Int. J. Environ. Res., 6(3):585-596, Summer 2012
ISSN: 1735-6865

Research Effort, Functional Integration, and Environmental Action-Based Competitive Advantage: An Empirical Study

Junquera, B. and del Brío, J.

Universidad de Oviedo, Facultad de Ciencias Económicas y Empresariales Avda. del Cristo, s/n 33071 Oviedo, Spain

Received 2 Aug. 2011; Revised 11 Dec. 2011; Accepted 17 Jan. 2012

ABSTRACT: This paper seeks to make an empirical analysis of the degree to which the research effort and functional integration into the design of environmental activity account for a company's environmental action-based competitive advantage. To do so, we have used a sample of 110 factories. It has been proven that both factors (the research effort and functional integration into the design of environmental activity) have a positive influence on the factories' environmental action-based competitive advantage. These outcomes are the main in this paper and they have major implications for companies' research policy. It proves that there is a new advantage to the managerial effort dedicated to this area: this effort has a positive influence on the relation between a company's environmental management and its environmental action-based competitive advantage.

Key words: Environment, Innovation, Concurrent, Research, Advantage, Management

INTRODUCTION

Eenvironmental protection is becoming a key competitiveness factor. On the one hand, firms are more and more concerned about the potential negative influence environmental actions may have on their competitiveness (Walley and Whitehead, 1994; Segarra-Ona *et al.*, 2011). On the other hand, companies carry out environmental actions in an attempt to develop unique, valuable and inimitable resources (Hart, 1995; Russo and Fouts, 1997). This may lead to either a low-cost position or a differentiated product, while at the same time, improving the company's relations with public administrations, society, and environmental groups (Maxwell *et al.*, 1997; Christmann, 2000).

Despite this, many firms are still unable to comply with the pertinent legislation. Several factors justify this inability: a) lack of integration of environmental issues into the corporate strategy (Banerjee, 1998); b) scant consideration natural environment protection within the manufacturing strategy (Newman and Hanna, 1996; Angell and Klassen, 1999), c) insufficient involvement of senior management (Ramus, 2001), and d) lack of motivation and insufficient employee skills when dealing with environmental issues (Azzone and Noci, 1998; Handfield *et al.*, 2001), amongst others. In fact, the relation between some of the previously cited factors and companies' environmental action-based competitive advantage has already been examined to a greater or lesser degree in the literature.

Nevertheless, these are not the only elements that constrain company's environmental action-based competitive advantage. Environmental research activity is very important. Some studies have already referred to this issue, albeit from a theoretical point of view (Kemp and Soete, 1992; Winn and Roome, 1993; Roome, 1994; Chatterji, 1995; Ataei *et al.*, 2011; Lahijanian, 2011; Najafi and Afrazeh, 2011; Mossalanejad, 2011; Pirani and Secondi, 2011). More specificly, our analysis will deal first of all with the environmental research effort. By the term 'environmental research effort', we are referring to all investments made by a company to generate environmental technology, whether it be internal, hiring of qualified RandD personnel, cooperating with other companies and institutions, or benefiting from a spillover effect from sectorial associations and universities. Secondly, we have focused on the organization of environmental research activity, that is, how workers and resources dedicated to creating knowledge regarding the natural environment protection are coordinated. A vantage point considers that in order to enhance the effectiveness of an innovation development process, a company must juxtapose the stages involved (Takeuchi and Nonaka, 1986). Although the literature has hardly studied the

*Corresponding author E-mail: beatrizj@uniovi.es

influence this kind of organisation has on environmental innovations, it is reasonable to predict that it is a highly efficacious approach. This statement is based on the notion that the interdisciplinary and interfunctional nature of environmental issues demands an organizational design that is underpinned by a more holistic, systematic mindset than has been traditionally applied (Welford, 1992). Hence, we will conduct an empirical study that will demonstrate to what degree research effort and the functional integration into the design of environmental activity account for a company's environmental action-based competitive advantage.

MATERIALS & METHODS

The theoretical model presented in this paper is based on the idea that two dimensions of a company environmental research activity have a direct bearing on its environmental action-based competitive advantage. On the one hand, the environmental research effort must be examined in its entirety, including both the internal investment in RandD, as well as the effort that results from adapting environmental technologies or cooperating with other companies and institutions. The second dimension examined is the organization of said environmental research activity. More specifically, we are referring to its degree of functional integration.

A company's research effort has many dimensions: a) internal RandD, b) hiring personnel, c) benefiting from the spillover effect, and d) cooperating technologically. This is also true for the natural environment protection. Although the works published with respect to the performance companies obtain from their environmental research effort continue to be all but non-existent, many such studies have been performed about traditional RandD activities. Thus, for instance, the literature has emphasized the need for the research effort to surpass a lower limit or 'RandD threshold' in order to obtain a return on the investment made (Freeman, 1975). The literature has precious few empirical studies regarding the natural environment protection. Nonetheless, some theoretical studies offer a few ideas that, in any case, must undergo subsequent empirical contrast. These studies have pointed out that, on the one hand, some firms decide to invest in internal RandD in order to decrease raw materials and energy consumption or to manufacture 'green' products. The relevance of internal RandD in protecting the natural environment is based on the idea that the environmental action-based competitive advantage will ultimately depend on the scientific and technical knowledge accumulated, on the equipment available, and on the company's own environmental capabilities (Kemp and Soete, 1992).

Likewise, the literature that has studied companies' classical technological and innovative activities has corroborated the importance of RandD personnel in knowledge generation (Mansfield, 1968). Insofar as the natural environment protection is concerned, the literature has also underscored the fact that in order to generate a sustainable, environmental action-based competitive advantage, the employees must take part in the strategy-formulation process and participate in decision-making (Klassen and McLaughlin, 1993; Azzone and Noci, 1998; Polonsky *et al.*, 1998; Handfield *et al.*, 2001). Just as it is essential that the human factor be involved if environmental knowledge is to be created (Hart, 1995), it is reasonable to think that this is particularly the case with research personnel. In line with these arguments, hiring RandD personnel would become a key dimension of the company's environmental research effort. Likewise, the knowledge provided by this personnel can be expected to improve the company's environmental action-based competitive advantage.

There are few papers that have analyzed how relevant the spillover effect produced as a result of investments made in environmental technologies by sectorial associations, universities, and other public institutions is for the companies. Nevertheless, the role of these institutions can be expected to be crucial, given that in general, companies require more and more knowledge to be applied to the natural environment. However, there is little incentive for private agents to invest in basic research, given that the knowledge that comes out of it is a public good, hence, these investments must be made by the Public administrations or by non-profit institutions (Nelson, 1959). Moreover, these institutions also provide qualified researchers, technologies applied to research and instruments, knowledge (for example, tacit knowledge), and networks of professional contacts (Freeman, 1998). All these contributions enhance managerial capabilities to solve complex problems. This may explain, in part, why the benefits of research appear in geographical areas and are not within everyone's scope (Lundvall and Jonson, 1994; Jaffe, 1989). However, the benefit of this knowledge is not automatic, since, while it is a public good, it does not come free-of-charge. That is, the company must have prior related knowledge (Dixon, 2000) in order to adapt said knowledge and, at that, investments are still needed to implement it. Hiring experts has been proven to be the best way to take advantage of external technology and to increase the company's own technology base (Garvin, 1993). If we link these relative arguments to the spillover effect from outside the firms, we can conclude that companies must resort to this externallygenerated knowledge as a mechanism to improve their environmental action-based competitive advantage. Likewise, there are alternative organizational solutions for environmental research activity in the companies, such as cooperation with other firms and institutions (Bayona *et al.*, 2001; Tether, 2002). The literature dealing with technology and innovation has discovered that the companies that cooperate technologically stand out for having high RandD investment and good innovative performance (Link and Bauer, 1987; König *et al.*, 1994; Vonortas, 1997; Kleinknecht and Reijnen, 1992). Various reasons have been identified to explain the formation of technological alliances by companies (Coombs *et al.*, 1996). Recently, the aim of most alliances has been explained as a means of access to new complementary forms of technology, the objective of which is to enrich the innovative process and companies' learning (Chesnais, 1988; Hagedoorn, 1993; Cantwell, 1998; Dyer and Sing, 1998; Inkpen, 1998). It is conceivable that this is particularly important in the case of highly-interdisciplinary environmental innovations (Welford, 1992). For example, networks are acknowledged more and more as a source of important innovation capabilities in developing new products and services (Asheim, 1996; Porter, 1998). In Germany and Denmark, industrial districts or clusters have been leaders in environmental innovations (Griffiths and Petrick, 2001). Consequently, they comprise suitable structures to obtain and spread relevant information for sustainable performance throughout the network. In this way, cooperation with other companies and with sectorial associations in conducting environmental research should represent a form of RandD investment. Sometimes, the idea is to cooperate so as to create an independent body aimed at developing technologies related to a given activity and in accordance with the objectives set out by the sectorial association. This body, in addition to creating technology, would provide technological consulting and training. It is also a source of researchers for the firms (Ouchi, 1984). If this same reasoning is applied to the natural environment protection, it can be concluded that carrying out joint environmental research activities by several companies, on the one hand, and by universities and other research institutes on the other, would constitute a kind of environmental research effort. Therefore, it is feasible to consider that cooperation with associations and public institutions, for the same reasons as for internal RandD, are key indicators of the environmental research effort in the companies that enable them to improve their environmental action-based competitive advantage. From all of the afore-mentioned we can lay down the first hypothesis of this paper:

Hypothesis 1. The greater the research effort aimed at protecting the natural environment made by a company, the greater its environmental action-based competitive advantage will be.

The traditional organization into the design of research activity had generally been made from a functional point of view. This means that the innovative process circulated from one department to another along a kind of chain of development, running from one end of the company to the other. This conception of innovative activity has a fundamental disadvantage: any problem that arises at one stage can stop and even undermine the entire development process (Takeuchi and Nonaka, 1986). In practice, the problem was not terribly important in technologically static environments, characterized predominantly by standardized products that were not very complex (Shenas and Derakhshan, 1994). However, starting in the eighties, the advantages of an alternative organization applied to research began to be recognized. This alternative organization is basically characterized by its functional integration. Some firms are even capable of getting all functional areas highly involved in the innovative process from very early on. By doing so, they are able to shorten the length of their development projects, carry them out more efficiently, in addition to attaining higher quality and better performance features from the innovations obtained (Womack *et al.*, 1990).

Functional integration into the design of research activity has been given many other names, such as interfunctional cooperation, 'tiger teams', or interfunctional teams (Pinto and Pinto, 1990). Irrespective of the term used, all of them refer to the interdependence and information shared amongst the different organizational units that comprise the company. Research has underscored the importance of functional integration in successful innovative design (Gupta *et al.*, 1985; Song and Parry, 1992a; Song and Parry, 1992b; Song and Parry, 1993a; Song and Parry, 1993b; Song and Dyer, 1995; Song and Parry, 1996). In an empirical study, Song et al. (1997) found statistically significant relations between functional integration and business performance. The accelerated rate of technological development and customers' demands for new and better products needed to be capable of innovating permanently and getting these innovations to market fast (Blackburn, 1991). Despite its relevance, no study has been conducted aimed at assessing to what degree the development of innovations capable of improving companies' environmental action-based competitive advantage demands a different, more interfunctional organizational design.

Some papers have revealed dimensions that define functional integration (Koufteros *et al.*, 2001): a) early involvement of all functional areas in the process, b) interfunctional teams for product development, and c) concurrent engineering.

Classical literature dealing with the innovative process within the company had already pointed out that the prior involvement of the different functional areas is fundamental to decreasing cycle time, as well as enhancing innovative capabilities (Clark *et al.*, 1987; Barkan, 1992; Millson et al, 1992). Adams et al. (1998) suggests that by means of broad functional involvement in data gathering and interpretation, organizations can lessen the perceived ambiguity of market information. Furthermore, this early involvement enables certain design characteristics to be improved, so that the companies can achieve shorter manufacturing times, lower manufacturing costs, and higher quality (Putnam, 1985; Whitney, 1988; Raturi *et al.*, 1990; Fleischer and Liker, 1992; Ulrich *et al.*, 1993). However, no study has addressed the applicability of these arguments to the environmental issues. Only a few studies have made a passing reference to the influence these dimensions of interfunctionality have on the environmental innovative process. In this sense, Bhat (1993) highlighted the relevance of the early involvement of each of the functional areas throughout the whole design process of 'green' products. In contrast, it seems reasonable to state that, if this characteristic enables the quality of product design to be improved, as the previously cited works have shown, the most likely thing is that the same holds true for the natural environment. As some works have stressed, this notion is based on the usefulness of quality management tools in environmental management (Struebing, 1996; Kitazawa and Sarkis, 2000; Klassen, 2000). Hence, it seems logical to assume that early involvement of functional areas in the innovation development aimed at protecting the natural environment enables companies to improve their environmental action-based competitive advantage.

In turn, some studies concerning companies' 'classical' innovative activity have indicated that greater uncertainty surrounding the tasks demands greater organizational flexibility and less structuring and standardization. In particular, teamwork is considered to be critical in order to involve different kinds of highly specialized knowledge (Gallagher and Krant, 1990) while at the same time, it is fundamental to improving market penetration time (Pawar *et al.*, 1994). Therefore, thanks to interfunctional teams, the new products are more successful, given that RandD will be better able to understand market needs, marketing will be more adept at understanding technological capabilities and restrictions, and both will have a clear understanding of competitive and manufacturing strategies (Calabresse, 1997). Insofar as natural environmental protection is concerned, the interfunctional team has also emerged as an indispensable factor in the successful development of new 'green' products by promoting the generation of ideas (Cramer and Roes, 1993; Hanna *et al.*, 2000; Kitazawa and Sarkis, 2000). The relevance of teamwork in environmental innovation development is based on the specificities linked to natural environment protection. In line with this idea, it must be remembered that McKee (1992) suggested that interfunctional teams are particularly useful in highly dynamic environments, such as what we find at the levels that are most demanding of environmental protection, given that they foster communication and organizational learning. In this regard, Henke et al. (1993; 217) endorses the notion that "a logical response to overcome communication barriers and share information is included in horizontal decision-making processes that cross over the traditional vertical lines of functional authority". Given its eminently interdisciplinary nature, this characteristic leads one to expect that teamwork is particularly beneficial in developing environmental innovations, and, as a result, aids in improving the companies' environmental action-based competitive advantage (Welford, 1992).

Concurrent engineering, also known as simultaneous engineering or concurrent design, is a key philosophy about the best practices in product development (Maffin and Braiden, 2001). The main opportunities for launching products onto the market are linked to concurrent engineering (Blackburn, 1991; Stalk and Hout, 1990; Clark and Fujimoto, 1991; Nayak, 1990; Youssef, 1994; Toni and Meneghetti, 2000).

One the one hand, the hallmark of concurrent engineering is its more highly interdependent process of new product development as compared with sequential development. Moreover, it has the advantage of making functional interdependence reciprocal with mutual feedback. Consequently, concurrent engineering consists of a type of functioning that induces the involvement into overlapping problem-solving cycles, that shorten times, by simultaneously executing tasks by changing the nature and frequency of information flow, the direction of the prior and subsequent tasks, and the whole organization's attitude in order to deal with preliminary information (Clark and Fujimoto, 1991). In turn, it allows the company to plan and implement a set of organizational innovations that increase the value of its products for its customers, bolster quality, shorten time to market, and lower costs (Koufteros *et al.*, 2002). At its utmost, concurrent engineering means common goals, total visibility of design parameters, the mutual consideration of all decisions, collaboration in conflict resolution, and continuous improvement (Carter and Baker, 1991; Painter *et al.*, 1991; Schrage, 1993; Hauptman and Hirji, 1999).

Only a few studies have studied the role of concurrent engineering in the natural environment protection. Only Kriwet et al. (1995) has suggested the important role that concurrent engineering has in minimizing the environmental impacts of the processes used on the one hand, and the the product impact during their use, on the other. In light of the characteristic interdisciplinarity of environmental problems (Welford, 1992), it is reasonable to think that a company's environmental action-based competitive advantage will improve with concurrent engineering. From the previous statements, we can deduce the second hypothesis of this paper:

Hypothesis 2. The greater the degree of functional integration into the design of environmental research activity of a company, the greater its capability to improve its environmental action-based competitive advantage will be.

The methodology used in this work is shown: a) questionnaire design, b) process before the questionnaire reception, c) main characteristics of the sample and d) measures used in the research, their reliability and validity.

The design phase of the questionnaire requires a series of different actions that support the validity of the instrument and the items included in it. We undertook a comprehensive review of the literature. We also took advantage of the accumulated experience in a previous case analysis. A third action was based on the precision used in defining the questionnaire items, which enables us to reduce ambiguity (Warshaw, 1980; Davis *et al.*, 1989). Later, the questionnaire underwent a pretest by personal interviews with three people who were in charge of the environmental department at different certified factories. The final design of the questionnaire covered: 1) general aspects, 2) environmental practices and 3) measures of the manufacturing decisions.

The population includes all factories with International Standard Organization 14001 (ISO 14001) or Eco-Management and Audit Scheme (EMAS) registration[1] (or both) dedicated to industrial activities. We then contacted the certification agencies – Asociación Española de Normalización y Certificación (AENOR), Laboratori General D'Assaigs i Investigació (LGAI), Bureau Veritas Quality International (BVQI), Det Norske Veritas (DNV), Entidad de Certificación y Aseguramiento, S. A. (ECA), Systems and Services Certification-International Certification Services (SGS-ICS), Lloyd's, Cámara de Madrid and Instituto Valenciano de Certificación (IVAC) and we created a database including all the factories certified by April 2003.

The initial database included a total of 1,542 factories. Seventy-four of them decided not to participate from the very beginning, which gave us a total of 1,468 factories. We later eliminated the services factories, given that the questionnaire did not fit their circumstances. This left us with a total of 1,023 remaining factories that were eligible to carry out the study. The questionnaires were sent out and received between the months of June and September 2008.

One hundred and ten valid questionnaires were received, that is a 10.75% response rate[2]. The sample representativity and distribution of the factories by sectors and sizes can be seen in Table 1. Two logit analyses were performed following Osterman's method (1994) in order to evaluate the sample representativity more reliably than a mere description. The dependent variable in both cases was the probability of response. The independent variables were, in the first case, factory size (as measured by the number of employees) and, in the second case, sector (as measured by means of as many dummy variables as the number of sectors minus one, which has been used as the basis for the study[3]). The results confirmed the lack of significance, since none of the independent variables –the number of workers in the first analysis or the dummy variables representative of the industrial sector in the case of the second analysis– fit the equation. Therefore, the afore-mentioned results confirm the lack of sample bias based on these variables[4].

We are now to present next the measures used in the study. Following recommendations by Malhotra and Grover (1998) internal consistency (or reliability) of the items has initially been carried out for each case through assessment of Cronbach's Alpha. Factor analysis using items from multiple measures in the research model has been used to establish construct validity.

Environmental action-based competitive advantage. We used the constructs developed by Brockhoff et al. (1999) and Christmann (2000) in order to create a construct about our factories' environmental action-based competitive advantage (POCMA). Nevertheless, our final construct includes key changes. The items are measured by five-point scales: 1 if the statement was not valid or was very little valid in the factory and 5 if the statement was very valid. The construct is composed of the next items regarding the company the factory belongs to: 1) 'The environmental quality is our company's strong point compared to our competitors', 2) 'Our company is a leader to introduce green products', 3) 'Our company is diversified and

Table 1. Comparison of Sample Distribution and Population by Size and by Sectors

SIZE				
	Population		Sample	
Workers	NUMBER	PERCENTAGE	NUMBER	PERCENTAGE
0-249	687	67.16	72	65.45
250-499	141	13.78	15	13.64
500-999	98	9.58	14	12.73
More than 1,000	97	9.48	9	8.18
INDUSTRIAL SECTOR				
	Population		Sample	
Sector	NUMBER	PERCENTAGE	NUMBER	PERCENTAGE
Food	104	10.17	11	10
Chemical	233	22.78	34	30.91
Energy	42	4.11	6	5.45
Construction	147	14.37	13	11.82
Automotion	103	10.07	9	8.18
Electronics	114	11.14	10	9.09
Materials	162	15.83	15	13.64
Machinery	118	11.53	12	10.91

offers different products to environmentally-important market segments', 4) 'Environmental protection in my company is a factor that improves the market share' y 5) 'Our environmental strategy improves our company's relative position in comparison to our competitors'. Internal consistency of the answers was calculated by Cronbach's Alpha. Construct validity was tested by factor analysis. Table 2 shows its main results.

Environmental research effort. The construct (FUINMA), although with important changes, was created after analyzing Autio's (1997) and Bayona et al.'s (2002) papers. It is composed by items valued by five-point scales: 1 when the item has not importance or little importance in a factory and 5 when its importance is very high. The construct is supported on the review of the literature and on our own conclusions. Items that compose the construct describe the analyzed factory: 1) 'Internal RandD investment in order to protect the natural environment', 2) 'Investment to adapt knowledge from sectorial associations in order to protect the natural environment', 3) 'Investment to adapt knowledge from universities and other research centres in order to protect the natural environment', 4) 'To hire RandD personnel as a key decision for the environmental activity', 5) 'Cooperation with companies or sectorial associations with environmental aims' and 6) 'Cooperation with public administrations with environmental aims'. Cronbach's Alpha is the indicador that lets us value the reliability of the construct. A factorial analysis shows the construct validity. It indicates us that the construct is a single variable's indicator. Table 3 shows the main results.

Functional integration into the design of the environmental research activity. The construct (INTFMA), although with changes, was created after considering Koufteros et al. (2001)' paper. The items were valued by five-point scales: 1 if the item has not importance or very little importance in the factory and 5 if its importance is very high. In accordance with the review of the literature and our own conclusions, the construct is composed of the next items: 1) 'Early involvement of the interfunctional coordination for the environmental innovations', 2) 'Creation of interfunctional teams for the treatment of the environmental issues' y 3) 'Concurrent design of the environmental innovations by several departments' employees'. Cronbach's Alpha values the reliability of the answers. We likewise test the construct validity by a factorial analysis. This means that the construct is a single variable's indicator. Table 4 shows the main results.

RESULTS & DISCUSSION

We show the results obtained from this empirical study. Table 5 indicates its main results. Regression models will be tested according with the hypotheses previously deduced. In order to avoid interpretation problems derived from collinearity between the different independent variables, two different explicative models were considered. Everything of both models analyzes what was the predicted in each hypothesis with regard to the environmental action-based competitive advantage of the factories: model 1

Table 2. Factor Loadings of the Environmental Action-Based Competitive Advantage in the Factory

ÍTEMS	POCMA
The environmental quality is our company's strong point compared to our competitors	0.799
Our company is a leader to introduce green products	0.845
Our company is diversified and offers different products to environmentally-important market segments	0.742
Environmental protection in my company is a factor that improves the market share	0.770
Our environmental strategy improves our company's relative positions in comparison to our competitors	0.663
Cronbach's Alpha	0.828
Eigenvalue	2.936
Percentage of variance explained	58.730

Table 3. Factor Loadings of the Environmental Research Effort in the Factories

ÍTEMS	FUINMA
Internal RandD investment in order to protect the natural environment	0.831
Investment to adapt knowledge from sectorial associations in order to protect the natural environment	0.629
Investment to adapt knowledge from universities and other research centres in order to protect the natural environment	0.794
To hire RandD personnel as a key decision for the environmental activity	0.794
Cooperation with companies or sectorial associations with environmental aims	0.803
Cooperation with public administrations with environmental aims	0.819
Cronbach's Alpha	0.908
Eigenvalue	4.058
Percentage of variance explained	67.633

Table 4. Factor Loadings of Functional Integration of the Environmental Research Activity in the Factories

ÍTEMS	INTFMA
Early involvement of the interfunctional coordination for the environmental innovations	0.900
Creation of interfunctional teams for the treatment of the environmental issues	0.888
Concurrent design of the environmental innovations by several departments' employees	0.776
Cronbach's Alpha	0.815
Eigenvalue	2.200
Percentage of variance explained	73.332

Table 5. Results of the Regression Analysis of the Different Models

	MODEL 1		MODEL 2	
Constant	$2.465 x 10^{-17}$	(……….)	$4,155 x 10^{-17}$	(………)
	0.000	1.000	0,000	1,000
ENVIRONMENTAL RESEARCH EFFORT (FUINMA)	0.484	(0.484)		
	5.749	(0.000)		
INTERFUNCTIONAL INTEGRATIION INTO THE DESIGN OF THE ENVIRONMENTAL RESEARCH ACTIVITY (INTFMA)			0.417	(0.417)
			4.765	(0.000)
R^2	0.234		0.174	
Adjusted R^2	0.227		0.166	
F	33.046		22.705	
Sig. F	0.000		0.000	
N	110		110	

is referred to its relationship with the environmental research effort and model 2 analyzes the relationship with regard to the functional integration into the design of the environmental research activity.

The environmental research effort influences a factory's environmental action-based competitive advantage, as we had predicted. The relationship was found to be statistically significant at $p<0.001$. The environmental research effort appears to explain around 22.7 per cent of factories' environmental action-based competitive advantage. Hypothesis 1 was therefore validated.

In accordance with our approach in hypothesis 2, the functional integration into the design of the environmental research activity influences the environmental action-based competitive advantage in the factories. The relationship was found to be statistically significant at $p<0.001$. The functional integration into the design of the environmental research activity appears to explain around 16.6 per cent of a factory's environmental action-based competitive advantage. As a result, hypothesis 2 is validated.

CONCLUSION

The objective of this paper has been to determine to what degree research activity focused on protecting the natural environment is related with a company's environmental action-based competitive advantage. Specifically, we were interested in two aspects of this type of research activity: a) the research effort and b) how the activity is organized. In order to make this contrast, a theoretical model was defined after meticulously reviewing the literature. The literature contemplated different aspects of the research effort, from the internal investment made and the investment aimed at taking advantage of the spillover effect from sectorial associations and public institutions, to investments made in cooperation with other institutions, and even including the effort put into hiring qualified research personnel. On the other hand, and insofar as the interfunctional integration into the design of the environmental research activity itself is concerned, we have considered the early involvement of the various functional areas for the development of ecological innovations, the interfunctional team, and the concurrent engineering of the innovative process for the natural environment protection.

The interest of this work is based on the fact that, although it is true that some studies had already suggested the relevance of these factors in accounting for the environmental action-based competitive advantage of the companies, it is no less true that until now, very little has been done to verify it empirically. The work was undertaken by using a sample of ISO 14001-certified factories located in Spain. There are two main conclusions to this paper. First of all, we have shown that the research effort aimed at protecting the natural environment has a positive effect on the factories' environmental action-based competitive advantage. Investment in internal RandD, investments made to take advantage of technological knowledge developed by industrial associations, universities, and other research institutes, hiring research personnel, and cooperation with other firms, sectorial associations, and public institutions all favor a company's environmental action-based competitive advantage. Likewise, the functional integration into the design of research activity constitutes another explanatory factor of the environmental action-based competitive advantage. Early involvement of all the functional areas, the creation of interfunctional teams, and the concurrent engineering of innovations with employees from several departments benefit the factories' environmental action-based competitive advantage.

However, and despite the contribution made in this study, there is much that remains to be done as regards how research activity is approached and a company's environmental action-based competitive advantage. On the one hand, we have not assessed to what degree research activity aimed at protecting the natural environment can enhance other dimensions of competitiveness, in addition to its mere environmental action-based competitive advantage. This type of analysis is of great interest, given that many firms do not initiate actions to protect the natural environment for the very reason that they believe that they will hurt their competitiveness by doing so. On the other hand, an analysis must be made to determine if there are specificities based on the type of environmental technologies generated by the firms. These are but some of the many issues that remain to be addressed. Clearly, a company's environmental action-based competitive advantage does not demand only research effort. There are other facets of the company (suppliers, customers, environmental technologies, etc.) that will also have a bearing on a company's capability to improve its environmental action-based competitive advantage. Hence, other works must consider if the joint influence of research activity and each of those aspects is relevant. These and other issues of similar importance will therefore be the object of analysis in future works.

ACKNOWLEDGEMENT

This work has been financed by the Spanish Ministerio de Ciencia e Innovación (ECO2009-08485).

REFERENCES

Adams, M. E., Day, G. S. and Dougherty, D. (1998). Enhancing new product development performance: An organizational learning perspective. Journal of Product Innovation Management, **15 (5),** 403-422.

Angell, L. C. and Klassen, R. D. (1999). Integrating environmental issues into the mainstream: an agenda for research in operations management. Journal of Operations and Production Management, **11 (5)**, 575-598.

Asheim, B. T. (1996). Industrial districts as 'learning regions': A condition for prosperity. European Planning Studies, **4**, 379-400.

Ataei, A. , Lee, K. S. , Lim, J. J. , Kim, M. J., Liu, H. B., Kang, O. Y. , Oh, T. S. and Yoo, C. K. (2011). A Review on Environmental Process Engineering. Int. J. Environ. Res., **5 (4)**, 875-890.

Autio, E. (1997). New, technology-based firms in innovation networks symplectic and generative impacts. Research Policy, **26 (3)**, 263-281.

Azzone, G. and Noci, G. (1998). Seeing ecology and "green" innovations as a source of chance. Journal of Organizational Change Management, **11 (2)**, 94-111.

Banerjee, S. B. (1998). Corporate environmentalism. Perspectives from Organizational Learning. Management Learning, **29 (2)**, 147-164.

Barkan, P. (1992). Productivity in the process of product development – an engineering perspective. In G. I. Susman (Eds.), Integrating Design for Manufacturing for Competitive Advantage (pp. 56-68). New York: Oxford University Press.

Bayona, C., García-Marco, T. and Huerta, E. (2001). Firms' motivations for cooperative RandD: An empirical analysis of Spanish firms. Research Policy, **30 (8)**, 1289-1307.

Bhat, U. N. (1993). Green marketing begins with green design. Journal of Business and Industrial Marketing, **8 (4),** 26-31.

Blackburn, J. D. (1991). Time-Based Competition. The Next Battle Ground in American Manufacturing. (Irwin: Business One)

Brío, J. A., Fernández, E. and Junquera, B. (2002). The role of the Public Administrations in the promotion of the environmental activity in Spanish industrial companies. Ecological Economics, **40 (2),** 279-294.

Brockhoff, K., Chakrabarti, A. and Kirchgeorg, M. (1999). Corporate strategies in environmental management. Research and Technology Management, **42 (4),** 26-30.

Calabresse, G. (1997). Communication and co-operation in product development: a case study of a European car producer. RandD Management, **27 (3),** 239-252.

Cantwell, J. A. (1998). Introduction. Journal of Economic Behavior and Organisation, **35 (2),** 133-137.

Carter, D. and Baker, B. S. (1991). Concurrent Engineering: The Product Development Environment for the 1990s (1). (Reading: Addison Wesley)

Chatterji, D. (1995). Achieving leadership in environmental RandD. Research and Technology Management, **38 (2),** 37-42.

Chesnais, F. (1998). Technological co-operation agreements between firms. Strategic Technology International Review, **4 (1),** 52-119.

Christmann, P. (2000). Effects of the 'best practices' of environmental management on cost advantage: the role of complementary assets. Academy of Management Journal, **43 (4),** 663-680.

Clark, K. B., Chew, W. B. and Fujimoto, T. (1987). Product development in the world auto industry. Brooking Papers on Economic Activity, **3 (3),** 729-771.

Clark, K. B. and Fujimoto, T. (1991). Product Development Performance: Strategy, Organization, and Management in the World Auto Industry. Boston: Harvard Business Press.

Coombs, R., Narandren, P. and Richards, A. (1996). A literature-based innovation output indicator. Research Policy, **25 (25),** 403-413.

Cramer, J. M. and Roes, B. (1993). Total employee involvement: Measure for success. Total Quality Environmental Management, **3 (1),** 39-52.

Cycyota, C. S. and Harrison, D. A. (2002). Enhancing survey response rates at the executive level: are employee –or consumer– level techniques effective? Journal of Management, **28 (2),** 151-176.

Davis, F., Bagozzi, R. and Warshaw, P. (1989). User acceptance of computer technology. Management Science, **35 (35),** 982-1003.

Dennis, W. J. Jr. (2003). Raising response rates in mail surveys of small business owners: results of an experiment. Journal of Small Business Management, **41 (3),** 278-295.

Dixon, N. M. (2000). Common Knowledge: How Companies Thrive by Sharing What They Know. Boston: Harvard Business School Press.

Dyer, J. H. and Sing, H. (1998). The relational view: Co-operative strategy and source of interorganisational competitive advantage. Academy of Management Review, **23 (4)**, 660-679.

Fleischer, M. and Liker, J. K. (1992). The hidden professionals: Product designers and their impact on design quality. IEEE Transactions on Engineering Management, **39 (3)**, 254-264.

Freeman, C. (1975). La Teoría Económica de la Innovación Industrial. Madrid: Alianza Universidad.

Freeman, C. (1998). The economics of technical change. (In D. Archibugui and J. Michie (Eds.), Trade, Growth and Technical Change (pp. 16-54). Cambridge: Cambridge University Press.

Gallagher, J. and Krant, R. E. (1998). Technology for intellectual teamwork: perspectives on research and design. (In J. Gallagher, R. E. Krant and C. Egido (Eds.), Intellectual Teamwork (pp. 393-408). New Jersey: Lawrence Erlbaum Associates.

Garvin, D. A. (1993). Building a learning organization. Harvard Business Review, **71 (4)**, 78-91.

Griffiths, A. and Petrick, J. A. (2001). Corporate architectures for sustainability. International Journal of Operations and Production Management, **21 (12)**, 1573-1585.

Gupta, A., Raj, S. P. and Wilemon, D. (1985). RandD and marketing dialogue in high-tech firms. Industrial Marketing Management, **14 (4),** 289-300.

Hagedoorn, J. (1993). Understanding the rationale of strategic technology partnering: Internationalisation modes of cooperation and sectorial differences. Strategic Management Journal, **14 (5),** 371-385.

Handfield, R. B., Melnyk, S. A., Calantone, R. G. and Curkovic, S. (2000). Integrating Environmental Concerns into the Design Process: The Gap between Theory and Practice. IEEE Transactions on Engineering Management, **48 (2),** 189-208.

Hanna, M. D., Newman, W. R. and Johnson, P. (2000). Linking operational and environmental improvement through employee involvement. International Journal of Operations and Production Management, **20 (12),** 148-165.

Hart, S. L. (1995). A natural resource-based view of the firm. Academy of Management Review, **20 (4)**, 986-1014.

Hauptman, O. and Hirji, K. K. (1999). Managing integration and coordination in cross-functional teams: An international study of Concurrent Engineering product development. RandD Management, **29 (2)**, 179-191.

Henke, J., Krachenberg, R. A. and Lyons, T. F. (1993). Cross-functional teams: good concept, poor implementation! Journal of Product Innovation Management, **10 (3)**, 216-229.

Inkpen, A. C. (1998). Learning and knowledge acquisition through international strategic alliances. Academy of Management Executive, **12 (4)**, 69-80.

Jaffe, A. B. (1989). Real effects of academic research. American Economic Review, **79 (5)**, 957-970.

Kemp, R. and Soete, L. (1992). The greening of technological progress. Futures, **24 (5)**, 437-457.

Kitazawa, S. and Sarkis, J. (2000). The relationship between ISO 14001 and continuous source reduction programs. International Journal of Operations and Production Management , **20 (12),** 225-248.

Klassen, R. D. (2000). Exploring the linkage between investments in manufacturing and environmental technologies. International Journal of Operations and Production Management, **20 (12)**, 127-147.

Klassen, R. D. and McLaughlin, C. P. (1993). TQM and environmental excellence in manufacturing. Industrial Management and Data Systems, **93 (6)**, 14-22.

Kleinknecht, A. and Reijnen, J. O. N. (1992). Why do firms cooperate on RandD? An empirical study. Research Policy, **21 (4)**, 347-360.

König, H., Licht, G. and Staat, M. (1994). FandE-Kooperationen und Innovationsaktivität. (In B. Gahlen, H. Hesse and H.-J. Ramser (Eds.), Europäische Integraonsprobleme aus Wirtschaftswis-Senschaftlicher Sicht (pp. 219-242). Siebeck: Tübingen).

Koufteros, X., Vonderembse, M. and Doll, W. (2001). Concurrent engineering and its consequences. Journal of Operations Management, **19 (1)**, 97-115.

Koufteros, X., Vonderembse, M. and Doll, W. (2002). Integrated product development practices and competitive capabilities: The effects of uncertainty, equivocality, and platform strategy. Journal of Operations Management, **20 (4)**, 331-355.

Kriwet, A., Zussman, E. and Selinger, G. (1995). Systematic integration of design for recycling into product design. International Journal of Production Economics, **38 (1),** 15-22.

Lahijanian, A. (2011). Public Participation in Environmental Education Centers. Int. J. Environ. Res., **5 (4)**, 951-960.

Link, A. and Bauer, L. L. (1987). An economic analysis of cooperative research. Technovation, **6 (4)**, 247-260.

Lundvall, B. A. and Johnson, B. A. (1994). The learning economy. Journal of Industry Studies, **1 (2)**, 23-42.

Maffin, D. and Braiden, P. (2001). Manufacturing and supplier roles in product development. International Journal of Production Economics, **69 (1)**, 205-213.

Malhotra, M. K. and Grover, V. (1998). An assessment of survey research in POM: from constructs to theory. Journal of Operations Management, **16 (4)**, 407-425.

Mansfield, E. (1968). Industrial Research and Technological Innovation: An Econometric Analysis. New York: Norton.

Maxwell, J., Rothenberg, S., Briscoe, F. and Marcus, A. (1997). Green schemes: Corporate environmental strategies and their implementation. California Management Review, **39 (3)**, 118-134.

McKee, D. (1992). An organizational learning approach to product innovation. Journal of Production Innovation Management, **9 (3)**, 232-245.

Millson, M. R., Raj, S. P. and Wilemon, D. A. (1992). A survey of major approaches for accelerating new product development. Journal of Product Innovation Management, **9 (1)**, 53-69.

Mossalanejad, A. (2011). The Role of Economic Policy and Environment in Sustainable Development. Int. J. Environ. Res., **5 (2)**, 395-402.

Najafi, A. and Afrazeh, A. (2011). Analysis of the Environmental Projects Risk Management Success Using Analytical Network Process Approach. Int. J. Environ. Res., **5 (2)**, 277-284.

Nayak, P. R. (1990). Planning speeds technological development. Planning Review, **18 (6)**, 14-19.

Nelson, R. (1959). The simple economics of basic scientific research. Journal of Political Economy, **67 (2)**, 297-306.

Newman, W. R. and Hanna, M. D. (1996). An empirical exploration of the relationship between manufacturing strategy and environmental management. Two complementary models. International Journal of Operations and Production Management, **16 (4)**, 69-87.

Osterman, P. (1994). How common is workplace transformation and how can we explain who adopts it? Industrial and Labor Relations Review, **47 (2)**, 173-188.

Ouchi, W. (1994). The M-form Society: How American Teamwork can Recapture the Competitive Edge. Reading: Addison-Wesley.

Painter, M. K., Mayer, R. J. and Cullinane, T. P. (1991). The many faces of concurrent engineering. Paper presented at Autofact '91 Conference, Illinois.

Pawar, K. S., Menon, U. and Riedel, J. C. K. H. (1994). Time to market. Integrated Manufacturing Systems, 5 (1), 14-22.

Pinto, M. B. and Pinto, J. K. (1990). Project team communication and cross-functional cooperation in new product development. Journal of Product Innovation Management, **7 (4),** 200-212.

Pirani, E. and Secondi, L. (2011). Eco-Friendly Attitudes: What European Citizens Say and What They Do. Int. J. Environ. Res., **5 (1)**, 67-84.

Polonsky, M. J., Rosenberger III, P. J. and Ottman, J. A. (1998). Developing green products: learning from stakeholders. The Journal of Sustainable Product Design, **1 (5),** 7-21.

Porter, M. (1998). Clusters and the new economics of competition. Harvard Business Review, **76 (6)**, 77-90.

Putnam, A. O. (1985). A redesign for engineering. Harvard Business Review, **63 (5/6)**, 139-140.

Ramus, C. A. (2001). Organizational support for employees: encouraging creative ideas for environmental sustainability. California Management Review, **43 (3)**, 85-105.

Raturi, A. M., Meredith, J. R., McCutcheon, D. M. and Camm, J. D. (1990). Coping with the build-to forecast environment. Journal of Operations Management, **9 (2)**, 230-249.

Roome, N. (1994). Business strategy, RandD management and environmental imperatives. RandD Management, **24 (1)**, 65-82.

Russo, M. V. and Fouts, P. A. (1997). A resource-based perspective on corporate environmental performance and profitability. Academy of Management Journal, **40 (3)**, 534-559.

Schrage, D. P. (1993). Concurrent design: A case study. (In A. Kusiak (Eds.), Concurrent Engineering –Automation, Tools, and Techniques (pp. 535-580). New York: John Wiley.

Segarra-Oña, M. V., Peiró-Signes, A., Albors-Garrigós, J. and Miret-Pastor, P. (2011). Impact of Innovative Practices in Environmentally Focused Firms: Moderating Factors. Int. J. Environ. Res., **5 (2)**, 425-434.

Shenas, D. G. and Derakhshan, S. (1994). Organizational approaches to implementation of simultaneous engineering. Journal of Operations Management, **14 (10)**, 30-43.

Song, X. M., Montoya-Weiss, M. M. and Schmidt, J. B. (1997). Antecedents and consequences of cross-functional cooperation: A comparison of RandD, Manufacturing and Marketing perspectives. Journal of Product Innovation Management, **14 (1),** 35-47.

Song, X. M. and Parry, M. E. (1992a). The RandD-marketing interface in Japanese high-technology firms. Journal of Product Innovation Management, **9 (2),** 91-112.

Song, X. M. and Parry, M. E. (1992b). The dimensions of industrial new product success and failure in China. (In L. P. Feldman, T. P. Hudtad and A. L. Page (Eds.), Managing Product Development: Winning in the 90s (pp. 30-41). Indianapolis: Product Development and Management Association).

Song, X. M. and Parry, M. E. (1993a). RandD-marketing integration in Japanese high-technology firms: Hypotheses and empirical evidence. Journal of the Academy of Marketing Science, **21 (2),** 125-133.

Song, X. M. and Parry, M. E. (1993b). How the Japanese manage in the RandD-marketing interface. Research and Technology Management, **36 (4),** 32-39.

Song, X. M. and Parry, M. E. (1996). What separates Japanese new product winners from losers. Journal of Product Innovation Management, **13 (5),** 422-439.

Stalk, G. Jr. and Hout, T. H. (1990). Competing Against Time: How Time-based Competition is Reshaping Global Markets. New York: Free Press.

Struebing, L. (1996). 9000 standards. Quality Progress, **29 (1)**, 23-28.

Takeuchi, H. and Nonaka, I. (1986). The new product development game. Harvard Business Review, **64 (1)**, 137-146.

Tether, B. S. (2002). Who co-operates for innovation, and why. An empirical analysis. Research Policy, **31 (6)**, 947-967.

Toni, A. De and Meneghetti, A. (2000). Traditional and innovative paths towards time-based competition. International Journal of Production Economics, **66 (3)**, 255-268.

Ulrich, K., Sartorius, D. Pearson, S. and Jakiela, M. (1993). Value of time in design-for-manufacturing decision making. Management Science, **39 (4)**, 429-447.

Vonortas, N. S. (1997). Cooperation in Research and Development. Boston: Kluwer Academic Publishers.

Walley, N. and Whitehead, B. (1994). It´s not easy being green. Harvard Business Review, **72 (3)**, 46-52.

Warshaw, P. (1980). Predicting purchase and other behaviors from general and contextually specific intentions. Journal of Marketing Research, **17 (1)**, 26-33.

Welford, R. (1992). Linking quality and the environment: A strategy for the implementation of environmental management systems. Business Strategy and the Environment, **1 (1)**, 25-34.

Whitney, D. E. (1988). Manufacturing by design. Harvard Business Review, **66 (4)**, 83-91.

Winn, S. F. and Roome, N. J. (1993). RandD management responses to the environment: current theory and implications to practice and research. RandD Management, **23 (2)**, 147-160.

Womack, J. P., Jones, D. T. and Roos, D. (1990). The Machine that Changed the World. New York: Rawson Associates.

Youssef, M. A. (1994). Design for manufacturability and time-to-market. Part 1: Theoretical foundations. International Journal of Operations and Production Management, **14 (12)**, 6-21.