COOPERATION FOR INNOVATION: THE IMPACT ON INNOVATORY EFFORT

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Abstract

Nowadays, in the development of new products it becomes necessary to recognise the importance wielded by agents external to the firm as a source of innovation activities. The complexity and dynamism of present environments make it obligatory to complement the internal knowledge base with others coming from outside, and thus a distinction is made between internal and external innovation sources. Since the former have been adequately studied and analysed in the literature, the present work aims to make progress in knowing the latter. For this purpose, an analysis has been made of the influence of nine types of cooperation with external agents on three indicators of innovatory effort in twenty industrial and service sectors in Spain. These indicators have been: the total intensity of innovation activities, the intramural R&D intensity and the extramural R&D intensity. The findings indicate the existence of very diverse effects on the basis of the partner chosen to cooperate with.

KEYWORDS: R&D cooperation, external innovation sources, innovatory effort, innovation intensity, intramural R&D, extramural R&D.

JEL Classification: O32

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1. INTRODUCTION

The environment in which economic activity takes place in most countries is characterised by a great deal of dynamism and complexity. Brusque changes in technology, in customers and competitors mean that firms have to renew themselves continuously in order to survive and in many cases, those changes take the form of seeking new ways of carrying out their activities, which include innovation activities.

Traditionally, economists in studying innovation processes used as their starting point the premise that product manufacturers were the starting point of these processes. In opposition to this, researchers on technological and organisational change have shown that if the manufacturer is assumed to be the only source of innovations, this considerably limits the view of the innovation process (von Hippel, 1988, 2005). For example, in the evolutionary view of technological change a modern innovation process is assumed, characterised not just by the need for feedback among the different stages, but also by the multidisciplinary nature of inputs and the many sources of relevant information for firms (Rosenberg, 1976, 1982). Similarly, in the literature on strategic management and specifically with the Resource Based Approach -*RBV*- (Penrose, 1959; Rumelt, 1984; Teece, 1984; Wernerfelt, 1984; Barney, 1991, Peteraf, 1993) it has been shown that agents from outside the firm constitute an important resource in the present-day competitive framework, particularly as far as the development of new products and processes is concerned.

In accordance with these ideas, variations in the performance of firms competing in the same industry could be explained by differences in their provision and use of resources (Barney, 1986a, 1986b, 1991, 2001; Peteraf, 1993; Wernerfelt, 1984) and these resources also include the sources of innovation used by firms.

Within this framework, it is thought that firms having valuable, rare, non-substitutable and inimitable resources will be able to achieve and maintain over time a position of advantage with regard to their competitors (Barney, 1995: 56). Consequently, it is not difficult to understand that in the midst of a large diversity of resources owned by a firm, tangible and intangible, the latter will be the ones offering the greatest chances of becoming a source of competitive advantage (Ray *et. al.*, 2004). These intangible ones can be amassed in the firm and their origin could be found in relationships that the former maintains with external agents in questions of innovation. Their high tacit component and social complexity (Dierickx y

Cool, 1989; Peteraf, 1993) makes these resources difficult for any competitor to identify and/or reproduce.

In accordance with these ideas, it is important for the firm to cooperate with other agents for the development of innovations (Mowery and Rosenberg, 1989; Arora and Gambardella, 1990), thus extending their possibilities and ways of learning. These external sources may have very different origins, from users to component and material suppliers and other agents involved in the innovation process (von Hippel, 1988, 2005; Arora and Gambardella, 1990; Gemünden *et. al.*, 1992; Powell *et. al.*, 1996).

Although in recent years the knowledge of cooperation in innovation activities has become considerably greater, there are still many aspects of this phenomenon requiring further attention. Among some of the questions outstanding is the study of the effects that external information sources exert on the intensity of innovation activity and on the strategy for acquiring technology.

In studies at firm level, the analysis of these relationships is not easy due to a problem of endogeneity between the two variables. An important body of empirical evidence has found that innovatory effort influences on the decision to cooperate for the development of innovations (Colombo and Garrone, 1996; Fritsch and Lukas, 2001; Tether, 2002; Belderbos *et. al.*, 2004; Bönte and Keilbach, 2005; Bayona *et. al.*, 2006) and a small group of studies has analysed the inverse causality, that is, the effects of cooperation on innovatory effort (D´Aspremont and Jacquemin, 1988, 1990; Katz and Ordover, 1990; Colombo and Garrone, 1996; Kaiser, 2002). This latter set of studies has been motivated by comparing the hypothesis that cooperation increases firms' innovatory effort and that this can be transformed into a source of competitive advantage.

Industry-level analyses could be appropriate to analyse these aspects, since they do not suffer from endogeneity problems in the sample selection (Callejón and García-Quevedo, 2005) and have also the advantage of used more accessible data, so it facilitates comparisons with other countries. In accordance with this evidence, we propose an aggregate study at industry level pursuing two aims: firstly, to determine what type of partner in cooperation has the greatest impact on the innovation intensity and, secondly, to discover the influence of these partners in how industries distribute internal technology development or buying-in as a source of competitive advantage.

Unlike other studies, as a novelty nine different types of cooperation are used, including cooperation with: 1) other firms within the same group, 2) customers, 3) suppliers, 4) competitors and firms from the same sector, 5) experts and consultants, 6) commercial laboratories or R&D firms, 7) universities, 8) public R&D agencies and 9) public technological centres. Furthermore, the effect of these sources has been calculated by using different indicators of innovatory effort and specifically three: 1) total intensity of innovation activities, 2) intramural R&D intensity and, 3) extramural R&D intensity. This latter distinction is made with the object of obtaining conclusions concerning the effect of cooperation with various external agents on the level of internal or external technological development.

The work is structured as follows. In Section 2 the theoretical framework of the paper is presented, offering a review of the most important reasons for cooperating in R&D with certain external agents. In section 3, there is a description of the methodology and data used as well as the sample of Spanish sectors from the viewpoint of their innovatory effort and the use of external agents for developing innovations. Section 4 records the findings and the discussion of the empirical analysis. Section 5 presents the main conclusions of the study, as well as future lines of research.

2. COOPERATION WITH EXTERNAL AGENTS FOR THE DEVELOPMENT OF INNOVATIONS

Currently, the idea that the innovation process is only originated in manufacturing firms has been completely rejected. Nowadays, the importance of having sources of information and knowledge located outside the firm has been well enough demonstrated, although other recent studies also remark the importance of internal sources of innovation (Baranano *et. al.*, 2005). In this context, throughout the literature it has been recognised that firms' performance will depend to a great extent on their ability to find, absorb and handle these sources in a productive fashion (Cohen and Levinthal, 1990).

The convenience of complementing the firm's internal knowledge base with external sources was initially recognised by Alfred Marshall in 1925. In his work, he stressed how important it was for economic progress that firms should develop positive externalities through a market-based organisation (Marshall, 1925:335). Furthermore, those external sources can be quite diverse, ranging from customers, suppliers of components and materials to competitors or other agents involved in the innovation process (von Hippel, 1988, 2005).

In this line, the R&D department of any firm is not the sole source of innovation activities. In a general sense, innovation sources are divided into two types: internal *versus* external (some of which are detailed in Figure 1). The former are related to the innovative activities carried out within the firm, especially in R&D, marketing and production departments. The second comprise: (a) market-based sources (such as competitors, buying embodied or disembodied technology, customers or users, experts and consultants, suppliers of equipment, materials, components and software, technological centres, commercial laboratories or R&D firms, etc.), (b) educational centres or research centres, among which there are public or private research institutes and universities and, (c) general publicly available information, regarding published patents, conferences, professional meetings and journals, fairs and exhibitions.

However, when obtaining information needed to develop innovations, firms have followed two types of strategy: generating this knowledge in-house or buying in, in other words, *make or buy,* in the terminology of Veugelers and Cassiman (1999) or Santamaría (2001). On the other hand, in recent times analysts have noticed a third hybrid form for obtaining this knowledge: cooperation with other agents in innovation activities (Navarro, 2002).

The above-mentioned comments make it clear that firms are different with regard to the innovation sources they use and, as a consequence, in their innovatory effort. Thus, knowing the source of innovation activity will be a determining factor in improving competitive advantage.

But, what is more, the motives for cooperating with one type of agent or another are very diverse, and this information is highly useful for a better understanding of the phenomenon of cooperation. Among the most important motivations are those related to technological complexity, risk/costs sharing and funding opportunities (Hagedoorn, 1993; Cassiman and Veugelers, 1998; Bayona *et. al.*, 2003). Thus, following Bayona *et. al.* (2001) these motives can be classified in two broad categories: (a) technology-related (such as the technological complexity of the industry or reduction in R&D expenditures) and (b) market-linked (such as creation of and introduction into new markets or new product launches). Below we list some of these motivations according to the type of agent.

Cooperation with customers and suppliers

Establishing a relationship with customers and suppliers is normally referred to as vertical or non-competitive cooperation, compared to horizontal cooperation, which is that existing between competitors. One of the main motivations for relationships with these agents is the high degree of efficiency achieved compared to other types of collaboration to conclude the innovation process in new products or process (Tether, 2002; Bayona *et. al.*, 2003; Santamaría and Rialp, 2007). In other cases, emphasis is given to the importance of this collaboration from the viewpoint of developing innovative activities and creating knowledge for firms (Tunisimi and Zanfei, 1998). They are also usually the favourite partners when the goals pursued by firms are of a commercial nature -breaking into new markets, internationalisation, etc.- (Bayona *et. al.*, 2001, Santamaría and Rialp, 2007).

Specifically in the case of customers, the information provided by these agents is particularly valuable in the case of complex technologies and/or products (Tether, 2002) or when the product presents high levels of novelty (Amara and Landy, 2005). This is due to the fact that user experience in handling them maybe very helpful both in improving existing design and in thinking up new models or applications. The joint development of a piece of technology with customers makes a contribution to improving market share or strengthening the firm's product credibility (Tether, 2002). Thanks to interaction with these partners, the firm acquires a profound knowledge of their needs, and can put this information to use to forecast the likely competitive success of a new idea (Gemünden *et. al.*, 1992).

Moreover, thanks to newly developed techniques[1] for working with these agents in innovation, it is possible to go beyond the improvement in the known qualities of the product or service, and even make it to identify needs which, in many cases, the customers themselves are unaware of as yet. This allows present day firms to deal rapidly with changes in consumer tastes as experienced by modern societies (von Hippel and Katz, 2002). As well as improving product design, these methods of collaboration provide other advantages such as a more

[1] For example, the Extreme Programming (XP) analysed by Gassmann *et. al.* (2006).

controlled development of the innovation process, with fewer costs and time, etc. (Jeppesen, 2002).

On the other hand, interest in relationships between manufacturing firms and their suppliers sprang up from the eighties onwards on the basis of the success of Japanese manufacturers of cars and electronic products, a success ascribed, among other factors, to the close relationships maintained by both groups of agents for the development of innovations (Bidault *et. al.*, 1998). In the West and most specifically in the United States and the United Kingdom, the recent trend in large firms to downsize and concentrate on their core competences, has led greater collaboration with suppliers to ensure the supply of quality inputs (Berderbos *et. al.*, 2004).

It is worth their while to go to suppliers in sectors characterised as having a highly competitive and changing environment where different types of research are required to maintain competitive position (Peters and Becker, 1998). In similar fashion to what happens with customers they facilitate the development of new products and processes and their adaptation to the market, improve their quality or increase the productivity and flexibility of the firm (Chung and Kim, 2003). Another important motivation for collaborating with suppliers is that they help to reduce production costs (Atallah, 2002) as well as the costs and risks involved in new product development (Chung and Kim, 2003).

Cooperation with competitors

Relationships with competitors are also known as horizontal cooperation and, however strange it may appear, they are a very common type of cooperation. These agreements are interesting because they contribute to strengthening international competitiveness in firms, industries and countries and to solving some of the problems related to market failures as well as other technological deficiencies found in them (Harabi, 2002). In spite of this, some authors are more in favour of vertical cooperation since they regard it as leading to greater investment in R&D, higher levels of outputs and greater welfare (Steurs, 1995).

At a private level firms participating in this type of agreement are seeking, among others, two aims: (a) to exploit economies of scale and range in R&D and, (b) take advantage of synergies which may arise from private contributions of knowledge and capability made by each partner to the common project. There is also the reduction of investment risk and market uncertainty, as well as overcoming financial difficulties which may affect a firm when starting up R&D activities -the costs are shared- (Harabi, 2002).

But in addition to the incentives which might lead a firm to have a relationship with a competitor, in this type of collaboration the risks incurred are greater than in other categories. These risks basically are related to the possibility of anti-competitive behaviour (Tether, 2002), as well as with the fact that the firms' key knowledge may fall into the hands of competitors quite involuntarily *–involuntary spillovers-* (Casiman and Veugelers, 2002; Miotti and Sachwald, 2003).Thus, these relationships occur in protected areas or using knowledge which is not key to the firm. That is, working areas are sought where common problems frequently crop up, whilst those where there might be rivalry are avoided (Tether, 2002; Cassiman and Veugelers, 2002). For these reasons, relationships with these agents are normally restricted to carrying out basic research and establishing standards in the sector (Gemünden *et. al.*, 1992; Tether, 2002), with collaboration in research projects where no rivalry exists.

Cooperation with agents of the public R&D system

Unlike what happens in the case of collaboration with competitors, cooperation with public agents does not imply any type of commercial risk, since these agents are not looking to apply their research in the market, but rather they are geared to generating R&D knowledge of a basic or generic nature (Miotti and Sachwald, 2003).

Research centres and universities play an important role in developing technological innovations since they make important contributions in new scientific and technological knowledge (Drejer and JØrgensen, 2005). They contribute to increase firms' technological and research capabilities, and make easier to work close to the technological frontier (Miotti and Sachwald, 2003). Thus, the fundamental reason for making use of them is to acquire such knowledge, which in most cases is basic in nature (Cassiman and Veugelers, 1998; Davenport *et. al.*, 1999; Bayona *et. al.*, 2000).

However, although currently these agents are not sufficiently ready to deal with the demand for more specific knowledge, there is a trend towards a change in this direction (Santoro and Chakrabarti, 1999). In this sense, it is worth pointing out that in certain cases the firm may make have access to specialized knowledge flows *(spillovers)* and to the results of public research carried out by these organizations, with the aim of exploiting technological opportunities which may spring up from this basic research (Mohen and Hoareau, 2003).

Possibly, one of the prime motives for taking part in this type of collaboration might be the chance of obtaining public funds to carry out research[2] (Davenport *et. al.*, 1999; Bayona *et. al.*, 2001; Cassiman and Veugelers, 2002; Miotti and Sachwald, 2003; Fontana *et. al.*, 2006). Along these lines and, in order to encourage relations between industry and research institutes, policy-makers, in many cases, have considered the existence of this type of links to be a requisite for choosing projects worth subsidising with public funds.

As well as the search for knowledge, many firms collaborating with universities and public research centres are spurred on by the fact of sharing risks (Cassiman and Veugelers, 1998) though other studies show that although risk reduction is one of the main reasons for cooperation in innovation activities, it is less so when the firm collaborates with agents of the public R&D system (Davenport *et. al.*, 1999; Montoro-Sánchez *et. al.*, 2006).

In any case, this type of relationship should never be a replacement for in-house R&D investment since, as occurs with the other outside agents, the firm needs to have an important in-house R&D capability to be able to absorb the scientific knowledge that might be provided by any of these agents (Cohen and Levinthal, 1990).

Cooperatation with experts and consultants

Often any of the agents of the public R&D system mentioned in the previous paragraph is too slow and does not react completely to firms' expectations as far as development of innovations is concerned. Occasionally, this leads to the need to seek alternative sources of information and knowledge. In this way, experts and consultants are seen as a good solution to this problem (Tether, 2002), in the sense that they can provide applied knowledge as well as more specialised information and skills.

The contributions made by this type of agents to firms are not only related to cost savings but also include a wide diversity of valuable inputs for the development of the innovation process. In this sense, it can be mentioned the possibility of sharing experiences, helping the

[2] Many of the relationships of cooperation set up with universities and research centres take place within the framework of programs for promoting research, both national and international.

firm in defining and articulating its specific needs in innovation, offering ideas on new needs and solutions or transferring ideas among firms, etc. (Bessant and Rush, 1995).

Furthermore, the fact of collaborating with experts and consultants unconnected with the firm provides a different viewpoint to that which may be held by those working inside it. The company staff is familiar with their own products and processes. And this normally acts as a brake on thinking up new possibilities. These agents pass on new and different information regarding the context in which the firm and its products operate, and this gives rise to the production of a larger number of innovative ideas (Bruce and Morris, 1998).

3. METHODOLOGY, DATA AND SAMPLE

In this work our aim is to make a quantitative analysis of the effect that cooperation with nine types of external agents has on the innovatory effort of the Spanish productive sector. The attempt is to identify, from among nine possible partners considered here, which has a significant impact on this effort and on the technology access strategy.

To achieve this aim, it could be possible to formulated three regression equations for the comparison of three models, corresponding to the three dependent variables: total intensity of innovation activities[3], intramural R&D intensity and extramural R&D intensity. However, as the error terms of the three models are likely to be correlated, an extension of regression model known as *multivariate model* (Greene, 2000) is usually a more appropriate estimator[4]. The multivariate regression model has the following specification:

$$\mathbf{Y_1 = \alpha + \beta_1 X_{1i} + \ldots + \beta_9 X_{9i} + \varepsilon_i} \qquad \textbf{(1)}$$

$$\mathbf{Y_2 = \alpha + \beta_1 X_{1i} + \ldots + \beta_9 X_{9i} + \varepsilon_i} \qquad \textbf{(2)}$$

$$\mathbf{Y_3 = \alpha + \beta_1 X_{1i} + \ldots + \beta_9 X_{9i} + \varepsilon_i} \qquad \textbf{(3)}$$

[3] Total intensity of innovation activities refers, not only to intramural and extramural R&D activities, but also to the effort shown in other activities such as training , acquiring new knowledge, introducing innovations into the market, design and other preparations, acquiring machinery and equipment, etc. (INE, 2003). Nonetheless, since intramural and extramural R&D are the activities accounting for the major share of innovation expenditure (65% of total expenditure in activities for innovation), they are more interesting for carrying out an individualised analysis.

[4] Anyway, we also present the results of three independent regression models in order to offer more robust results. The Appendix 1 offers these estimations and as can be seen, they do not differ from those of the multivariate model.

Where $Y_{1...3}$ refer to the innovatory effort and $X_{il...9}$ correspond to the nine types of cooperation. In Table 1 the measurements of the model's variables are described.

The data come from a sample of twenty sectors (see Tables 1 and 3) which make up the group of manufacturing and service firms in the Spanish economy. The information has been provided by the National Institute of Statistics (INE, 2003) and specifically on its *Encuesta sobre Innovación Tecnológica* (survey on technological innovation in firms) corresponding to the period 2001-2003. It is worth pointing out that this survey has been designed to provide information on the structure of the innovation process (R&D and other innovative activities) and enables the relationship between this process and firms' technological strategy, the factors influencing their capability to innovate and firms' economic performance to be shown.

In the period studied it can be seen (see Appendix 1) that the sectors which record the highest levels of innovation activities intensity were industrial sectors and more specifically, the Transport Machinery and Material sector, the Textile, Clothing, Leather and Footwear sector and Chemical Products sector. On the service side, the outstanding areas are Real Estate and Services to Companies, along with the Communication sector. As for the sectors making the least effort in innovation, compared to their turnover, we found Building and Energy and Water on the industry side and Financial Brokering and Commerce and Catering on the service side.

So far as intramural R&D intensity is concerned, in the case of manufactures once more the outstanding sectors are Chemical Products and Transport Machinery and Material, the efforts of which in R& D activities accounted for 1.52% and 0.92% of turnover respectively and, as far as services are concerned, those of Real Estate and Services to Companies, with 1.26% of their turnover. The sectors with the lowest intensity for in-house R&D activities during this period were once again the Building industry, with 0.05% and Commerce and Catering, Transport and Warehousing services, with values of 0.03% and 0.08% of their turnover, respectively.

It is worth highlighting that in comparison with the intensity of in-house R&D activities, extramural R&D intensity was considerably lower, in general in all sectors, except for the cases of Building (0.06% in extramural R&D compared to 0.05% for intramural R&D) and that of services to Commerce and Catering (0.02% in extramural R&D compared to 0.03% for intramural R&D). In this section the sectors with the highest intensities turned out to be exactly the same ones as in the previous case for manufacturing firms (Transport Machinery and Material and Chemical Products), whereas in the service sectors once again the outstanding cases were Real Estate and Services to Companies and Communications. The sectors devoting the least to extramural R&D were Food, Beverages and Tobacco in the first group, and those of Transport and Warehousing, along with Public, Social and Collective Services in the second group.

Furthermore, several studies indicate that cooperation levels are very different according to the type of sector (Hladik, 1985; Link and Bauer, 1989; Hagedoorn, 1993; Wang, 1994). In this context, there is no doubt that consideration of these sectoral differences becomes an important aspect when evaluating the effects of cooperation with different agents on the intensity of innovation activities in the productive sector.

Thus, in order to carry out this study, nine external sources with which cooperation for innovation could be possible have been considered (see Table 2). Specifically in Spain and only considering innovative firms or those with innovations in progress or unsuccessful ones (EIN), it is possible to highlight that 40% of these firms cooperated with suppliers, 26.9% did so with universities and 19.2% cooperated with experts and consultants. Those 5,710 firms which cooperated in innovation in the period 2001-2003 accounted for 15% of the total of the Spanish productive sector.

Regarding the form of cooperation by sector and taking into account the total number of firms in each sector (see Appendix 2) it can be seen that, in general terms, the clearly outstanding sector was Chemical Products, where 18.56% of the firms carried out some type of cooperation in this area. With lower levels of cooperation, between 10% and 12%, were the Metallurgy, Recycling and Transport Machinery and Material industries. With regard to services, Financial Brokering had the highest percentage of firms cooperating in innovation (10.6%).

If the type of agent with which cooperation took place is taken into account, the leading role corresponded to the universities, particularly in the case of Chemical Products (8.38%) and in Energy and Water industries (6.71%). Similarly, cooperation with experts and consultants was also important in the Recycling sector (6.66%) and cooperation with technological centres in the case of the Metallurgical industry (5.79%).

4. RESULTS OF THE STATISTICAL ANALYSIS AND DISCUSSION

Previous studies have shown that R&D intensity in firms is dependent on the number of cooperation agreements which have been conducted in previous years (Colombo and Garrone, 1996) and that cooperation has a positive influence in general on firms' innovation intensity (Kaiser, 2002). Many of the findings of this study point in this direction, but, what is more, we have considered the specific effect of different types of agents and different indicators of innovation strategy. This represents an important contribution to this field of research.

The findings in Table 3 show that total intensity of innovation activities at the industry level showed a positive and significant rise thanks to cooperation with customers and suppliers. In the former case, the findings are the opposite of those presented in other works which recognise that collaboration with customers during the development of innovation reduces innovation costs (Thomke and Nimgade, 1998; Herstatt and von Hippel, 1992; Jeppesen, 2002, 2005; Chan and Lee, 2004; Henkel and von Hippel, 2004; von Hippel, 2005). Nevertheless, there also exist other studies, for example, that of Lillien *et. al.* (2002) which have found that when there is cooperation with customers innovation costs increase or Tether (2002), who found a positive relationship between cooperation with customers and R& D intensity. Different arguments can be put forward to explain these findings. Firstly, cooperation with customers is frequently analysed in certain sectors and not with aggregate data as in this case. This could justify the difference between the findings of this study and those who have worked at firm level. Secondly, this type of cooperation could make it necessary to make investment in R&D geared to adapting the productive process to the new product or service designs thought up by the customer. Finally, it has also been pointed out in the literature that this type of cooperation could raise costs stemming from the means that the firm must provide to the customer for his information to be relevant for the innovation process.

Different studies have analysed the importance of different types of partners when cooperating and have found that customers are the most appreciate external source of information, followed by suppliers, both in Spain and in other countries (Baumert and Martínez, 2007; Bierly and Daly, 2007). Spanish firms cooperating with customers are mainly firms in hi-tech sectors (Bayona *et. al.*, 2003) whose contribution to the total industrial expenditure in R&D is high and they support the continuity of innovation activities in their firms. This trend also explains the findings obtained in the case of cooperation with suppliers, which also has a significant and positive influence on innovatory effort. This result is in accordance with other previous studies which have shown that vertical cooperation leads to higher R&D investments (Steurs, 1995). These findings can be explained if it is considered that effective collaboration with these agents requires a suitable infrastructure in which collaboration can be installed, which means spending more in research and development (Pérez Pérez and Sánchez, 2002).

If we take into account the distribution of R&D expenditures, cooperation with customers stimulates the development of the firm's internal potential and the acquisition of outside technology. That is, this type of cooperation favours complementarities between the two strategies for obtaining technology. Even though, it can be deduced from the literature that availability of external technology could reduce investment in in-house research and, consequently, the firm's competitive advantage, there are arguments to support the benefit of a complementary relationship between these two variables (Arora and Gambardella, 1990; 1994; Den Hertog and Thurik, 1993; Veugelers, 1997; Veugelers and Cassiman, 1999; Narula, 2001; Tsai and Wang, 2007). These complementarities are capitalised as long as there exists a certain absorption capability (Cohen and Levinthal, 1990; Veugelers, 1997). In this context, in-house R&D activities could serve to modify and improve the acquisition of external technology (Veugelers and Cassiman, 1999), an aspect which is determining for converting knowledge deriving from customers into a profitable activity.

The findings also indicate that cooperation with competitors or firms in the same sector increases the intensity of intramural R&D. The reasoning that would lie behind this is that bearing in mind that in this way the firm shares certain knowledge with its competitors, it will at the same time have to seek a way of maintaining an advantageous position against them and one way would be to raise its in-house R&D efforts, for example, by developing new, more efficient productive processes or even making use of patents. Additionally, for the Spanish case, the positive influence of this type of cooperation finds a relationship with public funds. The study by Heijs *et. al.* (2007) shows how subsidies geared to increasing firms' R&D investment also stimulated technological cooperation with firms in the same sector.

From the side of cooperation with agents from the public R&D system, this serves to strengthen technological capabilities (Cassiman and Veugelers, 2002, Miotti y Sachwald, 2003, Santamaría y Rialp, 2007) even if in our study a certain degree of interference among the three types of public agents has been found. And indeed, the motivations leading to cooperation with each of these partners are different (Montoro-Sánchez *et. al.*, 2006). In the case of buying in technology, on the one hand, cooperation with universities increases extramural R&D expenditures, presumably because of firms financing some of the innovation activities of those institutions to be able to have access to their research results and maintain follow up technological advances which might give rise to new products or processes. The consequence of this could be the promoting of the buying in of technology in those areas where the productive sector is technologically rather backward. Moreover, this cooperation takes place in many cases to guarantee access to public funds, which encourages the buying of external technology. On the other hand, the study shows that cooperation with public R&D agencies reduces these external expenditures and does not displace them towards in-house technology production. In Spain, these agencies stand as an alternative to the market in offering low-cost access to technological installations, equipment and services.

The findings also show that cooperation with public technological centres reduces in-house R&D investment. The fact that they are non-profit-making organizations gives greater confidence in the relationship with them and this, to a certain extent, can be transformed into a greater delegation of innovation activities and less concern over protecting the findings of these tasks (Santamaría and Rialp, 2007).Moreover, the easy access to the results of these research centres, enables technological opportunities to be exploited which might arise from their basic research (Mohen and Hoareau, 2003) without the need for any in-house effort. Although Spanish firms continue to argue that one of the main problems faced by this cooperation is that time limits are not met, they often go to these centres to replace their in-house R&D efforts.

5. CONCLUSIONS

At this moment in time the development of innovations cannot be based exclusively upon the firm's internal resources. Given the difficulty involved in obtaining the resources needed for innovation activities, firms are forced to collaborate with external agents to accede to complementary resources, and this has led to a sharp increase in the number of cooperation agreements in innovation. However, there are still many aspects of this phenomenon to be explored.

For this reason, we have presented an exploratory work which aims to contribute to the knowledge of these relationships by providing empirical evidence on the influence which collaboration with different external agents might wield on the total intensity of innovation activities, intramural R&D intensity and extramural R&D intensity in the Spanish productive sector. With this aim a total of twenty sectors have been considered and cooperation with nine different types of agents: 1) other firms within the same group, 2) customers, 3) suppliers, 4) competitors and firms from the same sector, 5) experts and consultants, 6) commercial laboratories or R&D firms, 7) universities, 8) public R&D agencies, and 9) public technological centres.

With this research we have provided an answer to two interesting questions referring to the phenomenon of cooperation in Spain. On the one hand, we have observed that cooperation with customers is what has the greatest impact on the intensity of innovation activities of manufacturing and service sectors in this country. Secondly, different effects have been observed on how sectors make the distribution between in-house technology development and buying-in according to the type of partner.

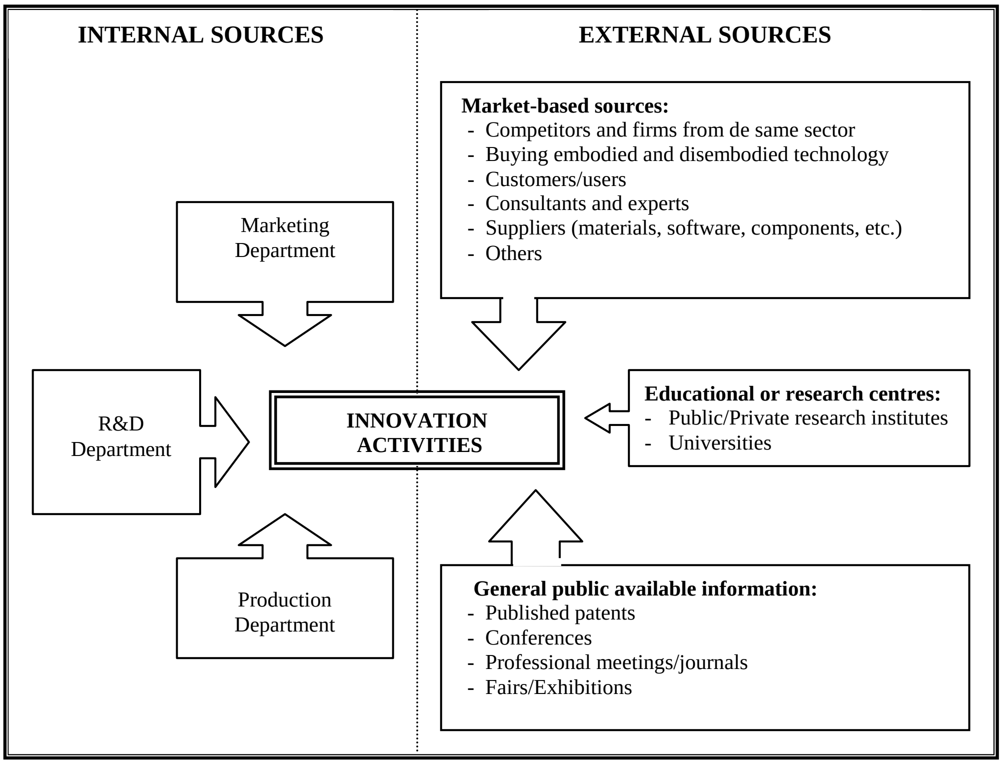
In this last case, the findings have indicated that cooperation with customers and suppliers produces a significant, positive increase in total intensity of innovation activities in the productive sector. It has also been noticed that cooperation with customers has been the only type to produce a significant stimulus both in in-house generation and buying technology from outside. In a certain way, it could be said that cooperation with customers proves to be an indicator of how importantly the firm regards innovation, since the greater this cooperation, the greater the number of resources that are devoted to innovation activities. This is one of the principal contributions of our study and it is particularly relevant for Spanish firms. The fact is that suppliers have proved to be the most frequently used partners in Spain whereas cooperation with customers is not very well developed. So it would be worthwhile to encourage and implement strategies to strengthen cooperation with these agents in questions of innovation.

Bearing in mind the way in which firms distribute R&D expenditure, the study has found that cooperation with competitors increases intramural R&D intensity. Presumably, firms sharing certain knowledge with their competitors will at the same time have to find a way to maintain a position of advantage over them and one way will be to increase their efforts in in-house R&D activities.

From this research the deduction can also be made that there is a certain degree of interference in cooperation with different agents of the public R&D system. Whereas cooperation with universities increases the acquisition of external technology, cooperation with public R&D agencies reduces it. This reveals that firms have engaged in cooperation for different reasons and that in some cases cooperation has been viewed as a means for obtaining technology and not as a support mechanism for the innovation process. The study also shows that cooperation with public technological centres significantly reduces internal technology development. These findings have important implications both for managers and policy makers. They have the chance to introduce changes into the private and public R&D system by looking at the area in which each of these agents is most efficient and distributing tasks so that innovative activity is stimulated beyond simple R&D.

Nonetheless, though the model proposed in this work explains around the eighty of the variation in innovatory effort in the Spanish productive sector, future research could extend the analysis by including variables allowing a comparative study to be made between sectors. Moreover, the relation between the type of agent and the innovation output could be considered.

Figure 1. Internal and external sources of innovation activities



Source: Own elaboration

Table 1. Description of the variables

Dependent representative variables of innovatory effort	
Total Intensity of innovation activities	(Innovation activity expenditures/Turnover) x 100
Intramural R&D intensity	(Internal R&D expenditures/Turnover) x 100
Extramural R&D intensity	(External R&D expenditures/Turnover) x 100
Independent representative variables of cooperation with external agents	
Coop. other firms within same group	% of firms in the sector that have cooperated with firms of the same group
Coop. customers	% of firms in the sector that have cooperated with customers
Coop. suppliers	% of firms in the sector that have cooperated with suppliers
Coop. competitors	% of firms in the sector that have cooperated with competitors
Coop. experts and consultants	% of firms in the sector that have cooperated with experts and consultants
Coop. commercial laboratories/R&D firms	% of firms in the sector that have cooperated with commercial laboratories/R&D firms
Coop. universities	% of firms in the sector that have cooperated with universities
Coop. public R&D agencies	% of firms in the sector that have cooperated with public R&D agencies
Coop. public technological centres	% of firms in the sector that have cooperated with public technological centres

Table 2. Innovation cooperation by type of partner, 2001-2003

	Total	%
EIN firms with innovation cooperation with:	**5710**	**100**
- Other firms within the same group	835	14.6
- Customers	733	12.8
- Suppliers	2283	40.0
- Competitors and other firms from the same industry	668	11.7
- Experts and consultants	1095	19.2
- Commercial laboratories and R&D firms	454	8.0
- Universities	1534	26.9
- Public R&D agencies	673	11.8
- Public technological centres	900	15.8

Source: INE, 2003.

* The same firm can cooperate with several partners.

Table 3. Results of multivariate regression model

Tipo de cooperación	MODEL 1 Total innovation activity intensity	MODEL 2 Intramural R&D intensity	MODEL 3 Extramural R&D intensity
- (Constants)	0,144	0,223	0,091
- Coop. other firms within same group	-0,731	-0,303	-0,212
- Coop. customers	1,587**	0,704**	0,343***
- Coop. suppliers	0,401*	0,074	0,010
- Coop. competitors	0,890	0,439*	-0,005
- Coop. experts and consultants	-0,488	-0,129	-0,191
- Coop. commercial labs/R&D firms	1,420	0,185	0,131
- Coop. universities	-0,426	-0,100	0,328**
- Coop. public R&D agencies	-0,234	0,077	-0,550**
- Coop. public technological centres	-0,293	-0,126*	-0,467
R^2	0,796	0,894	0,773

* = p≤ 10%, ** = p≤ 5%, *** = p≤ 1%

Appendix 1. Measurements of Total Expenditure in Innovation Activities. Expenditure on intramural R&D and extramural R&D by sectors and Intensity of these activities as part of Turnover during the period 2001-2003

SECTOR	Turnover	Total expenditures in innovation activities	Total intensity of innovation activity (%)	Intramural R&D expenditures	Intramural R&D intensity (%)	Extramural R&D expenditures	Intramural R&D intensity (%)
Industrial Sectors							
1. Extractive and Oil Industries	29863.56	176.20	0.59	70.07	0.23	28.21	0.09
2. Food, Beverages and Tobacco	71448.98	421.55	0.59	125.12	0.18	36.55	0.05
3. Textile, Clothing, Leather and Footwear	19528.28	466.73	2.39	69.87	0.36	15.68	0.08
4. Wood, Paper, Publishing and Graphic Arts	33787.43	236.51	0.70	54.78	0.16	17.12	0.05
5. Chemical Products	42892.07	995.10	2.32	652.68	1.52	202.40	0.47
6. Rubber and Plastic Materials	14520.73	158.28	1.09	72.63	0.50	14.93	0.10
7. Diverse non-Metallic Mineral Products	26321.75	150.03	0.57	51.60	0.20	23.74	0.09
8. Metallurgy	19878.66	133.19	0.67	47.11	0.24	15.14	0.08
9. Metal Industries	26964.30	345.14	1.28	116.07	0.43	18.05	0.07
10. Transport Machinery and Material	119713.44	2956.92	2.47	1107.07	0.92	1064.49	0.89
11. Diverse Manufacturing Industries	11900.00	78.54	0.66	32.94	0.28	10.06	0.08
12. Recycling Industries	961.46	8.56	0.89	5.31	0.55	0.72	0.08
13. Energy and Water Industries	24513.71	85.80	0.35	55.58	0.23	16.22	0.07
14. Building Industries	131492.78	236.69	0.18	72.02	0.05	83.74	0.06
Service Sectors							
15. Commerce and Catering	359308.06	1113.86	0.31	107.93	0.03	711.09	0.20
16. Transport and Warehousing	75060.82	547.94	0.73	56.66	0.08	20.55	0.03
17. Communication	39461.93	430.14	1.09	121.21	0.31	108.35	0.27
18. Financial Brokering	131930.00	395.79	0.30	144.27	0.11	67.32	0.05
19. Real Estate and Services to Companies	112455.06	2001.70	1.78	1412.80	1.26	323.07	0.29
20. Public, Social and Collective Services	34192.11	259.86	0.76	58.96	0.17	17.90	0.05

Millions of euros
Source: Own elaboration from INE data.

Appendix 2. Cooperation in innovation in the period 2001-2003 according to type of partner and economic sector

SECTOR	Total fimrs	Firms involved in innovation cooperation (%)*	Cooperation partner (%)								
			Same group	Custom.	Supplier	Compet./ firms of same sector	Experts and consultants	Commerc. lab/ R&D firms	Univer.	Public R&D agencies	Public technol. centres
1. Extractive and Oil Industries	820	2.80	0.12	0.12	0.61	0.73	0.61	0.73	1.34	0.49	0.49
2. Food, Beverages and Tobacco	5881	5.46	0.49	0.39	1.92	0.36	1.02	0.77	1.87	0.85	1.19
3. Textile, Clothing, Leather and Footwear	6373	3.15	0.11	0.24	1.88	0.49	0.55	0.30	0.27	0.24	0.53
4. Wood, Paper, Publishing and Graphic Arts	5783	3.34	0.36	0.10	1.71	0.31	0.35	0.21	0.50	0.16	0.55
5. Chemical Products	2171	18.56	3.09	3.27	3.04	2.12	3.36	2.44	8.38	4.24	3.87
6. Rubber and Plastic Materials	1503	9.05	1.60	1.66	1.86	0.67	1.26	0.60	2.20	1.00	2.46
7. Diverse non-Metallic Mineral Products	3703	5.13	0.32	0.19	1.76	0.76	0.54	0.19	1.19	0.49	1.62
8. Metallurgy	743	11.97	2.15	1.08	4.04	1.48	1.35	1.21	3.50	1.35	5.79
9. Metal Industries	7655	5.28	0.56	1.02	2.73	0.43	1.18	0.13	0.86	0.21	0.74
10. Transport Machinery and Material	7056	10.96	1.77	1.98	3.57	1.11	2.24	1.22	4.28	1.28	3.00
11. Diverse Manufacturing Industries	3628	3.75	0.22	0.30	0.80	0.25	1.21	0.66	0.69	0.36	0.85
12. Recycling Industries	120	11.66	0.83			1.67	6.66	0.83	3.33	0.83	
13. Energy and Water Industries	358	8.94	2.24	0.56	2.79	2.79	1.68	2.24	6.71	3.07	5.03
14. Building Industries	35108	0.79	0.10	0.01	0.18	0.01	0.29	0.02	0.27	0.04	0.05
15. Commerce and Catering	41189	2.04	0.24	0.11	1.20	0.30	0.37	0.06	0.19	0.16	0.04
16. Transport and Warehousing	8482	2.72	0.88	0.52	0.93	0.08	0.53	0.01	0.18	0.11	0.04
17. Communication	966	6.73	1.66	0.83	4.76	0.52	1.55	0.41	2.28	0.52	0.62
18. Financial Brokering	1142	10.60	1.84	0.26	4.99	1.58	3.15	0.26	2.63	0.09	0.09
19. Real Estate and Services to Companies	20212	4.71	0.77	1.15	1.62	0.90	0.93	0.47	1.85	1.09	0.80
20. Public, Social and Collective Services	10889	2.80	0.65	0.06	1.78	0.23	0.06	0.28	0.45	0.14	0.05

* The same firm can cooperate with several partners.
Source: Own elaboration from INE data.

Appendix 1. Results of three independent regression models

Tipo de cooperación	MODEL 1 Total innovation activity intensity	MODEL 2 Intramural R&D intensity	MODEL 3 Extramural R&D intensity
- (Constants)	0.144	0.023	0.091
- Coop. other firms within same group	-0.731	-0.303	-0.212
- Coop. customers	1.587***	0.704***	0.343**
- Coop. suppliers	0.401**	0.074	0.010
- Coop. competitors	0.890	0.439*	-0.005
- Coop. experts and consultants	-0.488	-0.129	-0.191
- Coop. commercial labs/R&D firms	1.420	0.185	0.131
- Coop. universities	-0.426	-0.100	0.328**
- Coop. public R&D agencies	-0.234	0.077	-0.550**
- Coop. public technological centres	-0.293	-0.126*	-0.047
R^2 Statistic of the Models			
R^2	0.796	0.895	0.773

* = p≤ 10%, ** = p≤ 5%, *** = p≤ 1

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