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User cooperation effects on firm's innovation outputs

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Abstract
We analyzed the effects of R&D cooperation with users and the intensity/continuity of such cooperation on firms' innovation output—whether radical or incremental. We also examined the moderating effect of firm size on these relationships. Results show that cooperation with users favours the development of both radical and incremental product innovations. In addition, we found that the higher the intensity/continuity of the relationship with users, the more likely radical innovations are to develop when compared with incremental innovations. We note that the positive effect of cooperation on the development of innovation is especially significant for small firms. Copyright © 2015 ASAC. Published by John Wiley & Sons, Ltd.

Keywords: cooperation with users, innovation output, product innovation, radical innovation, incremental innovation, intensity/continuity of cooperation, firm size

Résumé
Cet article analyse les effets de la coopération R et D avec les utilisateurs et l'intensité/la continuité d'une telle coopération sur le rendement de l'innovation des entreprises — que cette innovation soit radicale ou graduelle. Il examine aussi l'effet modérateur de la taille des entreprises sur ces relations. Les résultats révèlent que la coopération avec les utilisateurs favorise le développement des innovations-produits radicales et graduelles. Par ailleurs, plus l'intensité/la continuité de la relation avec les utilisateurs est élevée, plus les innovations radicales sont susceptibles d'être développées. L'effet positif de la coopération sur le développement de l'innovation est particulièrement évident pour les petites entreprises. Copyright © 2015 ASAC. Published by John Wiley & Sons, Ltd.

Mots-clés : coopération avec les utilisateurs, rendement de l'innovation, innovation-produit, innovation radicale, innovation graduelle, intensité/continuité de la coopération, taille de l'entreprise

Economic activity takes place in a very complex, dynamic environment. Brusque changes in technology, customers, and competition mean that firms must engage in a continual process of renewal in order to survive, and in many cases they must seek new ways of carrying out their activities, leading to innovation. Thus, firms need to design and adopt organizational structures and strategies that facilitate knowledge creation and transfer (Chen, Huang, & Hsiao, 2010; Saldanha & Krishnan, 2012). Firms need not—and indeed should not—rely exclusively on their own research and development (R&D), and should instead assimilate external ideas in order to leverage the potential of their own innovation capabilities and investments (Chesbrough, 2003a; Chesbrough & Crowther, 2006; Dogson, Gann, & Salter, 2006; Lindic, Baloh, Ribière, & Desouza, 2011). This idea is the central point of the "Open Innovation" model (Chesbrough, 2003a, 2003b), which emphasizes the interactive nature of the innovation process. According to this model, the phenomenon of innovation is influenced by various actors both inside and outside the firm (Kaufmann & Tödtling, 2001; Lindic et al., 2011; Pérez Pérez & Sánchez, 2002; Romijn & Albu, 2002). Generally, and particularly in the case of complex and radical innovations, maintaining cooperation relationships with a diverse group of agents is beneficial to firms as it allows for assimilation of knowledge and ideas from different sources (Pittaway, Robertson, Munir, Denyer, & Neely, 2004).

External partners can include a large and diverse number of knowledge sources (suppliers, users and consumers, competitors, universities, etc.). A firm's choice of such sources will differ widely according to the type of partner (Bayona, García-Marco, & Huerta, 2003; Miotti & Sachwald, 2003; Santamaría & Rialp, 2007; Tether, 2002). The choice of

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partner is very important and should be consistent with the firm's aims and strategies (Arranz & Fdez. De Arroyabe, 2008; Hagedoorn, 1990; Miotti & Sachwald, 2003). In general, a firm's motivation to cooperate with others can be grouped into two categories: technology-related, such as technological complexity in industry or reducing R&D expenditures and risks, and those linked to the market, such as creating or entering new markets, launching new products, or internationalization (Bayona, García-Marco, & Huerta, 2001).

This second group of motivation is the main reason for cooperation with users when firms are pursuing commercial aims (Bayona et al., 2001; Hagedoorn, 1993; Santamaría & Rialp, 2007; van de Vrande, de Jong, Vanheverbeke, & de Rochemont, 2009), and it is this type of cooperation that forms the subject of the present study. Firms place increasing importance on users as a source of ideas because they need to obtain accurate and updated information about market needs, an aspect that has become crucial for any firm's success. Users can provide firms with information on new technologies and on the evolution of markets (Rothwell, 1994; Whitley, 2002), which could be useful for generating highly novel ideas (Amara & Landry, 2005; Meyers & Athaide, 1991). This type of cooperation also helps firms to identify unsatisfied needs, which in some cases users are unaware of (von Hippel & Katz, 2002), and also reduces the cost of developing and implementing new products and services (Herstatt & von Hippel, 1992; Lilien, Morrison, Searls, Sonnack, & von Hippel, 2002).

We aim to contribute to the debate about the effectiveness and usefulness of users in the development of different types of innovation. Due to the kind of knowledge wielded by users, the literature tends to indicate that cooperation with users is particularly geared towards achieving product innovations (Schreier, Oberhauser, & Prügl, 2007; Urban & von Hippel, 1988). However, few previous studies have analyzed the effects of this cooperation on the degree of novelty of this innovation type (Amara & Landry, 2005; Nieto & Santamaría, 2007). As a result, no definitive conclusions have yet been drawn as to whether cooperation with users favours the development of incremental and/or radical innovations; clarifying this issue was the first objective of this study.

We also consider the impact of the intensity/continuity of this cooperation. This variable provides information about the structure of the relationships with users, and can be useful when planning a cooperation strategy with these agents. Sporadic or continuous cooperation could affect the processes of knowledge transfer and, as a result, the degree of novelty of the resulting innovation. To the best of our knowledge, no previous study has been conducted to date that considers the relationship between these variables; thus, we present proposals for the design of cooperation strategies according to the type of innovation desired by the firm.

Finally, we analyze the moderating effect of firm size on: (a) cooperation with users and the development of radical and incremental product innovations, and (b) the intensity/continuity of that cooperation and the type of product innovation. Size is an important variable because it can determine the necessity as well as the possibility of implementing cooperation strategies with users in order to develop new products. Nevertheless, this probable moderating effect has not previously been studied.

This paper is structured as follows. We next review the literature on product innovation and cooperation with users. We then provide a description of the sample characteristics, the methodology, and the measurements of the variables. Following that we present and discuss our empirical findings, and we then report the main conclusions together with the study's most significant contributions, its limitations, and possible future lines of research.

Literature Review

The current worldwide situation of reduced innovation cycles and falling R&D budgets is forcing firms to seek external partners for their innovation activities in order to remain competitive (Gassman & Enkel, 2004). To achieve this goal, it is essential that firms acquire, share, and leverage accurate knowledge on current as well as future user requirements (Teece, 2007). Many studies have confirmed that users have now become one of the most important sources of innovation (Lilien et al., 2002; von Hippel, 1982). The traditional approach in which the marketing department should carry out market research and pass on the resultant data to the R&D department has been replaced by the need to involve users directly in product innovation processes (Holman, Kaas, & Keeling, 2003).

This new approach is based on the belief that users provide knowledge that contributes to the development of more successful, new products (Atuahene-Gima, 1995; Souder, Buisson, & Garrett, 1997), improves the market share, and strengthens the credibility of the firm's products (Tether, 2002; Tidd & Trewhella, 1997). Such knowledge also contributes to the completion of the innovation process with greater levels of efficiency compared with the use of other external sources (Bayona et al., 2003; Mason & Wagner, 1999; Santamaría & Rialp, 2007; Tether, 2002; Tranekjer & Søndergaard, 2013). In addition, user knowledge enhances perceived customer orientation and creates more favourable behavioural intentions (purchase, loyalty, positive word of mouth, etc.) and corporate attitudes among users who have not actively participated in the innovation process (Fuchs & Schreier, 2011). As a result, the active participation of users could be very valuable for the design and implementation of different types of innovation.

It should also be kept in mind that developing successful innovations requires two types of knowledge, which are

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sometimes costly to acquire, transfer, and use (Sánchez-González, González-Álvarez, & Nieto, 2009; Szulanski, 1996; von Hippel, 1994) and which can be divided into two different domains: the application domain versus the technology domain (Reid & Brentani, 2004). The first type of knowledge concerns market needs and the use of innovations. The second type of knowledge is necessary to understand and analyze the technical feasibility of a technology (Magnusson, 2009; von Hippel, 1994). Users normally possess the former and manufacturing firms the latter (Prügl & Schreier, 2006; Sánchez-González et al., 2009; von Hippel, 1994, 2005), which implies the existence of a large gap regarding the levels of know-how between the manufacturer and the user (Magnusson, 2009; Ziamou, Gould, & Venkatesh, 2012). This situation also implies that users would normally be better at solving need-based problems (product innovations), whereas manufacturers are better equipped to suggest promising solutions for technology-based problems (process innovations) (Poetz & Schreier, 2012). The existence of these information asymmetries provides a significant advantage for those manufacturers with access to users' knowledge, as they are therefore better placed to identify and exploit innovation opportunities that others may not be aware of.

In addition, although user participation in the innovation process began in the industrial field (Shaw, 1985; von Hippel, 1976, 1977a, 1977b), it quickly spread to consumer goods areas (Franke & Shah, 2003; Herstatt & von Hippel, 1992; Lüthje, 2004; Lüthje, Herstatt, & von Hippel, 2005). This suggests that users make important contributions to the development of products in the consumer goods as well as the industrial sectors (Miotti & Sachwald, 2003; von Hippel, 1976, 1988).

Nevertheless, product innovation can be analyzed from different perspectives. One approach is based on the nature of the innovation, which may lead to a distinction being made between radical and incremental innovations (Gatignon, Tushman, Smith, & Anderson, 2002); however, this often gives rise to considerable confusion. A radical innovation has been defined as one going beyond the boundaries of existing technologies (Freeman, 1982), or as the appearance of a new technical characteristic (Saviotti, Stubbs, Coombs, & Gibbons, 1982).[1] An incremental innovation, on the other hand, may be understood as a succession of quantitative changes in known parameters, or known as the incorporation in a particular product of technical characteristics already in use in similar products (Saviotti et al., 1982). However, bearing in mind that any product may be studied as an integrated system with several subsystems, change will be perceived as incremental or radical depending on the hierarchical level, which is taken as a reference within that technological system (Gatignon et al., 2002).[2]

In this respect, according to the literature, regardless of their source, most innovations are minor or incremental (Hollander, 1965; Knight, 1963), and those originating from users are no exception. Furthermore, although current growth rates are forcing firms to constantly explore different mechanisms and strategies that will enable them to develop radical innovations (Danneels & Kleinschmidt, 2001; Green, Gavin, & Aiman-Smith, 1995), it is very difficult to maintain a steady rate of major advances over long periods of time.

A solution to this problem may be found in seeking knowledge and resources outside the firm. Firms that are too heavily focused on their internal expertise may risk excluding alternative and potentially more successful and novel solutions (Martin & Mitchell, 1998; Stuart & Podolny, 1996; von Hippel, 1994). It has frequently been observed that when a highly novel innovation is sought, firms place their trust in external agents to access the required knowledge not available inside the firm (Amara & Landry, 2005; Romijn & Albu, 2002; Tether, 2002).

Having a diverse group of partners is a significant variable in achieving innovations (Becker & Dietz, 2004; Chesbrough, 2003a; Laursen & Salter, 2006), and a diversity of knowledge sources makes a noticeable contribution to the generation of highly novel ideas (Cohen & Levinthal, 1990; Nieto & Santamaría, 2007). Nonetheless, the type of partner chosen may to a large extent determine the kind of innovation obtained (Whitley, 2002), and this should be kept in mind when deciding which agents to collaborate with.

Information provided by users allows the firm to access highly valuable resources such as tacit complementary knowledge, information about new technologies, accurate information on market needs and their evolution, and so forth. (Rothwell, 1994; Whitley, 2002). Furthermore, access to such information has been greatly facilitated by the growth of socially driven emergent technologies, such as the Web 2.0 technologies, which emphasize end-user involvement and encourages the interaction and participation of these agents in innovation activities (Lindic et al., 2011; Patrick & Dotsika, 2007; Saldanha & Krishnan, 2012). Therefore, given all the contributions that users can make as sources of information, it is worthwhile promoting cooperation between individuals and manufacturers when the desired innovation is radically novel (Christensen, Olesen, & Kjaer, 2005). The more radical an idea, the more difficult it is to prove its value. However, involving different stakeholders (in this case users) in innovation activities will render it easier to demonstrate the idea's value to potential buyers (Lindic et al., 2011). Furthermore, in comparison with ideas provided by a firm's professional staff, users' ideas may sometimes score higher in terms of novelty (Poetz & Schreier, 2012),[3] although few empirical studies have shown this (Amara & Landry, 2005; Nieto & Santamaría, 2007). Amara and Landry (2005) have suggested that information from users is used more often to introduce innovations that are brand-new at a national and international level—so-called radical innovations—but less often when the innovation is merely new to the firm—so called

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incremental innovations. Nieto and Santamaría (2007) found that market-based information (suppliers and users) has a positive significant effect on achieving both types of innovation output.

Other lines of research have shown that when the manufacturing firm innovates alone, what it usually achieves is an incremental improvement on existing product lines (Anderson & Tushman, 1990; von Hippel, 2005), whereas cooperation with users gives rise to ideas for radical innovations in the form of new product lines (Lettl, Herstatt, & Gemuenden, 2006; Lilien et al., 2002; von Hippel, 1988), as well as incremental innovations (Hollander, 1965; Knight, 1963). On the basis of the empirical evidence cited above, we hypothesized:

> *H1: Cooperation with users favours the development of radical and incremental product innovations.*

Following from these ideas, our next step was to analyze whether the intensity/continuity of a relationship of cooperation with users also exerted an influence on the generation of radical and/or incremental innovations. It has been suggested that users will be more or less deeply involved in the innovation process depending on the type of innovation sought (Lüthje & Herstatt, 2004; Veryzer, 1998). If an incremental innovation is required, then minimal collaboration, such as interviews or questionnaires, with the user will suffice. However, radical innovation will inevitably entail much deeper and longer user involvement in the innovation process. The kind of knowledge users have obtained from their experience of using and handling a product and the knowledge base for radical ideas are both tacit. Thus, effective transfer of this knowledge from the user to the manufacturer requires continuous contact between them. Moreover, longer periods of collaboration could also help users acquire more technological knowledge (Hienerth, Pötz, & von Hippel, 2007), which may in turn lead to more radical ideas (Lüthje & Herstatt, 2004). Consequently, we hypothesized:

> *H2: The higher the intensity/continuity of cooperation with users, the more likely the development of radical rather than incremental innovations.*

Lastly, studies of both innovation and cooperation frequently cite firm size as a control variable. However, little is known about the capacity of small firms to establish relationships with external agents. It is therefore necessary to determine whether imperceptible differences exist between firms of varying sizes (Anand & Khanna, 2000).

Previous studies have reported conflicting evidence about the relationship between firm size and cooperation for innovation. On one hand, an internal knowledge base is to some extent necessary to assimilate new knowledge from outside (Cohen & Levinthal, 1990). And while it is relatively easy for large firms to fulfil this condition (Cohen, 1995), small firms may be unable to opt for collaboration because they lack the necessary prior knowledge. On the other hand, because innovation can be costly and risky for small firms, they are not, in general, actively involved in their own innovation. Nonetheless, SMEs may choose to cooperate with external partners in order to overcome their limited innovation resources and obtain access to the knowledge and skills necessary to implement innovation projects that would otherwise remain beyond their capabilities (Oliver & Blakeborough, 1998). Thus, it has been reported that small firms that innovate present a greater tendency to collaborate than large ones (Veugelers, 1997).

In the case of collaboration with users, the evidence regarding the direction of the relationship is also unclear. Some authors have found a positive size effect for vertical collaboration (Heijs, Herrera, Buesa, Sáiz, & Valadez, 2005; Santamaría & Surroca, 2004) and collaboration with users (Santamaría & Rialp, 2007), whereas others have reported a negative size effect both in terms of tendency towards vertical collaboration (Bayona et al., 2003) and collaboration with users (Bayona et al., 2003; Santamaría, García, & Rialp, 2002). Our study contributes to existing knowledge about the relationship between cooperation with users (and its intensity/continuity) and the degree of novelty of the resulting innovation, analyzing the probable moderating effect of a firm size on these relationships. The inconclusive findings regarding the relationship between firm size and cooperation with users led us to our third working hypothesis:

> *H3: Firm size moderates the effect of cooperation with users on the development of radical and incremental innovations.*

Sample, Methodology, and Variables

Sample

The study was based on data obtained from the Spanish Business Strategies Survey (SBSS), which has been compiled every year since 1990 by the Public Enterprise Foundation (Fundación Empresa Pública or FUNEP), a foundation that designs the survey, supervises its annual implementation, and maintains the database. The section quantifying innovative activities by firms provides information about technological activities and R&D expenditures from a live sample of Spanish firms (approximately 1,800 annual observations). One of its main advantages is that it offers information at the firm level, rendering it a suitable sample unit for this study.

The sample is representative of the total population of Spanish manufacturing firms, whilst also being random and stratified according to firm size (in terms of the number

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of employees) and industry sector. The variables referring to technological cooperation with several partners, including users, were introduced from 1998 and onwards.

In line with Fritsch and Lukas (2001) and Miotti and Sachwald (2003), the sample contains firms that replied to the survey with no distinction made between those that have innovated and those that have not. Such a distinction could lead to biased results, as indicated in previous studies on innovative behaviour in innovating firms (Bayona et al., 2003; Nieto & Santamaría, 2007; Tether, 2002).

Given that not all participating firms always provided complete information and that those involved varied over the period in question (owing to new firms joining, takeover processes, excision processes, etc.), we conducted this study using an incomplete panel from 1998 to 2005, made up of 1,685 firms, giving a total of 10,115 observations.[4] Moreover, because of the large number of firms providing information, we decided to establish a minimum of four years' participation in the survey, which is half of the period considered, in order to ensure some consistency in the follow-up of firms as well as to avoid different time-of-permanence patterns.

Unlike other studies on cooperation with users that have focused on specific firms or sectors, the sample used in this study enabled us to analyze the effects of this cooperation using data across a large sample of firms from different sectors.

Method

To analyze the effect of user cooperation on innovation output, we estimated different models, where both the dependent variables–radical innovation and incremental innovation–were dichotomous. In order to ascertain the influence of cooperation with users on product innovation, as had been done with the panel data, we used a Logit model with random effects, which allowed us to monitor the individual heterogeneity. To complement this, Logit models were applied to a cross section in 2005 in order to analyze the effect of the intensity/continuity of collaboration with users on these types of innovation output.

Variables

Dependent variables. The characteristics of the resulting product innovation were used as the criteria to determine the type of innovation. Two dummies were designed with the following characteristics:

- *Incremental innovation*: this variable took the value 1 when the innovation obtained by the firm i in a period t involved changes in the framework of the product, its design or presentation, and 0 if not.
- *Radical innovation:* this took the value 1 if the firm i claimed to have introduced some modification in a product's functions in the period t, and the value 0 otherwise.

Explanatory variables. Two dummy variables were included in order to analyze the user cooperation impact together with its intensity/continuity.

- *Cooperation with users*. This was a dichotomous variable that took the value 1 when a firm i claimed that there had been technological cooperation with users in a period t, and 0 if not. This variable was lagged one period, since regardless of type, the innovation development takes time and the effects of cooperation with users on innovation output will need to be observed after a certain time lapse. Additionally, since 1998 was the first year in which the SBSS recorded information on collaboration with external agents, the observations for that year were lost in the analyses, so we used a 7-year period, 1999-2005. This occurred because all of the sample variables were measured in the year 1999 except for our lagged cooperation with users, which was measured in the year 1998.
- *Intensity/continuity of cooperation with users*. A discrete quantitative variable was designed to record the number of times a firm i reported technological cooperation with users throughout the period under consideration (1998-2005); therefore, this variable had values ranging from 0 to 8.

Control variables. The control variables included the firms' structural characteristics (firm size and ownership structure) and indicators of the firms' innovation activities such as the technological sector intensity, R&D intensity, and R&D cooperation with the external agents. In order to control for the firms' situations during the analysis period, we included information regarding mergers and takeovers as well as the respective year in order to take into account the economic cycle. The measures used for the control variables are shown in Table 1.

Results

Cooperation with Users and Product Innovation Type

The results of the Logit models used to analyze the effects of cooperation with users on the development of product innovation are presented in Table 2. Models 1 and 2 contain the explanatory variable (cooperation with users) and the control variables (including the "size" variable). To Models 3 and 4, we added the interaction terms between cooperation with users and firm size. In all four cases, Wald tests indicated that the variables chosen were on the whole highly significant. In addition, the Likelihood Ratio test of *rho* showed that this parameter significantly differed from zero (values equal to 1804.50, 939.39, 1743.15, and 894.34, respectively, with p-value < 0.01), indicating the existence of individual heterogeneity. As a result, using random effects models is more appropriate.

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Table 1
Measures of Control Variables

Variable	Measure	Description
Size	Number of employees	Log of the number of employees
Technological intensity of the sector	Low-tech intensity	1 if the firm belongs to a sector of low technological intensity, 0 if not
	Medium-low-tech intensity	1 if the firm belongs to a sector of medium-low technological intensity, 0 if not
	High and medium-high-tech intensity	1 if the firm belongs to a sector of high or medium-high technological intensity, 0 if not
Export propensity	Export propensity	(Volume of exports/total sales) × 100
Ownership structure	Foreign capital	1 if the firm has foreign capital shares, 0 if not
Innovation capacity*	Total R&D intensity$_{(t-1)}$	(Total R&D expenditures/total sales) × 100 (lagged one period)
Coop. with other external agents*	Coop. with other external agents $_{(t-1)}$	1 if the firm has cooperated with universities/technological centres, suppliers or competitors over the previous year, 0 if not
Mergers and takeovers	Takeover	1 if firm has taken over another firm in period *t*, 0 if not
	Excision	1 if firm has suffered a breakup in period *t*, 0 if not
	Excised	1 if firm has joined the sample in period *t* as a result of a breakup, 0 if not
Economic cycle	Year in the period 1998 – 2005	1 if the observation was recorded in the "*X*" year within the period 1998–2005, 0 if not

*For the same reason as in the case of cooperation with users, the *R&D intensity* variable and the variable related to *cooperation with other external agents* were lagged one period because their effects on innovation output would need to be observed after a certain period of time. In addition, the observations for 1998 related to cooperation with other external agents were lost in the analyses, so a 7-year period was used, 1999–2005.

The findings confirm our hypotheses, since collaborative relationships with users were shown to significantly affect product innovation development. Considering the effects on the two different types of product innovations—radical and incremental—we observed a positive, significant influence in both cases, supporting *H1*. To derive the percentage of change in the likelihood of developing both types of innovation, we used the formula $(\exp[\beta] - 1) \times 100$ in Models 1 and 2. The values obtained show that, all else being equal, cooperation with users increased the likelihood of developing incremental and radical innovations by 54.81% and 38.82%, respectively.[5] These results are consistent with findings reported in other studies, such as those by Hollander (1965) or Knight (1963) in the case of incremental innovations, and those by Amara and Landry (2005), Lettl et al. (2006), or von Hippel (1988), among others, in the case of highly original innovations.

These findings demonstrate that although the generally held view is that the market information provided by these agents is more useful when dealing with incremental innovations, this type of relationship is also highly suitable when the aim is to identify highly novel innovations (Amara & Landry, 2005; Lettl et al., 2006; Tether, 2002). We therefore conclude that it is beneficial to promote cooperation with users, as it is extremely useful for achieving both small, incremental changes as well as radical innovations. In many cases, sophisticated users, such as *lead users* (Urban & von Hippel, 1988; von Hippel, 1986, 1988), have far greater experience in the field in which the desired innovation is to be developed than does the manufacturer because the manufacturer is simply concerned with selling products (Schreier & Prügl, 2008). Therefore, as other authors have suggested, collaboration with these agents can lead to much more

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Table 2

Logit Models for Analyzing the Effects of Cooperation with Users on Innovation Output (Radical versus Incremental Innovations)

Variables		Increm. Innov. (Model 1)	Radical Innov. (Model 2)	Increm. Innov. (Model 3)	Radical Innov. (Model 4)
Constant		-6.621*** (0.329)	-6.956*** (0.367)	-6.831*** (0.335)	-7.152*** (0.377)
Cooperation with users$_{(t-1)}$		0.437*** (0.131)	0.328** (0.142)	1.817*** (0.456)	1.404*** (0.490)
Size		0.655*** (0.060)	0.556*** (0.063)	0.709*** (0.062)	0.607*** (0.067)
Coop. with users × size				-0.260*** (0.082)	-0.198** (0.087)
Sector	High and medium-tech intensity	0.785*** (0.195)	0.667*** (0.200)	0.788*** (0.193)	0.661*** (0.198)
	Low-tech intensity	0.545*** (0.188)	-0.116 (0.202)	0.551*** (0.186)	-0.115 (0.200)
Export propensity		0.006** (0.002)	0.001 (0.003)	0.006** (0.002)	0.001 (0.003)
Foreign capital		-0.407** (0.162)	-0.055 (0.168)	-0.393** (0.161)	-0.052 (0.166)
Total R&D intensity$_{(t-1)}$		0.027** (0.013)	0.035*** (0.013)	0.025** (0.013)	0.033** (0.013)
Coop. with other external agents$_{(t-1)}$		0.890*** (0.123)	1.091*** (0.142)	0.863*** (0.123)	1.06*** (0.141)
Takeover		0.033 (0.263)	-0.031 (0.283)	0.064 (0.262)	0.002 (0.282)
Excision		0.171 (0.502)	0.269 (0.570)	0.182 (0.501)	0.279 (0.567)
Economic cycle	Year 99	0.875*** (0.133)	0.153 (0.161)	0.863*** (0.133)	0.151 (0.160)
	Year 00	0.858*** (0.132)	0.421*** (0.155)	0.0849*** (0.131)	0.418*** (0.155)
	Year 01	0.268** (0.132)	0.183 (0.155)	0.263** (0.131)	0.179 (0.155)
	Year 02	0.301** (0.132)	0.188 (0.155)	0.300** (0.132)	0.183 (0.155)
	Year 03	-0.242* (0.139)	-0.137 (0.163)	-0.243* (0.138)	-0.142 (0.163)
	Year 05	-0.298** (0.142)	-0.347** (0.172)	-0.300** (0.142)	-0.347** (0.171)
Wald test χ^2		502.19***	365.58***	512.43***	371.76***
Log likelihood		-3688.72	-2594.36	-3683.75	-2591.79
Number of observations		10115	10099	10115	10099
Number of groups		1685	1685	1685	1685
LR test of rho = 0; Value χ^2 (1)		1804.50 (0.000)	939.39 (0.000)	1743.15 (0.000)	894.34 (0.000)

*p < 0.1 **p < 0.05 ***p < 0.01
Reference variables: *medium-low-tech sector* and *Year 98*.
The variables *Excised* and *Year 04* have been eliminated due to collinearity problems.
Standard errors in brackets.

original and attractive innovations (Lettl et al., 2006; Morrison, Roberts, & von Hippel, 2000; von Hippel, 1986). Indeed, to achieve innovations of this type, it has been shown that a good alternative is to leverage users who are familiar with analogous markets, that is, those not belonging to the same sector for which the innovation to develop is planned, but which may present similar needs or trends (Hienerth, Pötz, & von Hippel, 2007; Lilien et al., 2002; von Hippel, 2005; von Hippel, Thomke, & Sonnack, 1999).

Intensity/Continuity of Cooperation with Users and Innovation Type

To complement the previous analyses, four models were set up to measure the effect of the intensity/continuity of cooperation with users on innovation output. The findings of these models are shown in Table 3. The dependent variables were again incremental (Models 1 and 3) and radical innovations (Models 2 and 4). As intensity/continuity of cooperation refers to the number of years the firm claims to have maintained technological cooperation with these agents during the period 1998-2005. The data for the dependent variables as well as the rest of the independent variables correspond to the final period (2005).[6] Because it is a cross section, the last two groups of control variables are not included. As in the previous Table, Models 3 and 4 add the interaction between the explanatory variable (intensity/continuity of cooperation with users) and firm size.

The results obtained show that when the intensity/continuity of the relationship with users was considered (as opposed to considering only the decision on whether to collaborate), the effects on output innovation were slightly different. In this case, the effect of cooperation continued to be positive and significant for both radical and incremental innovations. However, this effect was less significant in the case of incremental innovations compared to radical innovations ($\beta = 0.036$; $p < 0.1$ and $\beta = 0.104$; $p < 0.05$, respectively). In addition, for Models 1 and 2 we also calculated the percentage of change in the likelihood of obtaining both types of innovations using the formula $(\exp[\beta] - 1) \times 100$.

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Table 3

Logit Models for Analyzing the Effects of Intensity/Continuity of Cooperation with Users on the Likelihood of Obtaining Product Innovations (Radical versus Incremental Innovations)

Variables		Increm. Innov. (Model 1)	Radical Innov. (Model 2)	Increm. Innov. (Model 3)	Radical Innov. (Model 4)
Constant		-3.368*** (0.313)	-4.554*** (0.447)	-3.917*** (0.364)	-5.858*** (0.596)
Intensity/continuity of cooperation		0.060* (0.036)	0.104** (0.043)	0.422*** (0.116)	0.665*** (0.148)
Size		0.169*** (0.064)	0.218** (0.086)	0.300*** (0.075)	0.508*** (0.114)
Intensity/continuity of cooperation x size				-0.066*** (0.020)	-0.101*** (0.026)
Sector	High- and mediumtech intensity	0.365* (0.215)	0.346 (0.267)	0.348 (0.215)	0.291 (0.268)
	Low-tech intensity	0.685*** (0.208)	0.078 (0.291)	0.682*** (0.209)	0.042 (0.294)
Export propensity		0.005 (0.003)	0.007* (0.004)	0.005 (0.003)	0.006 (0.004)
Foreign capital		-0.408* (0.208)	-0.567** (0.261)	-0.352* (0.204)	-0.473* (0.254)
Total R&D intensity$_{(t-1)}$		-0.003 (0.013)	-0.001 (0.015)	-0.003 (0.013)	-0.002 (0.015)
Coop. with other external agents$_{(t-1)}$		1.21*** (0.206)	1.455*** (0.293)	1.092*** (0.205)	1.213*** (0.288)
Number of observations		1277	1262	1277	1262
Log likelihood		-530.190	-317.679	-524.868	-309.860
Pseudo R^2		0.117	0.180	0.126	0.200

*$p < 0.1$ **$p < 0.05$ ***$p < 0.01$
Reference variables: *medium-low-tech sector* and *medium size.*
Standard errors in brackets.

The results indicate that intensity/continuity had a greater positive effect in the case of highly novel innovations compared with less original ones. In other words, when the duration of the relationship with users increased by one period, *ceteris paribus,* the likelihood of obtaining incremental innovations increased by 6.18% points, whereas for radical innovations it increased by 10.96 percentage points, thus confirming *H2*.

These results can be explained by the type of information possessed by users. When users who have been collaborating for a short time provide ideas, their knowledge is usually limited to personal experience and they may lack the ability to develop new applications. However, long-term cooperation makes it possible to share information with the users during the innovation process. This in turn extends their knowledge base and gives them the opportunity to generate more original ideas or even discover unfilled needs of which they were previously unaware (Leonard & Rayport, 1997; von Hippel & Katz, 2002). This could all lead to totally novel products.

Several interesting conclusions can be inferred from these findings. It has been shown that cooperation with users has a marked positive effect on product innovations, whether radical or incremental. If the intensity/continuity of the relationship is also considered, it is clear that cooperation with users leads to their acquiring knowledge that is especially valuable when firms develop radical innovations. Long-term cooperation may enable users to acquire a level of technical knowledge (Hienerth et al., 2007; Lüthje et al., 2005) that they would normally lack, and which might be of more interest to firms when developing more radical innovations (Lüthje & Herstatt, 2004; Veryzer, 1998). Radical innovations require knowledge of a tacit nature that is difficult to transfer and acquire. Continued cooperation, on the other hand, provides firms with easier access to this type of user knowledge. In addition, a longer period of user involvement in the innovation process implies a greater effort on the part of the manufacturer to adapt their innovation processes to this situation; therefore, our results may be interpreted as showing that this effort will be made when the aim is to obtain highly radical innovations that compensate for such an investment.

Thus, our findings not only support *H2*, but also provide additional information that may be very useful for firms when planning their strategies for innovation and/or collaboration. Understanding these cause and effect relationships in advance enables firms to better tailor their decisions according to the type of innovation they want to develop.

Interaction Effects

Once we added the interaction terms, the variables representative of cooperation remained significant, confirming that the results are robust. Consequently, *H1* and *H2* are again supported. In *H3* we posited that firm size moderates the effect of cooperation with users on innovation output. *H3* was also supported; the four interaction terms were statistically significant. These results imply that size moderates the effect of cooperation with users on the

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likelihood of developing radical and incremental innovations (Models 3 and 4, Table 2), and also moderates the effect of intensity/continuity of cooperation in both cases (Models 3 and 4, Table 3). The negative signs of the β coefficients indicate that the positive effects of cooperation with users and its intensity/continuity on the likelihood of obtaining incremental as well as radical innovations are much stronger for small firms.

In order to accurately interpret these results, it is important to remember that when a model is nonlinear, as is the case here, the interaction effects cannot be evaluated by simply looking at the sign, magnitude, or statistical significance of the coefficients of the interaction terms (Chunrong & Norton, 2003). The interaction effect can have different signs for different observations. STATA 12 offers several approaches that can be used to explain continuous by continuous and categorical by continuous interactions. We used the command *margins* for this purpose.

Table 4 shows the margin values—that is, the difference between cooperating and non-cooperating firms—which may or may not be significantly different for different firm-size values. The results shown in this table indicate the cooperation/noncooperation difference for various size values (expressed in logarithmic terms), from the minimum to the maximum firm-size values (ln = 0.69 and ln = 9.19, respectively).

Models 1 and 2 in Table 4 show the interaction between cooperation with users and firm size. The results indicate that the difference between firms that cooperate with users and firms that do not was significant for certain size values for both incremental and radical innovations. As firm size increased, the significance of these differences and the value of the coefficients decreased, and the sign of the coefficients changed from positive to negative (see also Figures 1 and 2). Furthermore, in both cases, the positive effect of cooperation observed in previous sections disappeared for firms with more than 488 employees. Therefore, our results appear to support the idea that cooperation with users is less important for the development of any kind of innovation as firm size increases. In other words, the positive effect of cooperation with users on innovation development is higher for smaller firms. Moreover, in the case of incremental innovations, the coefficient was negative and significant for the maximum firm size value.

Table 4
Estimations to Explain the Moderating Effect of Firm Size

	Increm. Innov. (Model 1)	Radical Innov. (Model 2)	Increm. Innov. (Model 3)	Radical Innov. (Model 4)
	Cooperation with users$_{(t-1)}$ at:		Intensity/continuity of cooperation at:	
Size (Ln size)	dy/dx	dy/dx	dy/dx	dy/dx
=0.69 (min. value)	1.638*** (0.402)	1.267*** (0.433)	0.032*** (0.008)	0.026*** (0.006)
=1.19	1.507*** (0.363)	1.168*** (0.393)	0.031*** (0.008)	0.025*** (0.006)
=1.69	1.377*** (0.325)	1.070*** (0.353)	0.030*** (0.007)	0.024*** (0.005)
=2.19	1.247*** (0.288)	0.971*** (0.314)	0.028*** (0.007)	0.023*** (0.005)
=2.69	1.117*** (0.252)	0.872*** (0.276)	0.027*** (0.007)	0.022*** (0.005)
=3.19	0.987*** (0.218)	0.773*** (0.240)	0.025*** (0.007)	0.020*** (0.005)
=3.69	0.857*** (0.187)	0.674*** (0.206)	0.022*** (0.006)	0.018*** (0.004)
=4.19	0.727*** (0.160)	0.575*** (0.178)	0.019*** (0.006)	0.017*** (0.004)
=4.69	0.596*** (0.140)	0.477*** (0.155)	0.016*** (0.005)	0.014*** (0.004)
=5.19	0.466*** (0.131)	0.378*** (0.142)	0.012** (0.005)	0.011*** (0.004)
=5.69	0.336** (0.134)	0.279* (0.143)	0.007 (0.006)	0.008** (0.004)
=6.19	0.206 (0.149)	0.180 (0.155)	0.002 (0.006)	0.004 (0.005)
=6.69	0.076 (0.173)	0.081 (0.178)	-0.004 (0.008)	-0.002 (0.006)
=7.19	-0.054 (0.202)	-0.017 (0.207)	-0.010 (0.010)	-0.008 (0.008)
=7.69	-0.184 (0.235)	-0.116 (0.240)	-0.017 (0.012)	-0.016 (0.011)
=8.19	-0.315 (0.270)	-0.215 (0.276)	-0.024* (0.014)	-0.026* (0.015)
=8.69	-0.445 (0.307)	-0.314 (0.314)	-0.032* (0.016)	-0.037* (0.019)
=9.19 (max. value)	-0.575* (0.344)	-0.413 (0.353)	-0.040** (0.019)	-0.049** (0.024)
Number of obs.	10115	10115	1262	1262

*p < 0.1 **p < 0.05 ***p < 0.01
dy/dx for factor levels is the discrete change from the base level (models 1 and 2).
Dy/dx estimates the amount of change in the probability of obtaining radical or incremental innovations with a one unit change in "intensity/continuity of cooperation" whilst holding "size" constant at different values (model 3 and 4).
Standard errors in brackets.

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Figure 1. Average marginal effects of cooperation with users with 95% CIs

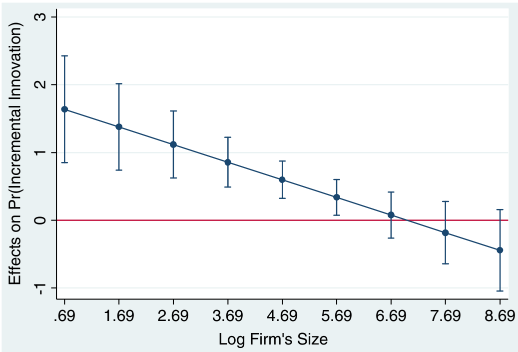


Figure 2. Average marginal effects of cooperation with users with 95% CIs

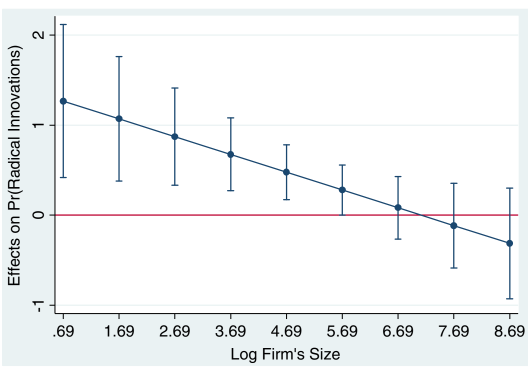


Figure 3. Average marginal effects of intensity/continuity of coop. With 95% CIs

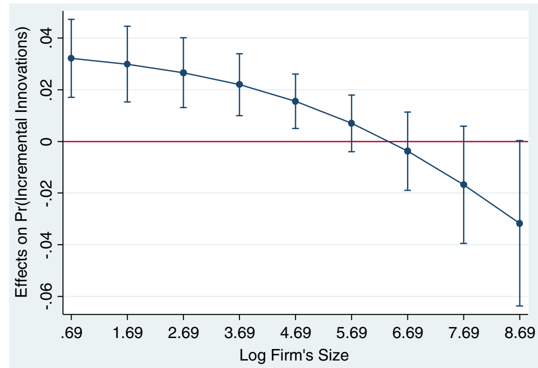
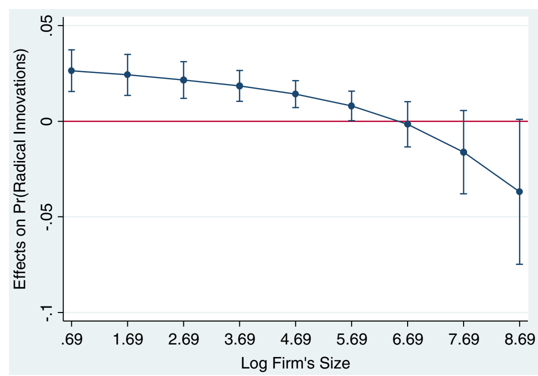


Figure 4. Average marginal effects of intensity/continuity of coop with 95% CIs



Models 3 and 4 in Table 4 present the interaction between intensity/continuity of cooperation and firm size. The general picture is quite similar to the previous one. In this case, the values obtained present the amount of change in the likelihood of innovation output with an increase of one year in the intensity/continuity of cooperation whilst maintaining size constant at different values. Once again, as size increased, the significance levels decreased and the sign of the coefficients changed from positive to negative (see also Figures 3 and 4). In this case, the significant positive effect of the intensity/continuity of cooperation disappeared for firms with more than 296 employees and became significantly negative for those with more than 3605 employees.

In the light of these results, we can conclude that is important to take firm size into account when analyzing the effect of cooperation with users on the development of radical and incremental product innovations. Our findings shed light on the previously inconclusive results reported for the relationship between cooperation and firm size, and support the notion that cooperation with these agents is more useful for small firms compared with large firms (Bayona et al., 2003; Oliver & Blakeborough, 1998; Santamaría et al., 2002).

Results of Control Variables

Below, we present a summary of the most important results obtained for the remaining model variables. Table 2

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shows that the sign and significance of all coefficients remained consistent across models for each dependent variable, and can therefore be interpreted in conjunction. For the two types of innovation, *size* was observed to have a significant, positive effect on all Spanish manufacturing firms. Large firms are better positioned to develop any kind of innovation compared with smaller firms because their level of internal knowledge is higher and they have a greater capacity to assimilate external knowledge, which may be lacking internally (Cohen & Levinthal, 1990).

As for the *technological intensity of the sector,* the β coefficients indicate that for both models of incremental innovations, belonging to high-tech, medium-high-tech, and low-tech intensity sectors has a positive, significant effect compared with belonging to medium-low-tech intensity sectors, and it is therefore difficult to draw conclusions. One explanation for this finding may be that these types of innovation are relatively easy for any firm to implement, regardless of their sector or technological base. On the other hand, it is clear that the development of radical innovations was significantly enhanced when firms belonged to a high-tech or medium-high-tech sector. This is to be expected if we bear in mind that in order to achieve innovations of this kind it is essential to have previous experience and a good knowledge base, which is only possible if the firm operates in a sector that forces it to be highly active and dynamic in innovation.

A firm's *export propensity* significantly enhanced the development of incremental product innovations. It seems obvious that international markets would lead to an increase in the level of competitiveness, which in many cases makes it necessary to improve product functions. However, Spanish manufacturing firms seem to lack the motivation to strive for highly novel innovations when they face the challenge of entering foreign markets, perhaps because the technological level of the Spanish productive sector is relatively lower than that of many other countries, whether European (e.g., Germany and France) or non-European (e.g., United States or Japan). Thus, Spanish firms are clearly at a disadvantage when competing on innovation, and seem to have opted for less radical innovations.

The presence of *foreign capital* also had a significant but negative effect on the development of incremental product innovations because when a firm is a subsidiary of a multinational, new product designs will be developed by the parent company. Therefore, multinational subsidiaries are not required to make the same effort towards innovation as firms that are wholly nationally owned and have to produce their own innovations (Blind & Jungmittag, 2004; Pini & Santangelo, 2005). As was expected however, *R&D intensity* acted as a stimulus for obtaining all types of innovation. Furthermore, the greater the past innovative capacity of a firm, the more likely it was to possess the resources and knowledge base to obtain further innovations of any type.

The variable representative of cooperation with other external agents during the previous year was observed to significantly enhance the development of product innovations, whether radical or incremental. These results are in line with the Open Innovation paradigm, which suggests that firms need not and indeed should not rely exclusively on their own R&D but should also use external ideas in order to leverage the potential of their innovation capabilities and investments (Chesbrough, 2003a, 2003b; Chesbrough & Crowther, 2006; Dogson et al., 2006; Laursen & Salter, 2006; van de Vrande et al., 2009).

It should also be noted that the macroeconomic conditions prevailing in some years favoured the development of different types of innovation output. The scarcity of available data has prevented further analysis of these findings, but such an analysis would certainly be very useful in identifying an explanation for these effects.

Turning lastly to Table 3, *size* had a positive and significant effect on both types of innovation. Regarding the *sector's technological intensity,* an unclear relationship was observed in the case of incremental innovations and was not significant in the case of radical ones. *Export propensity* had a significant influence in the case of radical innovations, and the presence of *foreign capital* had a significant albeit negative influence on both types. *R&D intensity* had no effect on the innovation result in either of the models and, as in the previous models, *cooperation with other external agents* had a significant and positive effect.

Discussion

Summary

The main objective of this study was to examine the effects of R&D cooperation with users on firms' innovation outputs. We considered the intensity/continuity of the user cooperation as well as the moderate role of the firm size with respect to this relationship. Although results have shown that this type of cooperation had an influence on the development of both radical and incremental innovations, the probability of obtaining radical innovations was greater when firms maintained cooperation over time. We conclude that small firms obtained a higher positive impact derived from user cooperation.

Applied Implications

The results of our study show that collaboration with users favours the development of both radical and incremental innovations. However, it must be stressed that the effect is greater in the case of radical innovations when the relationship is maintained over time. These findings have important implications for firms with regard to the design of their innovation strategies. Prior knowledge of the impetus this

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cooperation gives to the development of different kinds of innovation will make it easier to define a strategy in accordance with the desired innovation result. We have shown that sporadic collaboration with users is of interest when a firm's aim is to achieve product innovations, regardless of their novelty; however, long-term relationships with users are more likely to result in the development of radical innovations. Although the knowledge users initially possess is based on their experience of using products, if they are allowed to continually take part in the innovation process, they will be able to develop a higher level of technical skill and thus extend their knowledge base whilst increasing the possibilities of contributing to the design of more radical innovations.

Our results suggest that besides helping to achieve the desired innovation, the closer and more enduring the relationship with users, the more valuable their contributions for any intended innovation. However, permanent cooperation requires deeper involvement with users, and our results seem to suggest that this would be of particular interest if the firm can transform its effort into more profitable results (such as radical rather than incremental innovations). In addition, it is also worth bearing in mind that highly novel innovations may provide the key to establishing a competitive advantage, which is sustainable in the long term given that the knowledge required to put them into practice has a high tacit component. These characteristics reduce the likelihood of imitations, and as a consequence, the cooperating firm may establish the bases for a successful differentiation strategy that renders it more competitive.

Thus, whereas sporadic cooperation with users makes firms more competitive when they need to produce a practical, rapid response to the market, maintaining a permanent relationship over time is more geared towards attaining long-term economic results and improvements in a firm's competitive position in the market. Therefore, managers must consider not only the kind of innovation they wish to develop, but also the time horizon for the innovation outputs to become economic results. If the objective is short-term sales, sporadic cooperation with users is a good way to provide a quick response to market demands. However, if the aim is to create value and achieve a solid market position, it is worthwhile considering a permanent strategy of cooperation with users.

In order to maximize the benefits of using external knowledge, firms must implement new tools and practices for the development of innovations (Slowinski & Sagal, 2010). In the specific case of users, major advances have been made in the design of techniques and mechanisms that facilitate both sporadic and continuous interaction between firms and these agents. Social software, Web 2.0, and the semantic web are all technologies that increase the role of end users in the innovation process, attuning design tasks more closely to their needs (Patrick & Dotsika, 2007; Saldanha & Krishnan, 2012). These technologies have been used to create, for example, innovation communities, communities of practice, and user toolkits, and for broadcasting, the adoption of platforms, crowdsourcing, and so forth. (Slowinski & Sagal, 2010; van de Vrande et al., 2009; von Hippel, 2001), all of which greatly facilitate the transfer of information and the maintenance of close and continuous relationships with users. Many of these uses are based on costly technologies whose success depends on management capability (Lindic et al., 2011). Therefore, they are of particular interest to firms when they believe that such channels will enable them to achieve innovations that provide an advantage over their competitors (radical innovations). In addition, the more radical an idea, the more difficult it is to demonstrate its value and achieve sales. However, involving users in the innovation process makes it easier to transmit the idea's value to potential buyers (Lindic et al., 2011). Firms that promote user participation are associated with a positive corporate image, reflected in the market's general preference for companies of this kind (Fuchs & Schreier, 2011); managers can therefore leverage this strategy to create a competitive advantage in the marketplace.

This study also provides empirical evidence of a moderating firm-size effect on the user cooperation influence with regard to the development of innovations, supporting the notion that cooperation with users is particularly beneficial to smaller firms. What this study has demonstrated is that this positive effect occurs in firms up to a given number of employees, and that above this number, both cooperation with users and the intensity/continuity of the relationship no longer exert a significant influence. Indeed, in the case of very large firms, the effect becomes negative.

In light of our results, our basic recommendation would be for smaller firms to use cooperation with users as a source of information and knowledge. Such cooperation could be beneficial in the development of various product innovations, whether radical or incremental, because it would allow firms to redress their lack of internal capability. In addition, in the virtual environments in which firms currently work, the greater flexibility of small firms makes it easier for them to implement technologies such as those described above, based on Web 2.0 culture (Cook, 2008; Lee & Lan, 2007), rendering them more competitive with larger firms.

Contributions to Scholarship

The contributions of this paper to the previous literature are manifold. First, we analyzed the impact of cooperation with users on how radical the resulting product innovation is, with a distinction being made between radical and incremental innovations. Second, we examined the effect of the intensity/continuity of cooperation on these innovation outputs, which is a variable that to the best of our knowledge, has not been previously considered. Third, we investigated the moderating effect of firm size on the effects of cooperation with users on the likelihood of developing both types of

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innovation. Furthermore, in contrast to the bulk of research in this field, which has been based on case studies and specific sectors, in the present paper we used data from a large sample of firms from different sectors, thus implying better generalization of conclusions than found in previous studies (Gopal, Drishnan, Mukhopadhyay, & Goldenson, 2002). All these relationships have been tested using a sample of Spanish firms, a context in which cooperation with users has rarely been studied.

Limitations and Future Research Directions

Although the findings and conclusions to be drawn from this research should be interpreted with a number of limitations, mainly deriving from the data source we used, these nevertheless also indicate possible lines of future research. The first limitation is related to the measurement of product innovations, whether radical or incremental, through the use of dichotomous variables. It would be very useful to have further information on the multiple items implying product innovation in order to obtain more accurate results and ensure greater rigour in this regard. Although cooperation with users, measured as a dichotomous variable or via the duration of the relationship, served as the basis for this study, it would also be interesting to obtain further information on how these relationships were established and maintained. Future research could assess the effect of cooperation with users not only on the probability of achieving innovations, but also on how successful such innovations are in the market, in order to suggest more suitable competitive strategies for specific cases. Finally, because SBSS only provides information about the novelty of product innovations, results should be interpreted with caution. It would, however, also be valuable to see what would happen in the case of process innovations.

Notes

1 Dahlin and Behrens (2005) have defined radical innovation as meeting three conditions: 1) to be new, 2) to be unique, and 3) to have an effect on future technologies.

2 For example, a new turbine, which could solve a particular problem, may be deemed a radical innovation at that level, but the same change would be incremental if it were viewed from the standpoint of an aeroplane as a whole.

3 This analysis focuses on the usefulness of crowdsourcing initiatives among users compared to professional in-house activities for the generation of new product ideas (Poetz & Schreier, 2012).

4 The sample of chosen firms is representative of the total population of firms.

5 The hazard rates associated with cooperation with users in Models 1 and 2 (Table 2) are 1.458 ($1.458 = e^{0.437}$) and 1.388 ($1.388 = e^{0.328}$), indicating an increase in the likelihood of developing incremental and radical innovations of 54.81% ($54.81 = [1.458 - 1]*100$) and 38.82% ($38.82 = [1.388-1]*100$), respectively.

6 Except in the case of R&D intensity and cooperation with other external agents, which were lagged one period.

JEL Classifications: O31, O32

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