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Effects of customer cooperation on knowledge generation activities and innovation results of firms



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Abstract This study has analyzed the effect of cooperation with customers on firms' innovation activities. This issue is particularly novel and important as customers provide information that will be very useful to generate new products and to make the innovation process more efficient. This paper makes important contributions to the literature by analyzing how the cooperation with customers affected the creation of technological knowledge and the economic returns derived from such knowledge. Results have shown that firms cooperating with customers increased investments geared toward expanding the technological knowledge base within the firm's technological domain yet managed to reduce investments oriented to extend the frontier of technological knowledge, at least in the short term. It was also observed, that this cooperation had positive effects on firms' economic returns derived from the sales of products new for the market allowing companies to maintain a competitive advantage over their rivals.

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Introduction

At present the research that regards the cooperation with customers and analyzes the impact on the innovation activity of firms has generated an increasing interest. This significance is reflected in the proliferation of academic studies

that point out that this type of cooperation offers multiple advantages to firms, of which especially three groups merit emphasis. The first derives from the information provided by these agents and which results essential for the development of the innovation process. This information may relate to: new technologies and market evolution (Whitley, 2002), scientific information and complementary technology to that already managed by the R&D team (Rosenberg, 1990) and information geared toward the generation of ideas with a high degree of novelty (Amara and Landry, 2005). The second group is related to the

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development of innovations. It has been pointed out that customers facilitate the development of more attractive products and services (Lilien et al., 2002; Franke et al., 2006) that have a higher probability of commercial success (Poetz and Schreier, 2012), as they allow for the identification of non-satisfied needs which in many cases not even customers are conscious to hold (Souder et al., 1997; von Hippel and Katz, 2002). Finally, the third group of advantages is related to the innovation process efficiency. It has been shown that customer cooperation reduces the costs of the development process and of new product and services implementation (Herstatt and von Hippel, 1992; Lilien et al., 2002; Jeppesen, 2002).

Despite of the importance attributed to customer cooperation, it still remains necessary to broaden the study concerning the effects on firms' innovation process. It has already been established that this cooperation can increase or diminish firms' innovation effort (*inputs*) and influence the development of different innovation types (*outputs*). Nonetheless, the method applied in previous empirical studies did not answer questions on whether cooperation with these agents contributed to generate technological knowledge with a different strategic value and/or to obtain economic returns from the innovation process, aspects that are key in the development of innovation strategies. This work is intended to give a first step to answer these questions by comparing the innovation activity of firms who cooperated with customers with those who did not. To address the first issue, the effect of cooperation on technological knowledge generation during the early stages of the innovation process was analyzed. In general, studies have so far dealt with the influence of cooperation on the net R&D expenditure, to the best of our knowledge, no previous study has analyzed the effect of cooperation with customers in relation to the distribution that firms make of their R&D expenditures with regard to the following activities: basic research, applied research and technological development. These activities generate knowledge with different strategic values and contribute to expand the technological knowledge frontier of the firm (basic research), and/or increase the knowledge base within their technological domain and market (applied research and technological development).

With regard to the second question, the effect of cooperation on the economic returns of new products and their degree of novelty was examined. In general, the literature has adopted a qualitative perspective with regard to the type of innovations developed by firms that cooperate with customers (von Hippel, 1988; Miotti and Sachwald, 2003; Tether, 2003; Amara and Landry, 2005; Nieto and Santamaría, 2007). However, this approach does not offer a broad knowledge with regard to the role of this cooperation respective to the economic success of the firm in the market. There exist multiple factors that influence on the economic returns of the innovation process, some being controllable by the firm (as for instance: their innovation orientation, R&D investments or the service provided to the customer, among others) while others are out of their control (for example, the economic situation of the country or changes in consumer taste, etc.). In this context, cooperation with customers is presented as an alternative within their innovation strategy that seeks to improve the competitive position of the firm, so that its effects on the economic indicators

should not be underestimated. Only by comparing the economic returns of firms who cooperated with those who did not, can the real contribution of cooperation be determined with regard to the firm's success and its competitive position in the market.

In this study a method of nonparametric matching was used to analyze the effects of cooperation with customers by comparing firms that cooperated *versus* companies that did not and belonged to a control group. The method controls the observed differences between the two groups of firms so that the results are in principle, attributable only to the effect of cooperation. In addition, the study assumes a time-dependent data structure to analyze the effects over a period of four years. The study has evaluated the immediate effects of cooperation on different technological knowledge-generating activities as well as on the long term effects in the case of the economic returns. A sample of Spanish firms belonging to a wide range of sectors has been taken into account, manufacturing as well as services sectors, thus allowing achievement of a deeper knowledge and more general results with regard to the effect of customer cooperation on firms innovation activity.

This article has been structured as follows. In the second section a literature review is carried out with regard to the customer cooperation effects on the inputs and outputs of the innovation process. The third section details the methodology used and the fourth describes the data sample and variables of the study. The fifth section shows the results of the analysis and their discussion. Finally, in the sixth and last section, conclusions are drawn including some implications for firms and the limitations of the study together with future research lines.

Effects of customer cooperation on the innovation activity

Traditionally, economists have considered that product manufacturers were the starting point of the innovation process. Nonetheless, researchers studying technological and organizational change have shown that assuming that the manufacturer is the only source of innovations limits considerably the big picture of the innovation process (von Hippel, 1988, 2005). The evolutionary perspective of technological change, for example, shows an innovation process characterized not only by the need for feedback between the different stages it consists of, but also by the multidisciplinary nature of the inputs as well as by the diversity of external information sources (Rosenberg, 1976, 1982). Similarly, literature on strategy has pointed out that external agents act as an important resource in the current competitive environment, particularly with regard to the development of new products and processes (Barney, 1991; Peteraf, 1993). Therefore, today it is known that firms need to establish networks and relationships with other agents of the innovation system to complement their resources and internal capacities with outside ideas (von Hippel, 1988; Chesbrough, 2003a; Laursen and Salter, 2006). This approach is the central point of the so-called "Open-Innovation" model (Chesbrough, 2003a,b), which emphasizes on the interactive nature of the innovation process and suggests that firms must not rely exclusively on their internal R&D

activities, since with more extended and intense external relationships the greater will be their ability to adapt to changes and innovate (Chesbrough, 2003b; Chesbrough and Crowther, 2006; Laursen and Salter, 2006).

Among the different cooperation alternatives that firms sustain, we can find cooperation with customers. While considerable progress has been made with regard to the analysis of the effects of this type of cooperation, there exists no clear knowledge of its influence on certain key aspects of the innovation process as for instance: the generation of technological knowledge (*input*) and the economic returns derived from that knowledge (*output*). The literature in general has used a descriptive approach analyzing separately the effects on the inputs and the outputs of the process. However, we consider that it is necessary to take into account both aspects in order to provide a more comprehensive, objective and accurate insight. This dual perspective is important as the inputs and outputs of the innovation process are closely related. An analysis of the cooperation effects on the “ingredients” operating during the process and on the “results” obtained will truly allow assessing the influence of these types of relations on the firm’s innovation activity.

In the case of the inputs of the innovation process, the literature has determined that cooperation has effects on R&D expenditures and on the innovation effort of firms. In some cases it has been found that customer cooperation reduced innovation investment (Herstatt and von Hippel, 1992; Jeppesen, 2002, 2005; Henkel and von Hippel, 2004; von Hippel, 2005; Lettl et al., 2006) and lead to higher levels of innovation process efficiency (Tether, 2002; Bayona et al., 2003; Santamaría and Rialp, 2007a). Firms cooperating with customers would spend less effort in terms of time and money to achieve a certain innovation (Lettl et al., 2006), not only being able to reduce the costs of the trial and error process (Jeppesen and Molin, 2003; Lettl et al., 2006), but also the number of faulty prototypes until attaining the desired product (Lettl et al., 2006). In contrast, other authors with opposite results have pointed out that there exists a positive relationship between cooperation and investment in R&D activities (Fritsch and Lukas, 2001; Belderbos et al., 2004; Santamaría and Surroca, 2004; Motohashi, 2005). In the process of cooperation with customers firms would increase not only their innovation expending (Lilien et al., 2002), in addition also the intensity of their innovation activity (Tether, 2002).

Although the literature has focused on analyzing the effects of cooperation in terms of process cost and efficiency, the issue of knowledge generation has so far not been studied extensively. Even though it has been established that cooperation shapes R&D expenditures, it still remains unknown how it influences during the early stages of the innovation process, namely, the moment in which firms adopt strategic decisions about the breadth and depth of their technological knowledge stock. It is expected that during the cooperation with customers, or after it, the firm will carry out processes of searching for solutions that will derive in the improvement or development of new products or services. During these processes, customers have passed from participating only when required by the manufacturer to provide information about latent or patent needs – MAP (*Manufacturer Active Paradigm*) to play a more active role in the development and implementation

of new products – CAP (*Customer Active Paradigm*) (von Hippel, 1978). These ideas were combined by von Hippel (1995) in the action modality known as “*interactive user and manufacturer-based design*”. This model states that customers and manufacturers interact continuously throughout the different stages comprising the generation of ideas and development of new products; consequently, the final innovation will be the result of a continuous process of trial and error, in which customers participate actively in the evaluation of successive prototypes and in the design and final development of the product.

As a result of these interaction processes between customers and the manufacturer, it could happen that firms alter their R&D investment portfolio. How they are modified allows drawing conclusions whether cooperation with these agents generates positive firm effects taking into account the expansion of their technological knowledge frontier or with regard to the exploitation of the existing knowledge. In this respect, it has been shown that R&D activities generate knowledge with different strategic values (Coccia and Rolfo, 2008). Basic research, for instance, is an activity that helps firms stay updated about the latest technological advances expanding their technological knowledge frontier (Henard and McFadyen, 2006). Conversely, applied research and technological development are used to find solutions to concrete problems affecting the core areas of the business and of the firm’s survival (Corsten, 1987). These activities generate knowledge close to firm’s technological domain and to their market, which helps to create and maintain a certain technological distance with respect to their competitors (Roper et al., 2004).

Contact with customers is in general, an exploratory method to obtain information on the requirements of the market, which is particularly useful for the development of technologies and complex products (Tether, 2002). This information reveals market needs as well as those derived from the context in which the products and services are used (von Hippel, 1994, 1995, 1998; Sánchez-González et al., 2009). Due to this reason, it is expected that cooperation with customers will encourage the firm’s investments directed toward expanding their knowledge base within their technological domain and market, as to provide responses to the afore mentioned needs.

Applied research and technological development activities serve precisely for that purpose. These activities are carried out with a specific practical objective in mind (Roper et al., 2004) and are directed toward facilitating the processes of knowledge transformation into products and services for the market. While basic research can be crucial to generate ideas for the development of new products, the contribution of the knowledge generated by this activity in aspects concerning marketing are in general uncertain (Henard and McFadyen, 2006). For this reason, it seems unlikely that customer collaboration will help to extend the knowledge frontier of firms outside of their current framework. Accordingly, this study tests the following hypothesis:

Hypothesis 1. Firms that cooperate with customers invest more in applied research and technological development compared to firms which do not cooperate with these agents.

Literature has also examined the effects of customer cooperation on the *output* of the innovation process evaluating whether these types of relations have an influence on the generation of innovations. Due to their experience in the use of products, customer cooperation will especially be oriented toward the development of product innovations (Tether, 2002). One of the characteristic dimensions of these innovation types is their novelty degree. Given this characteristic, usually incremental and radical innovations can be distinguished. Innovations are considered incremental when they involve some substantial improvement that entails a certain novelty degree without distancing from the existing technology. On the contrary, a radical innovation is one that involves a completely different or innovative contribution with respect to the already existing technology and which normally leads to assume high costs and risks. According to literature, given the difficulty involved in the design and implementation of radical innovations (von Hippel et al., 1999), the development of innovations with a low degree of novelty tends to be more frequent (Hollander, 1965).

In the case of customer cooperation, these relationships can give rise to ideas about new product lines (radical innovations), as well as ideas aimed to improve existing products (incremental innovations). A priori, customer knowledge and experience are particularly related to the use of the products that they handle, in this manner, normally when they contribute ideas they are often limited to familiar products. Nonetheless, as a consequence of their participation in the innovation process their knowledge base is expanded, which offers additional opportunities to generate new ideas or even discover needs that up to that moment had remained unknown (von Hippel and Katz, 2002). Furthermore, it has been observed that ideas provided by customers are better valued in innovation terms and benefit to the user than those provided by the firm's professionals (Poetz and Schreier, 2012). Although these agents can contribute to the development of both types of innovations, their involvement will be higher or lower depending on the type of innovation desired (Veryzer, 1998; Lüthje and Herstatt, 2004). If what the firm seeks is an incremental innovation, all of which is required consists of scarce customer participation (for example, through interviews or questionnaires), nevertheless, if the goal comprises a new innovation it is unavoidable for customers to participate in a more intense fashion during the innovation process.

Despite of recognizing widely the importance of customers in the process of innovation development, there are few empirical studies that have examined the effect of this cooperation on the economic returns of product innovations and their degree of novelty (Amara and Landry, 2005; Nieto and Santamaría, 2007). In general, empirical evidence handles the issue of the effect on the outputs from a qualitative point of view, without taking into account the possible success that these innovations have been able to achieve in the market. For example, in the study of Amara and Landry (2005) qualitative measures are used to determine the novelty degree asking firms if the innovations obtained are new only to the firm, new to the country (Canada) or new at a global level. On the other hand, Nieto and Santamaría (2007) analyzed the cooperation effect on dichotomous variables that indicated a high novelty degree if the product complied with new features compared to a low novelty degree

if changes affected only the design, presentation or the components of the product.

As a result, traditional *proxy* measures of innovation results do not reflect the real extent of the economic effects that this cooperation could produce. So far it has been observed that customer cooperation reduces innovation process costs and helps to improve the innovation efficiency (Herstatt and von Hippel, 1992; Lilien et al., 2002; Jeppesen, 2002), being these magnitudes being of an economic type. Then again, considering the fact that if the invention has not arrived to the market then it cannot be considered an innovation, while lacking economic returns it cannot be spoken of market success, it results therefore essential to establish the impact of this cooperation on the average economic returns of the innovation process. Therefore, in this study the sales of products new for the firm and new to market have been used, which in addition also allows to take into account the novelty degree of the innovation.

From all of the above we pose the following question: could firms that cooperate with customers achieve higher economic returns than those that do not? Taking into account previous studies, it follows that the information provided by these agents and especially their direct involvement in the innovation process, leads to more successful new product developments (Atuahene-Gima, 1995; Souder et al., 1997; Fritsch and Lukas, 2001). This can occur because innovation activities based on commercial information, such as that provided by customers, have a higher chance of success compared to those based on other information types, whose economic value contemplates a higher degree of uncertainty (Dahlin and Behrens, 2005; Audretsch and Aldridge, 2008). In addition, cooperation with customers can be considered a complementary good (Teece, 1986; Fernández-Sánchez, 2004). To the extent that such goods are difficult to imitate by a competitor, chances increase that an innovative firm will commercially benefit from its innovation (Tripsas, 2001) and will attain higher economic revenues compared to those firms that do not possess innovations of this kind. Customer cooperation is a useful strategy that helps to identify accurately the requirements of the market and can therefore generate higher economic returns compared to firms that do not make use of it. Also, the fact that a firm can adopt this type of cooperation to be the first to make a move in the market allows companies to achieve higher than normal benefits, at least during a certain period of time (Scherer, 1980), also to achieve a greater market share compared to subsequent competitors (Fernández-Sánchez, 2004). Due to all of the above the following hypothesis is formulated:

Hypothesis 2. Firms that cooperate with customers obtain higher economic returns derived from new products compared to firms that do not cooperate with these agents.

Methodology

This study has used a nonparametric matching method to analyze the effect of cooperation with customers, C_i , on the innovation activity of firms, Y_i . The method estimates the effect of cooperation by comparing the innovation activity of firms that cooperated (factual state) with the results they could have reached if they had not done so

(counterfactual state). Given that a firm i cannot be observed cooperating and not cooperating simultaneously with these agents, the counterfactual state is estimated with information derived from a control group. The construction of this control group is not straightforward, given that the firms' decision to cooperate with customers is not random and in addition the profile of companies that cooperate differs from those who do not. This generates an econometric problem named "selection sample bias". The matching estimate reduces this bias by matching firms that cooperated with companies that did not cooperate but were similar in terms of their observable characteristics X_i . Due to the fact that the matching of firms of many characteristics in an n -dimensional vector is generally unfeasible, the method summarizes the characteristics of each company into a scalar variable or *propensity score* [$p(X_i)$] in order to make the matching process more feasible (see Rosenbaum and Rubin, 1983). In the present study, $p(X_i)$ is defined as the conditional probability of cooperating with customers in the innovation process, given certain firm characteristics X_i . In this way, the *matching estimator* compared those firms that cooperated *versus* companies who did not and nonetheless display the same propensity to do so. This study used a Probit model to estimate $p(X_i)$, since it is literature's most commonly used model. In the model the dependent variable took on the value of 1 if the firm cooperated with customers and 0 otherwise.² The vector of covariates X_i was made up of variables representative of different firm characteristics which allowed the distinction between companies that cooperated from those that did not, and which in turn influenced on the propensity to cooperate. The number of variables was reasonably chosen to ensure a correct matching viability.

Due to the low probability of locating two firms with the same value of $p(X_i)$, different matching processes exist which use a proximity criterion to identify the companies that are part of the control group. The most commonly used is the *Nearest Neighbor Matching* (NNM) method. This method selects for each firm that cooperated a company which did not cooperate yet took on the closest $p(X_i)$ value. This study concretely used the *bias-corrected nearest-neighbor matching* method proposed by Abadie and Imbens (2006), which has the property of correcting the bias that can result when the matching between units is not exact. In addition, a number of conditions were imposed to obtain more robust results. In this sense, the matching process not only sought firms with the same *propensity score*, they simultaneously had to meet the condition of having the same situation with respect to their previous R&D expenditures and past subsidies obtained. In the same manner, we imposed the conditions that the matching process had to be between firms operating in the same sector of activity.

Once the control group was formed, considering that Y_i represents a measure of the firm's innovation activity and C_i takes the value of 1 when the company cooperated with customers and zero otherwise while $p(X_i)$ represents the *propensity score*, the customer cooperation effect can

be estimated as the difference between the innovation activity of cooperating firms and the innovation activity of the non-cooperating companies, it follows:

$$\tau = \frac{1}{N_1} \sum_{i|c_i=1} [Y_{i,c=1}(1) - Y_{i,c=0}(0)] \quad (1)$$

Dehejia and Wahba (2002) make a thorough review of this methodology, while Abadie and Imbens (2006) give detailed explanations regarding the *bias-corrected matching estimator*.

Sample and variables

Sample

The data used to carry out the present research derives from the Panel of Technological Innovation – Panel de Innovación Tecnológica (PITEC). This panel was specifically created with the objective of taking advantage of a database allowing analysis of the innovation behavior of Spanish firms together with their evolution. Starting in the year 2003 the panel gathers information regarding Spanish firms belonging to two subpopulations, the first corresponds to companies with more than 200 workers while the second to companies that declare to implement internal R&D expenditures. The representation of the first subpopulation comprises 73% of the firms whereas 60% in case of the second subpopulation.

The final sample used in the present study consisted of 4713 firms which recorded innovation expenditures, of which 656 collaborated with customers. The data sample covered the period between the years 2004 and 2007. In order to carry out the analysis, as already noted above, a time-dependent data structure was assumed in which the year 2004 was chosen as the reference point. In the year 2004 the propensity of firms to cooperate with customers was estimated and the matching was undertaken. With regard to the estimation of the cooperation effect on the inputs, the effect in the year (2004) was analyzed and also in the subsequent year (2005). In the case of the outputs the effect was analyzed in the periods 2004–2006 and 2005–2007. The reasoning behind this temporal difference lies in the fact that in the survey the variable measuring the *outputs* records the average percentage of innovative product sales introduced in the past three years. As a result, the variable for the period 2004–2006 records the average percentage of innovative product sales obtained in this first period (including the year of cooperation), while the value of 2005–2007 reflects the mean percent achieved in this second period. The variable which indicates whether the firm cooperated or not with customers was determined by exogenous variables which in some cases adopted values corresponding to the year 2003 to reduce endogeneity problems and improve the matching quality.

Variables

The covariate X_i vector used to estimate the *propensity score* $p(X_i)$ – that is, the propensity to cooperate with customers in 2004 – included variables which according to

² Cooperation could have been established with customers of the same country (Spain), of Europe or other countries, in an independent or simultaneous form.

the literature, influence on this propensity (Kaiser, 2002; Santamaría et al., 2002; Tether, 2002; Bayona et al., 2003; Belderbos et al., 2004; Bönnte and Keilbach, 2005; Heijns et al., 2005; Santamaría and Rialp, 2007a,b; among others). In first place, variables have been included representative of the structural characteristics of the firm such as: size (logarithm of workers number), age (dichotomous variable which indicates whether the company was recently created or not), property structure (dichotomous variable which indicates whether the company was domestic or not) and the propensity to export (ratio between exports and sales). Next, we also included indicators of the firm's innovation activity, such as *dummy* variables to determine if the company belonged to the manufacturing or services sectors of high and medium technology and also if the company showed past R&D expenditures (value corresponding to the year 2003). In the same manner, a dichotomous variable was considered which indicated whether in previous years the firm had received subsidies for R&D activities (corresponding to the year 2003).

The attempt to measure innovation has always been a difficult task for researchers. This study has combined indicators of the firm's innovation process *inputs* and *outputs* to estimate the effect of cooperation on the innovation activity Y_i . The innovation inputs has been measured through the innovation effort, calculated as the ratio between innovation expenditure over firm sales multiplied by one hundred.³ To analyze the effect of cooperation with customers with regard to the distribution that firms make of their R&D expenditures in basic research, applied research and technological development, these variables have been defined as the percentage represented over the total domestic expenditure in R&D multiplied by one hundred. As to the innovation *output* two variables have been taken into account: (a) the ratio between sales of products new for the market over total sales, multiplied by one hundred (high degree of novelty) and (b) the ratio between sales of products new for the firm over the total sales of the company, multiplied by one hundred (low degree of novelty).

Results

The methodology used to identify the innovation activity differences between firms cooperating with customers and companies of the control group requires two preliminary analyses. The first analysis consists of a Probit model estimation yielding the variable that returns the propensity of firms to cooperate with customers also known as *propensity score*. In a second instance, an analysis is carried out to detect significant differences with respect to this variable between firms that cooperated and the control group.

Being only a preliminary analysis, the Probit model estimates are reproduced in Annex 1, followed by a summary of the most significant results with regard to the profile of

the firms that cooperated with customers. It was concluded that firm size, previous R&D experience, belonging to the high-tech services sector and obtaining public funding all influenced positively and significantly on the propensity to cooperate with these agents. However, the fact that the firm was domestic reduced this propensity.

Estimation of the marginal effects showed that within this group of variables belonging to the high-tech services sector and obtaining public funding were the variables which influenced mostly on the propensity to cooperate with customers and which in addition would also increase the propensity significantly, *ceteris paribus*, by 12 and 19 percentage points, respectively. These results reflect the current situation of the Spanish productive system. Most of the R&D growth in Spain has been driven by the expansion of the services sector, which is annually growing at a rate of 16% compared to 7.9% of the industrial sector (OECD, 2007). This is especially due to the efforts undertaken to acquire and search for new resources and sources of knowledge by the high-tech services firms. Taking into account the special characteristics of the services (for example, they are produced and consumed at the same time), it is foreseeable that the link between these firms and their customers will be narrower and more continued than in the case of physical products (Ettlie and Rosenthal, 2011). On the other hand, although public funding is not one of the main motivations to cooperate with customers with regard to the development of innovations, the results of our study demonstrate that public funding can be used to promote the interest of firms to collaborate with such agents, as other authors have already pointed out (Belderbos et al., 2004; Santamaría and Surroca, 2004; Santamaría and Rialp, 2007a).

The second preliminary analysis was carried out to ensure the matching quality and robustness of the results.⁴ The Student's *t* test was used to verify whether the mean *propensity score* values were equal before and after matching. Results of this test are displayed in Annex 2. As can be observed, significant differences were detected before matching with regard to the *propensity score* of the firms cooperating with customers and the non-cooperating companies (control group). After matching these differences between groups disappeared thus demonstrating the high matching quality achieved and that the methodological assumptions had been attained.

Once these prior analyses had been undertaken, estimation of the causal effect of cooperation with customers in accordance with Eq. (1) required to compare the innovation activity of cooperating firms with the innovation activity of non-cooperating companies of the control group. This process of comparison was repeated to estimate the cooperation effect on each of the variables representative of the innovation process *inputs* and *outputs*. Results are displayed in Table 1.

In the case of the *inputs*, in a previous and complementary analysis to the main effect of cooperation with

³ Although this variable was not used to contrast the hypotheses, in the analysis it is included with a complementary character to compare our findings with previous studies and thus provide a fuller picture of the cooperation effects.

⁴ In this study we have used 4 nearest-neighbor observations for each treatment. That is to say, each cooperating firm has been compared with 4 possible control firms. Studies which have used this type of research methodology have obtained more robust results with this practice (see González and Pazó, 2008).

Table 1 Customer cooperation effects on firms' innovation activity.

	Year Coef.	Year Coef.
<i>Inputs</i>	2004	2005
Innovation effort	0.45 ^{***}	0.41 ^{***}
Basic research	-2.84 ^{**}	0.21
Applied research	3.54 ^{**}	2.12
Technological development	2.90	4.76 ^{**}
<i>Outputs</i>	2004-2006	2005-2007
% Sales of products new for the firm	1.07	1.22
% Sales of products new for the market	0.67	1.78 [*]
% exact matchings (sector)	100	100
Potential control group (number of firms)	2624	
Cooperating firms (number of firms)	656	

^{***} $p < 0.01$.

^{**} $p < 0.05$.

^{*} $p < 0.10$.

customers on the distribution of R&D expenditures, we also took into account the effects of this cooperation on the whole of the innovation effort detecting that it influenced in a positive and significant manner. In addition, although the literature points to the need for a certain time delay since cooperation occurs until the effects are reflected in firms' innovation activities, the present study has revealed the existence of immediate effects on the *inputs*. In this manner, the innovation effort of firms cooperating with customers was 0.45 percentage points significantly greater than companies of the control group in the year of cooperation and 0.41 percentage points the following year. These results are in line with previous studies who have pointed out that customer cooperation increased the innovation effort of firms (Colombo and Garrone, 1996; Kaiser, 2002). It follows that the cooperation with customers can become a source of competitive advantage, through the continuous strengthening of the innovation activities.

Concerning the cooperation effects with customers with regard to the distribution that firms make of their private R&D expenditures in basic research, applied research and technological development, the present study has revealed the existence of significant differences with regard to the R&D portfolio of cooperating firms compared to those that do not cooperate. In line with the theoretical arguments that have already been presented, it was observed that customer cooperation promoted activities of applied research and technological development.

In the year of cooperation 2004, firms that collaborated with customers showed a significantly lower investment in basic research of 2.84 percentage points compared to the non-cooperating firms, while the investment in applied research was significantly greater by 3.54 percentage points. The fact that these two effects occurred simultaneously the year of cooperation and resulted not significant in the following year of 2005, manifests that firms which used this strategy pursued as an objective short-term solutions to

market needs, in detriment of expanding their technological knowledge base to other fields.

On one hand, investment in basic research is carried out without a specific purpose and serves as a contact with the latest technological advances of a particular field, allowing access to knowledge which subsequently can be very useful to develop other types of R&D activities (see Beesley, 2003). In the search for cooperation partners, the value of the resources that each type of agent can provide should also be taken into account (Surroca and Santamaría, 2007), since innovation outcomes may be different depending on the complementary or similar nature between the knowledge of the firm and that of the possible partners (Surroca and Santamaría, 2007; Quintana García and Benavides Velasco, 2010). In vertical cooperation, normally the objective is to acquire complementary knowledge, particularly of a commercial nature (Arranz and Fdez de Arroyabe, 2008). The basic research investment reduction in the case of the customer cooperating firms simply reveals the preference of these companies to develop near-market research activities.

On the other hand, applied research generates knowledge to address practical issues of a specific nature, being closer to the technological domain of each firm (Roper et al., 2004). Firms that invest in these types of research activities presumably do so to lay down a distance with their competitors in the short term. In this context, it should be considered that the customer information provided derives from his experience in the use and/or handling of products, while it is the manufacturer who holds the necessary knowledge to conceive and physically manufacture the products that meet the established needs (von Hippel, 1994, 1998; Sánchez-González et al., 2009). Therefore in the process of customer cooperation, firms become aware of existing market needs and in consequence direct efforts toward applying their knowledge to design products which meet market needs quickly.

Finally, it was also observed that firms cooperating with customers made a significantly greater effort of technological development activities in the year 2005 (significantly higher by 4.76 percentage points compared to non-cooperating firms), yet not in the year 2004. These results would indicate that a certain period of time needs to elapse from the moment the customer provides his knowledge until it materializes into a technological development phase, although the present study reveals that the time interval does not need to be excessively long. Investments in technological development can lead these firms to focus on *advanced core technologies* and invest less in technologies that are outside their *core domain* (Santoro and Chakrabarti, 2002). Firms that cooperate with customers will try to profit from the advantage gained by the knowledge provided by these agents to carry out technological developments that will allow them to provide prompt market solutions and obtain benefits.

In the case of the *outputs*, the second hypothesis was only partially confirmed since cooperation with customers had positive effects on the economic returns of products new for the market, while no significant effects were detected in the case of products new for the firm. Therefore, in addition to affecting economic returns it can be said that customer cooperation also has an effect on the degree of innovation novelty by encouraging the development of

radical compared to incremental innovations. In this manner, even though it has been generally thought that the information provided by customers is more useful in the case of non-novel innovations, the results of this study have shown that these relationships are also highly suited when innovations with a high degree of novelty are sought (von Hippel, 1988; Meyers and Athaide, 1991; Shah, 2000; Tether, 2002; Amara and Landry, 2005; Lettl et al., 2006; Poetz and Schreier, 2012). Firms cooperating with customers significantly increased the sales of products new to the market by 1.78 percentage points during the period 2005–2007 compared to firms that did not participate in cooperative relationships. This effect could be interpreted not only in terms of an economic return increase, in addition also as a greater commercial success of the products with a high degree of novelty for these kinds of firms. Therefore, in the Spanish case, cooperation with customers would help to make innovation investments profitable and would be based on a strategy of differentiation in contrast to an imitation strategy. It is possible to think that firms cooperating with these agents seek to improve their competitive position in a medium and long term through the development of radical innovations that differentiate them from their competitors. Nonetheless, the fact that these effects begin to turn up years after the cooperation has taken place, denotes the need for a certain period of time to elapse until the ideas contributed by customers materialize into sales of products with a high novelty degree.

To summarize, taking into account the effects on the *inputs* and the *outputs*, the present study has revealed that firms cooperating with customers increased their innovation efforts and oriented their R&D activities toward the generation of technological knowledge with clear market applications (applied research and technological development). In addition, these effects were observed in the year of cooperation as well as in the following year. It can also be concluded that such cooperation was beneficial to the development of radical innovations that help to improve the competitive position of the firm in the market. Such innovations are typical of firms with a strong technological orientation (Ettlie et al., 1984) and their generation requires the renewal and expansion of the knowledge base in order to create skills not previously possessed by the company (see Herrmann et al., 2006). The results of the current study confirm these statements, as the profile of the customer cooperating firms was characterized by the existence of prior R&D experience, belonging to the high-tech services sector and receiving public R&D funding.

Conclusions

In this study we have analyzed the effects of cooperation with customers in the generation of technological knowledge during the early stages of the innovation process (inputs), as well as on the economic returns derived from the sales of innovations with varying novelty degrees (outputs). The study has been carried out by comparing the innovation activity of firms that cooperated with customers *versus* companies that did not cooperate and belonged to a control group.

In an early stage of our analysis we estimated the propensity of firms to cooperate with customers. Results revealed that size, belonging to the high-tech services sector, have had previous experience in R&D and obtaining public funding all increased significantly the likelihood to cooperate with these agents. An estimation of the marginal effects revealed that the variables belonging to the high-tech services sector and obtaining public funding contributed the most to this propensity. Therefore, results have shown that firms collaborating with customers have a clear innovation orientation.

The analysis to estimate the effects of cooperation found that it influences both the *inputs* and the *outputs* of the innovation process. In the case of *inputs*, results showed that customer cooperation increased the innovation efforts and influenced on firms' investments in different technological knowledge-generating activities. R&D activities serve to broaden the base of technological knowledge of firms although with different purposes. It has been observed that in the short run, firms that cooperated with customers increased investments aimed to expand the knowledge base within their technological domain (applied research) and to materialize knowledge into goods and services (technology development), while at the same time they decreased investments in activities aimed to expand the technological knowledge frontier (basic research). These results highlight that cooperation with customers endorses firms to develop R&D activities which involve the search for solutions to specific problems that affect the firms' core business areas (applied research and technological development). These ideas are in line with the paradigm of *Open Innovation* (Chesbrough, 2003a,b, 2006) and are consistent with previous research results showing that the use of the *Open Innovation* strategies contributed to the R&D efforts of companies being transformed into successful innovation results (Santamaria et al., 2010).

On the other hand, R&D activities are related to the business cycle and growth (Rafferty, 2003). During expansion processes, firms reduce their investments in basic research since the contribution of these activities to product success in the market is quite uncertain. Under these circumstances, an investment increase in applied research and technological development could possibly lead to knowledge that can be applied more quickly to solve market problems and would therefore allow retrieving economic results in the short term (Damanpour, 1996; Henard and McFadyen, 2005). Different R&D activities compete to obtain scarce resources, the results of the present study show that firms will resort to customer cooperation during expansion and growth processes.

With respect to the *outputs*, this study has demonstrated that customer cooperation influenced positively and significantly on the economic returns generated by products with a high novelty degree. This entails that the information provided by these agents helps firms to compete with products new for the market using a strategy of differentiation, which in turn helps to augment their competitive advantage. Customer cooperation allows achieving such innovations as it redirects the firm's R&D portfolio toward searching novel solutions to market requirements or can even lead to identify needs that have not yet been discovered by the customer. In other cooperation types, as for instance that

established with suppliers, firms run the risk that radical innovations developed jointly could arrive to competitor hands (Czarnitzki and Thorwarth, 2012). In contrast, customer cooperation could offer a greater security with regard to the commercial success of such innovations, helping the firm to maintain a certain distance from its rivals and thus ensuring a top competitive market position. In conclusion, it is convenient to encourage the idea of counting with customers to develop innovations because it is very positive to attain small improvements, although especially, to obtain greater economic returns derived from innovations holding a high novelty degree.

Important firm management implications can be extracted from the analysis of the effects on the *inputs* and *outputs*. In this sense, customer cooperation has proven to be a valuable source of information because it affects the generation of technological knowledge (*inputs*), together with the economic results of the innovation process as well as the novelty degree of the innovations developed (*outputs*). Therefore, it is important to advise the firm's management while taking the decision on whether or not to cooperate with customers, that they must keep in mind the effects generated by these relationships on both aspects of the innovation process. In addition, the study has also revealed that firms who cooperated with these agents were more involved in applied research and technological development, all in order to obtain short term economic results of their innovations and to pursue a differentiation strategy that allowed them to maintain a better competitive position next to rival companies.

These results also have implications for *policy-makers*. The *Open Innovation* paradigm promotes the division of innovation activities among Universities, Industry, Government and other agents. According to previous studies, cooperation strategies as well as other alternatives of *Open Innovation* are highly useful for firms and their picking should keep in mind the type of innovation being pursued (Santamaría et al., 2010; Spanjol et al., 2011). As this study has shown, customer cooperation increased innovation efforts and promoted the development of radical innovations. Therefore, *policy-makers* should consider this type of cooperation as an opportunity to improve the innovation and competitiveness levels of the firms in their country. The majority of Spanish firms are small companies that often do not recognize the need to carry out R&D activities. It is also common place for Spanish firms to lack the organizational capacities and the necessary human resources to exploit knowledge and undertake by themselves innovation activities. Public policy should encourage customer cooperation in order to improve this situation, facilitating firms an access to new knowledge at a low cost. *Policy-makers* should promote cooperation through initiatives that strengthen these types of relationships taking into account the positive effects exerted on the *inputs* and *outputs* of the innovation process.

Finally, a necessity persists to point out the main limitations of this work, some of which could possibly bestow future research lines. In first place, we recommend that both results and conclusions of this study should be interpreted with caution. While it remains true that due to the methodology used the observed differences between the two groups of firms are, in principle, attributable to the

cooperation effect, it would also be desirable to explore new methodologies which allow to analyze a greater number of factors influencing on the innovation activity. In second place, we need to clarify that the purpose of this study was not to undertake an *input-output* analysis; nevertheless, a first step has been taken to clear the way for further research that examines the cause-effect relationships. Last, extending the time period of analysis would allow drawing improved conclusions with regard to the dynamic effects of this cooperation type and consent to establish the effects in the current economic context.

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Annex 1. Estimation of the Probit model and its marginal effects

Variables ^a	Coef.	M.E.
Size log.	0.04**	0.01**
Recently created firm	0.15	
Domestic firm	-0.21***	-0.05***
Export ratio	0.01	
High-tech manufacturing sector	0.12	
Medium high-tech manufacturing sector	0.08	
High-tech services sector	0.68***	0.19***
R&D expenditures	0.01*	0.01*
Public funding	0.52***	0.12***
<i>N</i>		4713
Number of cooperating firms in 2004		656
Log likelihood		-1759.62
Pseudo- <i>R</i> ²		0.09
Correctly classified (%)		86.51

M.E.: marginal effects.

^a All variables are lagged one period (2003).

* $p < 0.10$.

** $p < 0.05$.

*** $p < 0.01$.

Annex 2. Comparison of mean propensity score values before and after matching

	$C_i = 1$ Mean	$C_i = 0$ Mean
<i>Before matching</i>		
Propensity score	0.18	0.13***
<i>N</i>	656	4070
<i>After matching</i>		
Propensity score	0.18	0.18
<i>N</i>	656	2624

Note 1: Significance levels (*** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$) indicate that mean values are statistically different according to a two tailed *t*-test.

Note 2: C_i took on the value of 1 if the firm cooperated with customers and zero in the opposite case.

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