.

A central, decisive feature in the concept of absorptive capacity is the knowledge itself. In other words, the complexity of the knowledge and the types of knowledge involved in absorptive capacity are also important (Van den Bosch et al., 2003). Lim (2008) analyses the dynamics of absorptive capacity in the semiconductor sector from an evolutionist perspective, arguing that absorptive capacity takes three types of forms: disciplinary, domain-specific and encoded. Each form requires different organisational mechanisms to assimilate knowledge and different partners in cooperation to acquire new knowledge (Lim, 2008). Although the type of knowledge it is possible to absorb is a key issue in absorptive capacity, it has been largely neglected in the literature (Lim, 2008; Van den Bosch et al., 2003) even when evidence has been found in studies of the relation between R&D and cooperation (Veugelers and Cassiman, 2005).

In a relatively recent paper, Zahra and George (2002) argued that notions of the assimilation and exploitation of knowledge express a conceptual gap in the construct of absorptive capacity, largely due the ambiguity and diversity of definitions, components and antecedents available [Zahra and George, (2002), p.185]. With a view to offering an integrated perspective, the authors put together a two-dimensional model that distinguished *potential* absorptive capacity from *realised* absorptive capacity [Zahra and George, (2002), p.189–192].

A *Potential absorptive capacity*: Potential absorptive capacity includes knowledge *acquisition* and *assimilation* capacities. The former involves skills in identifying and acquiring external knowledge and the latter refers to skills in analysing, interpreting and understanding the knowledge acquired from external sources.

B *Realised absorptive capacity*: The capacity to acquire and assimilate knowledge does not guarantee its exploitation in terms of results; for this to happen processes of *transformation* and *exploitation* of knowledge are necessary. The former refers to taking knowledge on board and effectively integrating it into an organisation's routines and processes. The latter involves activities creating recombinations of new and existing knowledge to innovate (in products or processes) as a way of creating commercial value.

We argue that, to the extent that absorptive capacity is essentially an interactive process of knowledge and learning, the HRST are at the core of the process, since the qualified staff is in a position to evaluate, assimilate, transform and exploit knowledge. However, the profile and number of HRST in an organisation are key factors for any trade-off in innovation processes, i.e., what we call critical mass. Critical mass expresses the accumulated capacity to learn and produce knowledge-based innovations and no attempt to understand absorptive capacity in businesses can afford to neglect it (Castro Spila et al., 2008). However, the profile of the HRST (such as the disciplines they belong to, the academic level achieved and the research function they fulfil in innovation activities) may lead to different kinds of cooperation to obtain external knowledge and yet this acquired and assimilated knowledge may still not be transformed into specific innovations (exploitation). So the three types of absorptive capacity proposed by Lim (2008) should be considered within the framework of Zahra and George (2002) distinctions in dealing with the potential for and actual materialisation of absorptive capacity. The present paper is oriented in this direction.

2.2 Potential absorptive capacity: acquiring and assimilating knowledge

From the viewpoint of absorptive capacity, innovation may be understood as a process of social interaction with three major characteristics. To begin with, it is a resource-oriented, dynamic process of knowledge on the knowledge itself (Cohendet and Meyer-Krahmer, 2001). This creative *resourcefulness* acting on knowledge is much more likely to take place when accumulated knowledge is available (Cohen and Levinthal, 1990). Second, this resource-based, accumulative process generates learning externalities and is not independent of the conditions of production, i.e., it is a socially, temporally and spatially situated process (Cohendet and Meyer-Krahmer, 2001; Nonaka and Takeuchi, 1995). Thirdly, innovation is a process combining ‘basic knowledge’, which permits the general understanding of the traditions and techniques used in a particular field of disciplines and technologies, and a ‘diversity of knowledge’, which enables the creative use of a range of knowledge (Lane and Lubatkin, 1998). This combination of knowledge strengthens the platform from which learning by interaction is possible and increases the levels of creativity applied to the solution of complex problems (Cohen and Levinthal, 1990; Lane and Lubatkin, 1998; Van den Bosch et al., 2003; Zahra and George, 2002).

Innovation understood as a social, interactive process that generates learning externalities possesses a broad range of internal and external knowledge sources.

a Internal sources: In intra-organisational learning, the knowledge source is to be found within the organisation itself and is captured through learning by doing and learning by using. The former suggests that the more firms practice what they do, the more they learn and the better they perform (using trial-and-error methods). The latter suggests that the use and application of new technologies to the company’s core activities increases learning and knowledge creating expertise and new opportunities to explore and solve problems (Amara et al., 2008; Cohen and Levinthal, 1990; von Hippel and Tyre, 1995).

b External sources: In inter-organisational learning, the source of knowledge is outside the limits of the organisation and is captured by taking part in innovation networks that provide access to new information and the opportunity to become familiar with competencies of the partners in cooperation (Lane and Lubatkin, 1998). Innovation networks are indirect channels for the circulation of knowledge, ideas and best practices and posses learning and innovation externalities.

2.3 Realised absorptive capacity: applying knowledge

In the last instance, problem solving is a process that integrates knowledge and learning oriented towards the application of knowledge. It is a technical and social process that brings into play the set of skills and knowledge acquired through other forms of learning (Cohen and Levinthal, 1990; von Hippel and Tyre, 1995). As we suggested earlier, it is not enough to observe the 'conditions for the possibility' of innovation with regard to the potential expressed by critical mass and interactive learning; the empirical results of the process also need to be observed. In other words, the capacity to transform and effectively codify knowledge the organisations possesses. So the results of the process of applying knowledge are innovations varying in kind that may have to do with the product, process, marketing, organisational and business practices (OECD, 2005), or publications (articles, working documents) or patents. The first enable firms to demonstrate other kinds of competencies and other types of results (Okubo and Sjoberg, 2000). The second show the degree of originality of the knowledge the innovation-oriented organisation manages. Apart from signifying high levels of knowledge codification, patents also express the effort to protect intellectual copyright and the yield due from the investment made in the exploitation of knowledge.

3 Results: SME in the Basque Country

3.1 The Basque Country: the research context

A Spanish region situated in the north of the country, up against France's south-western border, the Basque Country measures 7,235 square kilometres in all, with 2,129,339 inhabitants. It is Spain's third most important regional economy after the regions of Madrid and Catalonia. It has a wide margin for self-government in administration and implementation of, among others, treasury and tax policy, industrial and economic promotion policy and research and innovation.

Ranked 55th out of 203 innovative European regions in the Regional Innovation Scoreboard 2006 (Hollanders, 2007), the Basque Country is the ninth region in Europe in terms of the highest number of highly qualified people in the workforce (EUROSTAT, 2008). Figures for investment in R&D show that. Over the last decade, R&D expenditure as a percentage of the regional GDP was higher than the Spanish average and lower than the European average (Table 1).

To illustrate the features of the regional context related with disciplinary absorptive capacity we provide information on regional HRST profiles. As Table 2 shows, the HRST in engineering and technologies clearly predominated in the last ten years, and that this profile is quite different from the HRST profile for Spain as a whole, where the HRST of exact and natural sciences abound (Table 2). However, in the Basque Country the HRST in this latter area enjoyed the largest relative increase (366% of percentage variation). Data on internal R&D expenditure by discipline (Table 3) clearly show that on average more than 70% of the total regional outlay on R&D in the last ten years was habitually allocated to engineering and technologies.

The figures highlight some features of the region. To begin with, the regional government has plenty of freedom to implement policies, a faculty readily acknowledged by other studies of the Basque Country as a major factor in moving and shaking innovation (Cooke et al., 1997). Second, it is a relatively dynamic scenario for innovation (Regional Innovation Scoreboard 2006) with a significant pool of qualified human resources (EUROSTAT, 2008). In third place, the region has a long technological, rather than scientific record. This is reflected both in the regional HRST profile, so different from the rest of Spain, and in the share of these disciplines in total regional expenditure on R&D.

Table 1 Science and technology indicators: Basque Country, Spain and European Union-27 (2006)

	BC	*Spain*	*EU-27*
Expenditure R&D/GDP (%)	1.47	1.20	1.84
Fulltime R&D staff/population employed	13.2	9.6	9.5
Full time researchers/population employed	8.3	5.9	5.7
Financing (%)			
Business	61.2	47.1	54.5
Authorities	35.4	42.4	34.8
Other sources	0.3	4.6	2.2
Foreign	3.1	5.9	8.5
Spending (%)			
Business	79.5	55.6	63.5
Authorities	3.3	16.6	13.3
University	17.2	27.7	22.2

Source: EUSTAT (2008a)

Table 2 Full-time R&D staff according to scientific discipline Spain (1995 and 2001) and Basque Country (1995, 2001 and 2005)

Discipline	*Spain*	*Basque Country*	*Spain*	*Basque Country*	*Basque Country (1995–2005)*	
	1995	*1995*	*2001*	*2001*	*2005*	*Vr. %*
Exact and natural sciences	*30%*	7%	*27%*	*9%*	14%	*366%*
Engineering and technology	*33%*	*63%*	*35%*	*67%*	*65%*	*133%*
Medical sciences	*16%*	*11%*	16%	*9%*	10%	107%
Agricultural sciences	7%	1%	8%	3%	3%	*359%*
Social sciences and the humanities	*14%*	*18%*	*15%*	*11%*	9%	12%
Total	100%	100%	100%	100%	100%	127%
	46,828	8,532	79.268	16,120	19,331	

Note: Percentage variation for Basque Country: 1995–2005.

Source: EUSTAT (2007) and INE (2007)

Table 3 Internal R&D expenditure (€000s) according to scientific discipline and character

	1997	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*
Exact and natural sciences	9%	7%	9%	10%	6%	10%	8%	10%	9%	12%	9%
Engineering and technology	74%	74%	78%	76%	79%	77%	77%	77%	75%	74%	72%
Medical sciences (inc. pharmacy)	7%	7%	6%	5%	6%	6%	5%	7%	8%	8%	11%
Agricultural sciences (inc. livestock, forestry and fishing)	1%	2%	2%	3%	3%	3%	4%	2%	4$	2%	4%
Social sciences and the humanities	9%	10%	5%	5%	5%	4%	5%	4%	4%	5%	4%
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Source: EUSTAT (2008b)

3.2 Methodology and study hypothesis

To study absorptive capacity, critical mass and HRST demand in the Basque Country, information was gathered on 286 companies, 194 of which (68%) performed R&D and 92 of which (32%) were members of business clusters. The figures are for 2004 and 2005. The sample had a sample error of 4.4% and a confidence level of 95%. HRST were classified in line with the criteria of the OECD (1995).

A previous paper (Castro Spila et al., 2008) dealing with the same sample of companies looked at the relation between the critical mass of HRST and the capacity to absorb knowledge. Critical mass refers to the HRST profile and relative size required for the sustained, successful acquisition, assimilation transformation and exploitation of knowledge. The analysis compared two types of businesses. Companies classed as E3 performed three types of activities: R&D, innovation and cooperation for innovation, while E0 firms did not perform any of these activities. The study showed that the critical mass of HRST was a key factor in the differences in innovative/non-innovative behaviour between one type of firm and the other (see Castro Spila et al., 2008).

In the present paper, we were interested in exploring the concept of disciplinary absorptive capacity, defined as the skill shown by firms in acquiring and assimilating scientific knowledge used to solve innovation-related problems. This type of absorptive capacity presupposes the existence of scientists trained in different disciplines and areas and who habitually have sufficient freedom to explore possible solutions to innovation-related problems. Companies with disciplinary absorptive capacity implement cooperation strategies with universities and scientific centres and are active in publishing articles in scientific journals [Lim, (2008), p.6].

The need to analyse disciplinary absorptive capacity arose from the evidence pointing to the existence of a good number of firms (in our sample) where 100% of their HRST belonged to engineering and technology fields, and another substantial number of firms that displayed a critical mass of HRST combining staff in engineering and technologies with staff from the exact and natural sciences. As regards the critical mass discipline breakdown, the information was not surprising given the disciplinary profile of regional R&D personnel in the Basque innovation system, where engineering and technology predominate (Table 2).

In analysing disciplinary absorptive capacity, we classified the firms in the sample into two types:

- E1 companies: These are firms whose critical mass comprises 100% of their HRST associated with engineering and technologies areas. They account for 43% of the sample and had a critical mass of 12%. Finally, they were companies with a longer record as practically 50% had been set up before the 1990s (Tables 4 and 5).
- E2 companies: Companies whose critical mass comprises HRST drawn from engineering and technology and the exact and natural sciences. Accounting for 10% of the sample, they had a critical mass of 30%. The 79% of these firms were created recently, after the 1990s (Tables 4 and 5).

Table 4 Critical mass compared total E1 and E2 firm

Kind of firm	*Firms*	*Total human resources*	*Total human resources in science and technology*	*Critical mass indicator*
	N	*N*	*N*	*% HRST/HR*
Total firms (sample)	286 (100%)	2,5842	2,353	9%
E1	124 (43%)	11,641	1,361	12%
E2	29 (10%)	1,839	559	30%

Source: CSM-BX (2006)

Table 5 Age of E1 and E2 firm

Type of firm	*Year founded*			
	< 1969	*1970 to 1989*	*> 1990*	*Total*
E1	15%	33%	53%	100%
E2	4%	17%	79%	100%

Source: CSM-BX (2006)

Two exploratory hypotheses are given below as an aid to understanding the differences between E1 and E2 companies as regards potential and realised absorptive capacity.

Hypothesis 1: There are differences between E1 and E2 companies in the disciplinary makeup of their critical mass. For E1, this suggests less scientific research activity in comparison to E2, which are more oriented towards science-based innovations. In line with this suggestion, the sources of external knowledge should differ too. In E1 cooperation agents should be predominantly technology-oriented (e.g., technology centres) and for E2 cooperation agents should predominantly be scientific (e.g., universities or research centres) (potential absorptive capacity).

Hypothesis 2: The HRST critical mass of E1 and E2 companies is different (12% and 30% respectively). The relative size of the critical mass should be expressed in differing results regarding business innovation capacity; therefore, it is to be expected that the percentage of innovative companies in the E1 group will be lower than in the E2 group. Likewise, both groups should obtain different types of results from the application of knowledge. In E1 patents should predominate while in the E2 scientific publications should be more prominent as a means of codifying knowledge y and protecting R&D results (realised absorptive capacity).

3.3 Potential absorptive capacity: assimilation and acquisition

Critical mass (% HRST/HR) expresses the possibilities of assimilating knowledge by having staff working on science and technology. Tables 4 and 6 give comparative information on the firms' critical mass characteristics. To begin with, E1 and E2 both exceed the relative critical mass of the set of companies that does not reach 10%. However, we know the E1 (12%) have a much lower critical mass than the E2 (30%), and these differences are even greater in the composition of the critical mass. E1 have 32% of researchers while E2 have 50%, and the latter double the critical mass of PhDs in E1 (Table 6).

Table 6 Profile of critical mass as percentage of total

Critical mass	*E1*	*E2*
Researchers	32%	50%
PhDs	3%	6%

Source: CSM-BX (2006)

Participation in innovation networks facilitates the acquisition of external knowledge. Table 7 provides comparative information on the geographical origin of E1 and E2 partners in cooperation. In both cases the partners are basically regional (74% and 71% respectively). Table 8 gives information on the cooperation partners according to the type of organisation in question. The data suggests that the cooperation pattern in basically firm-to-firm and firm-to-technology centre. Cooperation with universities is on a similar level for both types of companies.

The figures highlight three interesting features of the potential absorptive capacity of E1 and E2 firms. There are differences in the disciplinary absorptive capacity observed according to size and critical mass makeup. Does this imply a clearly different cooperation pattern from the partners' viewpoint? According to the data, this relation is not so clear.

To start with, the size of the critical mass would seem to be associated with a greater capacity for joining and integrating in networks and sustaining cooperation for innovation. The figures in Table 4 suggest that the E2 have a greater cooperation ratio than the E1 and this might be due to the existence of a larger proportion of staff working on R&D activities, meaning more resources available for cooperation.

Second, the figures show how important geographical proximity is where cooperation partners are concerned (E1: 74% and E2: 71%) (Table 7). This probably expresses a sort of regional clusterisation of partners in cooperation for both types of firms. The regional cooperation pattern is independent of the specific makeup of E1 and E2 disciplinary absorptive capacity. The figure opens up a relatively unexplored dimension in the absorptive capacity approach regarding spatial considerations affecting the inter-organisational cooperation networks; even when efforts are made to incorporate the concept of absorptive capacity into regional dynamics (Abreu et al., 2008; Criscuolo and Narula, 2008; Kinder and Lancaster, 2001; Roper and Love, 2006) references to the role of geographical, institutional or organisational proximity are scarce in analytical perspective.

Third, disciplinary absorptive capacity, albeit with some reservations, seems to be associated with the type of cooperation partners companies choose (Hypothesis 1). The figures show that the large majority of E1 firms tend to cooperate with other firms and technology centres, which have an engineering- and technology-oriented profile. But E1 firms nonetheless also cooperate with universities. E2 firms tend to be more diversified in their choice of partners in cooperation and a small (but significant for our argument) number of companies even cooperate with public research bodies oriented towards the exact and natural sciences (Table 9). So it is true to say that E1 businesses focus their partners in technology, while E2 firms tend to choose both technological and scientific partners when it comes to innovation.

Table 7 Origins of partners of cooperation according to type of firm (2004–2005)

Area	*E1*	*E2*
Basque Country	74%	71%
Spain	13%	20%
EU-25	12%	9%
Other countries	1%	1%
Total partners	100%	100%

Source: CSM-BX (2006)

Table 8 Type of cooperation agents according to type of firm (2004–2005)

Type of partner	*E1*	*E2*
Firms	65%	54%
Universities	15%	14%
Technology Centre	20%	27%
OPIS/CSIC	0%	5%
Total	100%	100%

Source: CSM-BX (2006)

3.4 Realised absorptive capacity: applying knowledge

Finally, Tables 9 and 10 show the products obtained by both types of companies. In the first place, differences in critical mass size between E1 and E2 firms would not appear to have any relation with the results of applying knowledge, as 90% of the firms in both groups performed some product, process, organisational or marketing innovation in the 2004–2005 periods. The first part of Hypothesis 2 is not corroborated by the data. Second, critical mass composition in terms of disciplines would seem to have a bearing on the products obtained from the application of knowledge. Indeed, the E1 knowledge distribution pattern is based on article without impact indexes and working papers. In other words, they use the grey literature (Jeffery, 2000) to communicate and share knowledge. E2 companies publish in scientific journals with impact indexes, virtually ignoring grey literature as an option for disseminating their results. Third, E1 register patents in a far greater proportion than E2. These figures are consistent with hypothesis that the disciplinary composition of the critical mass organises a different set of results from the application of disciplinary knowledge. Scientists tend naturally to maintain the habit of publishing in journals with impact, even when they are working in business. Likewise, engineers and technology workers tend to generate more patents than scientists do, although this is not exclusive to the former.

Table 9 Activities of E1 and E2 firms (in % total)

Activities	*E1*	*E2*
	%	*%*
Innovation	90	90
R&D	85	83
Coop. on innovation	68	76

Source: CSM-BX (2006)

Table 10 Type of firm according to type of product obtained in 2004–2005 (% of total)

Products	*Total products*	*E1*	*E2*
Art. c/ISI-Thompson	100% (294)	14%	86%
Art. s/ISI-Thompson	100% (156)	90%	10%
Patents	100% (55)	60%	40%
Working papers	100% (242)	86%	14%

Source: CSM-BX (2006)

4 Discussion and implications

The concept of absorptive capacity is a particularly important construct in facilitating the analysis of the internal and external relations of companies seeking to appropriate and exploit external knowledge (Lane et al., 2002). From this perspective, in this paper we introduced the notion of critical mass of HRST in the concept of disciplinary absorptive capacity and we tried to show that there is a relation between the disciplinary profile of the critical mass, the products obtained and the partners in cooperation companies link up with to innovate. The study does not provide a complete explanation of the role of the critical mass of HRST (size and composition) and the process of transformation of potential absorptive capacity into realised absorptive capacity. That would have required a study focused on management between potential and realised capacities. Our paper concentrates mainly on stressing and grounding the importance of the disciplinary profile of the critical mass of HRST in the production of innovations and in the development of networks.

Our research has unearthed three interesting findings. The first, the size of the critical mass, i.e., the proportion of company staff working in R&D, is a major factor in comparing innovative firms with companies that do not innovate (Castro Spila et al., 2008), but does not seem to be a particular important factor when comparing innovative companies with other innovative firms, as the figures in this study demonstrate: 90% of the firms compared performed innovation activities despite the fact that E1 (12%) had a much smaller critical mass than the E2 (30%). The second finding has to do with the disciplinary makeup of the critical mass. As noted above, disciplinary makeup affects the type of products considered to be the result of applying knowledge. So businesses with scientific staff (exact and natural sciences) publish in scientific journals and register patents, although in a smaller proportion if compared to firms with a critical mass in engineering and technology. Tangentially, but no less important, companies with scientists on the payroll tend to behave more in line with more academic forms (publications). The third finding refers to the partners on cooperation. The figures show that when the disciplinary makeup of the critical mass is combined (engineering and technology + exact and natural sciences), as in the E2, partners tend be more heterogeneous and diversified than they are for companies with a critical mass exclusively composed of engineering and technology staff. The diversification of internal knowledge also diversifies the sources of access to and acquisition of external knowledge.

These results have two types of implications. To begin with, the paper provides evidence about the concept of disciplinary absorptive capacity, largely neglected in the literature on absorptive capacity (see Lane et al., 2002). Second, in the framework of a new model for regional innovation policy based on the promotion of interactive learning systems (Benz and Furst, 2002; Nauwelaers and Wintjes, 2000), it sheds more light on the role of critical mass in HRST; furthermore, its links with absorptive capacity enables us to fine-tune and combine innovation policy tools with science and technology human resources policies to improve competitive levels in firms and regions alike.

Acknowledgements

The authors would like to thank the anonymous referees for their contributions. Research performed with aid from: bizkaia:xede (Vizcaya Provincial Council), Red Guipuzcoana de Ciencia, Tecnología e Innovación (Guipúzcoa science, technology and innovation network – Guipúzcoa Provincial Council) and the Basque Government's SAIOTEK programme.

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