The importance of diverse collaborative networks for the novelty of product innovation

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Abstract

Competition today is driving firms to introduce products with a higher degree of novelty. Consequently, there is a growing need to understand the critical success factors behind more novel product innovations. This paper theoretically and empirically analyzes the role of different types of collaborative networks in achieving product innovations and their degree of novelty. Using data from a longitudinal sample of Spanish manufacturing firms, our results show that technological collaborative networks are of crucial importance in achieving a higher degree of novelty in product innovation. Continuity of collaboration and the composition of the collaborative network are highly significant dimensions. Collaboration with suppliers, clients and research organizations in this order have a positive impact on the novelty of innovation, while collaboration with competitors has a negative impact. The greatest positive impact on the degree of innovation novelty comes from collaborative networks comprising different types of partners.

Keywords: Product innovation; Degree of novelty; Collaborative networks; Technological partner; Spain

1. Introduction

Current competitive pressures are driving firms to introduce higher-quality products faster and more cheaply than competitors. The challenge is becoming increasingly important in today's rapidly changing world (Barnett and Clark, 1998). Meeting this challenge has led entrepreneurs, researchers and politicians to take a special interest in the different mechanisms and strategies that help to achieve innovations with high levels of novelty (Green et al., 1995; Danneels and Kleinschmidt, 2001).

There is growing interest in understanding the relationship between a firm's innovativeness and its different skills and characteristics (Freel, 2005). Levels of innovativeness and competitiveness, however, may not simply depend on skills that firms can find and exploit in-house, but on the effectiveness with which they can gain access to external sources of technological knowledge and skills (Kline and Rosenberg, 1986; Kogut, 1988). Technological resources, though, are not allocated efficiently in the market (Galende, 2006), making market transactions difficult to organize and opening the door to major relational problems (Pisano, 1990). Collaborative agreements—a solution between the organization and the market—eliminate some of these problems and allow partners to pool resources and exploit complementarities (Das and Teng, 2000; Belderbos et al., 2004a).

Networking reflects a recognition that technological innovations are less and less the outcome of an individual firm's isolated efforts (Fischer and Varga, 2002; Drejer and Jørgensen, 2005). Despite the increasing number of studies on the effects of networks on firms' technological activities (Miotti and Sachwald, 2003; Belderbos et al., 2004a; Faems et al., 2005; Hoang and Rothaermel, 2005), understanding their impact remains an important and under-researched topic in the literature on management innovation (Amara and Landry, 2005). Critical issues such as the selection of partners (Howells et al., 2004) and what type of networks favor innovation (de Man and Duysters, 2005) still require further research. While we have many papers that analyze

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the motives behind collaboration with different partners (Fritsch and Lukas, 2001; Miotti and Sachwald, 2003; Tether, 2002; Belderbos et al., 2004b), far fewer attempt to assess the impact of these partners on innovation (Miotti and Sachwald, 2003; Belderbos et al., 2004a).

The contribution of this paper is to analyze theoretically and empirically the role of different types of collaborative networks in the achievement of product innovations and their degree of novelty. We are specifically interested in answering the following questions:

(1) How does technological collaboration affect the degree of novelty of product innovation? And particularly, how do experience and continuity of the collaboration affect the degree of novelty?
(2) Is it possible to distinguish different effects depending on the type of collaborative network? In other words, is it possible to observe different trends according to type and diversity of partners?

The data used for our empirical study are from a longitudinal sample from the *Spanish Business Strategies Survey* (*SBSS*) for the years 1998–2002. This widens the traditional focus of previous studies on cross-sectional data and enables us to include dynamic aspects such as continuity of collaboration in the analysis.

In the following section, we develop some theoretical arguments to assess the impact of different types of networks on a firm's innovativeness. We describe our data and empirical models in Section 3 and our results in Section 4. The final section includes our conclusions and describes some managerial implications.

2. The impact of technological collaboration on the novelty of product innovation

2.1. Collaboration and innovation performance

The decision to collaborate is a variant of the make-or-buy decision, framed largely in terms of transaction cost economics (Hennart, 1988; Williamson, 1989). The exchange of intangible assets—such as technological assets—differs from the exchange of other assets on account of market imperfections linked to information-based resources (Pisano, 1990). This explains the internalization of innovation activities in cases where transaction costs are higher in the market than inside the firm. Internal organization costs can also spiral in cases where the innovation activities are performed under the hierarchy. For this reason, in-between options based on technological collaboration coexist between the hierarchy and market; these options can be highly efficient instruments to coordinate the innovation activity of the firm (Tripsas et al., 1995; Ulset, 1996). Firms, then, collaborate in order to acquire resources and skills they cannot produce internally when the risks of collaboration are not too great.

Alliances are common in many industries (Hagedoorn, 1993) and have become an important strategic tool (Hoang and Rothaermel, 2005). In technological activities, networks and alliances are the main sources of innovation (Von Hippel, 1988). One explanation for this is that joint R&D within well-organized networks enhances the innovation activities of the cooperation partners, thereby increasing the probability of realizing new products (Vonortas, 1997). In terms of innovation inputs, firms will look to their partners to provide the resources and technological capabilities they lack, maximizing firm value by effectively combining the partners' resources and exploiting complementarities (Kogut, 1988; Gulati, 1995). Consequently, the implementation of additional capabilities from outside should have a positive effect on innovation achievement (Becker and Dietz, 2004). Indeed, this is what Miotti and Sachwald (2003) and Faems et al. (2005) found in their research on the relationship between collaboration and innovation performance. The impact that collaboration may have, however, on the degree of novelty of the innovations achieved has not been analyzed yet.

Using data on innovative firms in the UK, Tether (2002) found that collaboration was more frequent among firms pursuing higher level rather than incremental innovations. This is because—as Amara and Landry (2005) found—firms introducing innovations with a greater degree of novelty are more likely to use a wider range of information sources to develop or improve their products. The greater underlying complexity of more novel innovations leads us to think that firms lacking the resources and knowledge necessary to achieve innovations of this type need partners that can supply them. Thus, it seems reasonable to hypothesize that firms that collaborate and have access to information from partners will be in a better position to achieve more novel product innovations.

2.2. Continuity of collaboration

The innovative capability of firms is largely dependent on cumulative knowledge built over many years of experience (Hoecht and Trott, 2006, p. 678). Network experience should be considered as an incremental learning process in two ways: (i) in terms of the technical learning of innovations and (ii) in terms of the management of collaborative ties (Powell et al., 1996).

Evolutionary perspective sees innovation as a dynamic process that develops over time with different paths and patterns for each firm (Dosi, 1988). In this process, the firm accumulates technological knowledge and shapes its resource base and capabilities for innovation. As a result of this path dependence, a firm's current innovation capabilities are determined by its history and experience (Nelson and Winter, 1982). Having participated in technological collaborations in the past, then, may be a hugely important dimension when it comes to analyzing current innovation capability, as it enables the firm to strengthen its resource endowment over time. Cohen and Levinthal (1990) coin the term "absorptive capacity" in this process-oriented context to explain the innovation capability of the firm; absorptive capacity is dependent on the firm's level of prior-related knowledge. It goes without saying that previous experience of collaboration makes up part of this knowledge.

Experience of collaboration will also have an effect on the management of collaborative agreements. The literature on organizational learning (Levitt and March, 1988) shows that firms repeatedly engaged in an activity learn from experience and accumulate knowledge. This argument is also valid in the context of alliances as firms learn how to manage these hybrid organizational forms by repeatedly engaging in them. This has a positive effect on subsequent alliance performance mainly because firms develop and establish routines, policies and procedures based on their experiences (Hoang and Rothaermel, 2005). Similarly, Powell et al. (1996) point out that once a firm begins to collaborate it will gain experience and develop a reputation as a partner. Whatever the source, firms need to sustain a pattern of interaction over time, building up a shared understanding and common ways of working together (Laursen and Salter, 2006).

All of the above leads us to argue that firms with experience of collaboration acquired through long-standing relationships are likely to enjoy better alliances, which in turn could have positive implications for innovation outputs. Amara and Landry (2005) established that sustained and intense interactions between firms and external sources of technical information increase the likelihood of this information being used to develop innovations with a higher degree of novelty. If we accept these arguments and define 'continuity' as the decision to follow a path of collaboration over time—with the same or different partners—we would expect continuity of technological collaboration to encourage product innovation, particularly its degree of novelty.

2.3. *Impact of different partners*

A firm's choice of a suitable technological partner is crucial. There are significant differences among the types of partners that can determine how the collaboration is managed and what kind of innovation can be achieved (Whitley, 2002). The specific characteristics and objectives of each type of partner lead us to expect that different partners will bring different results. In this sense, the decision to pool resources with another organization depends on weighing the risks against the expected results (Powell et al., 1996).

On the one hand, firms engage in joint R&D because it allows the utilization of external resources for their own purposes directly and systematically (Becker and Dietz, 2004). This is why the collaboration will be so much more efficient and fruitful if the firm has a partner with resources that complement its own and that are relevant to the innovation being sought. On the other hand, the disadvantages of joint R&D are caused by transaction costs (Williamson, 1989; Pisano, 1990), especially for coordinating, managing and controlling the activities of the different parties involved. These costs are linked to the specificity of the assets, asymmetric information, possible opportunistic behavior of one or more of the parties, and uncertainty about the appropriability of the rents produced by the assets involved (Tripsas et al., 1995). With this in mind, then, it would be interesting to go further and analyze the relationship between type of partner and degree of novelty of innovations.

Vertical collaboration (with clients and suppliers) allows a firm to gain considerable knowledge about new technologies, markets and process improvements (Whitley, 2002) and has a more significant impact on both product and process innovation (Miotti and Sachwald, 2003). Listening to clients, as well as suppliers, at early stages of product development should deliver innovation results more quickly (Liker et al., 1999). And, of course, the more novel the design, the more important such linkages are (Meyers and Athaide, 1991).

Fritsch and Lukas (2001) state that innovative efforts targeted at achieving product innovations are associated with client collaboration. Indeed, there is strong evidence that getting more market information from clients and, in some cases, direct involvement between clients and the development team leads to more successful new product development (Atuahene-Gima, 1995; Souder et al., 1997, among others). The advantages provided by clients and users as sources of information suggest that they could be used more frequently by firms when the innovations under development carry a higher degree of novelty (Amara and Landry, 2005). Tether (2002) also concludes that collaboration with clients could be beneficial when the aim is to develop more novel or complex innovations. Suppliers are also valuable sources of information to develop or improve products. In particular, collaboration with suppliers enables a firm to reduce the risks and lead times of product development, while enhancing flexibility, product quality and market adaptability (Chung and Kim, 2003).

The purpose of collaboration with competitors, in general terms, is to carry out basic research and establish standards (Gemünden et al., 1992; Tether, 2002; Bayona et al., 2003). Thus, firms are likely to work with competitors whenever they share common problems that are outside the competitor's area of influence—for instance, a regulatory change (Tether, 2002). Pre-competitive research programs can also provide the grounds for working with competitors (Tidd and Trewhella, 1997; Dussauge and Garrette, 1998). As Bayona et al. (2003) argued, however, this type of collaboration does not seem to be the most appropriate mechanism to achieve product innovations. We must remember that problems of information leakage and the risk of hold up are greater with competitors. This is likely to tip a firm's cost-benefit analysis against collaborating with competitors when the objective is to achieve product innovations and even more so when innovations with a high degree of novelty are the target.

Research organisations (ROs; Universities and Technological Institutes) have not traditionally focused on filling out the innovation processes of firms, but on providing them with new scientific and technological knowledge (Lundvall, 1992; Drejer and Jørgensen, 2005). This has changed, however, in the last few years and ROs have been under considerable pressure to move closer to industry for two main reasons. First, governments have encouraged these institutions to undertake more research directed at boosting the competitiveness of industry (Tether, 2002). Second, pressure on funding has pushed universities into greater collaboration with industry (Gibbons et al., 1994). In fact, several studies have documented the important role that universities and other research institutions have on technological innovation (Bozeman, 2000; Vuola and Hameri, 2006). Consistent with this interpretation, Belderbos et al. (2004b) highlight collaboration with ROs as the most effective way to achieve innovations intended to open new markets and segments.

All this encourages us to hypothesize that each type of partner will have a different impact on the degree of novelty of innovations, though establishing a priori which partners will have the most significant effect is difficult. It seems probable, however, that partnerships with clients and suppliers will be most relevant to achieving product innovation with a higher degree of novelty, while collaboration with competitors will have the weakest effect on product innovations.

2.4. Diversity of partnership network

Evolutionary economists highlight the role of searching for external options in helping organizations to find sources of variety and allowing them to create new combinations of technologies and knowledge (Nelson and Winter, 1982). Such variety provides opportunities for firms to choose among different technological paths (Metcalfe, 1994).

Recent work does suggest that using a wide range of external actors and sources should help the firm to achieve and sustain innovation (Chesbrough, 2003; Laursen and Salter, 2006). Indeed, Becker and Dietz (2004) explicitly state that collaboration with different partners on research and development raises the likelihood of achieving product innovation. Collaborating with different partners should substantially enhance innovation due to the amount and variety of knowledge to be shared, thereby enabling the alliance partners to fill out their initial resource and skill endowments. Increasing the number of parties involved, however, certainly brings with it greater risks of opportunistic behavior. Overall, though, knowledge diversity facilitates the innovative process by enabling the individual to make novel associations and linkages (Cohen and Levinthal, 1990).

Hoang and Rothaermel (2005) argue along these lines when they warn that the benefits of collaborating with the same partner over time should not be overstated. In fact, additional alliances with the same partner may provide only redundant information and could result in inertia (Gulati, 1995). Hoecht and Trott (2006) go further by highlighting the risk of becoming dependent on a partner (e.g., hold up).

All in all, then, a broader spectrum of experiences with diverse partners seems advisable (Anand and Khanna, 2000). We can, then, argue that the variety of partners (heterogeneous network) will have a more significant impact on the degree of novelty of product innovations than collaboration with only one type of partner (homogeneous network).

Table 1 summarizes the different research issues that are considered in this paper, along with the arguments and theoretical perspectives that underpin them.

3. Methodology

3.1. Sample and Data

The source for our empirical analysis is the *SBSS*. This is a firm-level panel of data compiled by the Spanish Ministry of Science and Technology and the Public Enterprise Foundation (*Fundación Empresa Pública FUNEP*) from 1991 to 2002. The *SBSS* covers a wide range of Spanish manufacturing firms operating in all industry sectors; approximately 1800 observations are available for each year. The sample is representative of the population of Spanish manufacturing firms; it is random and stratified according to firm size (in terms of the number of employees) and industry sector (Fariñas and Jaumandreu, 2000). The 1998 survey was the first to give information on firms engaged in technological collaboration, including partner specifications (i.e., type of partners). Consequently, our study is based on data for the period from 1998 to 2002.

Our final sample contains 6500 observations from 1300 firms that have remained in the survey during the 5-year period. It should be noted that we have followed Fritsch and Lukas (2001) and Miotti and Sachwald (2003) in including all the firms responding to the survey, with no distinction made between innovating and non-innovating firms. Such a distinction could give rise to biased results, as was acknowledged by earlier studies on the behavior of innovative firms (Bayona et al., 2001, 2003; Tether, 2002; Cassiman and Veugelers, 2002).

3.2. Variables

3.2.1. Dependent variables: high and low degree of novelty of product innovations

As Becheikh et al. (2006) point out, innovation measurement has always been a thorny task for researchers. Indeed, the question of innovation novelty has been

Table 1
Summary of theoretical arguments underpinning the expected relationships

Research issue	Theoretical perspectives	Main arguments	References
Collaboration and innovation performance	Transaction cost economics	Technological collaboration, as a hybrid mechanism between hierarchy and market, may be an efficient way of organizing innovation activities.	Hennart (1988); Williamson (1989); Tripsas et al. (1995)
	Resource based view	The firm looks to complete its resource portfolio and innovation capabilities by effectively combining the partners' resources and exploiting complementarities.	Kogut (1988); Gulati (1995)
Continuity of collaboration	Evolutionary theory	The firm's current innovation capability is determined by its history and experience.	Nelson and Winter (1982); Dosi (1988)
		Current knowledge is a function of the firm's level of prior related knowledge.	Cohen and Levinthal (1990)
	Organizational learning	The firm learns how to manage R&D collaborations by repeatedly engaging in these hybrid organizational forms. Thus, the firm learns and gains experience of collaboration.	Levitt and March (1988); Powell et al. (1996)
Impact of different partners	Resource based view	Partners contribute different resources and technological capabilities that improve and complement the firm's innovation capabilities.	Miotti and Sachwald (2003); Becker and Dietz (2004) among others
	Transaction cost economics	Difficulties of joint R&D are caused by transaction costs and risks. The choice of partner depends on calculations of risks versus return.	Pisano (1990); Powell et al. (1996)
Diversity of partnership network	Evolutionary theory	Diverse sources of knowledge allow the firm to create new combinations of technologies and knowledge. Such variety provides opportunities for the firm to choose among different technological paths.	Nelson and Winter (1982); Metcalfe (1994)
	Resource based view	Collaboration with different partners should enhance innovation due to the amount and variety of knowledge to be shared, thereby enabling the alliance partners to fill out their initial resource and skill endowments.	Becker and Dietz (2004); Gulati (1995)

handled in different ways by different authors (Lakemond and Berggren, 2006). We follow Liker et al. (1999) in using a criterion based on the characteristics of the product innovation to distinguish a greater or lesser degree of newness of the innovation. Consequently, we considered two dichotomous variables to gauge the degree of novelty of product innovation:

(1) HIGH describes innovations with a higher degree of novelty. It takes the value 1 when the firm declares new product functions resulting from innovation; otherwise its value is 0.
(2) LOW describes incremental product innovations. It takes the value 1 for innovations with a lower degree of novelty (e.g., product innovations involving changes in the design, presentation or any component); otherwise its value is 0.

3.2.2. Collaboration and continuity

Firms indicated whether or not they had engaged in technological collaboration, which allowed us to construct a dummy variable (COOP). We used a lagged variable here to allow for the delay between beginning to collaborate and obtaining results. To analyze the impact of continuity on collaborative agreements we constructed a model that attempts to explain the results obtained in the last year under analysis (2002). To do this we constructed the variable CONTIN to record the number of years a firm had participated in collaborative networks from 1998 to 2001. The variable can take integral values between 0 and 4, depending on the number of years the firm had been involved in collaborative networks.

3.2.3. Type of partners and diversity of networks

We distinguished four dichotomous variables to measure the effects of different types of partners: (1) collaboration with ROs exclusively (COOPRO); (2) collaboration with clients exclusively (COOPCLI); (3) collaboration with suppliers exclusively (COOPSUP); and (4) collaboration with competitors exclusively (COOPCOM).

We used these mutually exclusive variables for the estimates to avoid potential problems of multicollinearity and to capture the impact of each partner more clearly by separating it from the effects attributable to other partner types in heterogeneous networks. For firms that collaborated with more than one partner, we constructed the variable MULTPART. This dichotomous variable measures the heterogeneous nature of the collaborative network. It takes the value 1 if the firm has worked with partners belonging to at least two different categories; otherwise its value is 0. As with the variable COOP, these are all lagged variables.

3.2.4. Control variables

We included controls for firm-specific characteristics—size, R&D intensity and export intensity—and industry characteristics. In addition, year dummy variables have been included when using the 5-year period of the sample.

Size is measured by sales (SALES) and the square of sales (SALES2) to measure potential non-linear effects (Cassiman and Veugelers, 2002). In line with Becker and Dietz (2004), we included a control variable for the intensity of internal R&D (R&D)—the ratio of internal R&D expenditure to total sales—to explain the production of innovations. This variable captures the notion of absorptive capacity (Cohen and Levinthal, 1990) in so far as firms that conduct their own R&D are better able to use externally available information. A control variable for the firm's export activity (EXPORT)—the ratio of total exports to total sales—has also been introduced. The idea is to show that export and internationalization have a positive significant effect on innovation (Galende and De la Fuente, 2003; Romijn and Albadalejo, 2002).

Industry effects are other critical control variables for innovation. The classification proposed by Pavitt (1984) makes it possible to capture the impact of the industrial sector as well as the purely technological effects. This classification includes four dummy variables: (1) supplier-dominated sectors (SUPP-DOM); (2) scale-intensive sectors (SCALE); (3) sectors with specialized suppliers (SPEC-SUPP); and (4) science-based sectors (SCIENCE).

Table 2 contains the descriptive statistics and correlations of the variables used in this study.

3.3. Model specification

As both dependent variables—HIGH and LOW—are dichotomous, estimation models such as *logit* or *probit* (Aldrich and Nelson, 1984; Greene, 2000) would normally be appropriate. However, as the error terms of the two models are likely to be correlated, an extension of *probit* known as *bivariate probit* (Greene, 2000) is usually a more appropriate estimator. The *bivariate probit* model has the following specification (Breen, 1996):

$$Z_{i1} = \beta_1' x_{i1} + \varepsilon_{i1}; \quad y_{i1} = 1 \text{ si } z_{i1} > 0, \quad y_{i1} = 0 \text{ si } z_{i1} \leq 0,$$
$$Z_{i2} = \beta_2' x_{i2} + \varepsilon_{i2}; \quad y_{i2} = 1 \text{ si } z_{i2} > 0, \quad y_{i2} = 0 \text{ si } z_{i2} \leq 0,$$
$$(\varepsilon_{i1}, \varepsilon_{i2}) \sim N(0, 0, 1, 1, \rho).$$

This model produces estimates of the coefficient vectors $\beta 1$ and $\beta 2$ for the two equations, of ρ (the correlation between the error terms ε_{ij} of the equations), and of the standard errors for these parameters. We can then test if the correlation between the equations is statistically significant and decide whether the *bivariate* estimator is the most appropriate model. If this correlation is not significant, separate (*univariate*) *probit* estimation of the equations is preferable as *bivariate probit* is less efficient (Greene, 2000, pp. 853–854). The *bivariate probit* model was estimated using the Stata 8 routine, based on the method of simulated maximum likelihood. The difference between the specifications of each model lies in the explanatory variables (collaboration, continuity and type of network).

4. Empirical results

4.1. Collaboration and continuity

Table 3 provides estimates of the impact of collaboration—and its continuity—on the degree of novelty of product innovation. The ρ parameter is highly significant

Table 2
Means, standard deviations and correlations

	Mean	St.dev.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. LOW	0.128	0.335	1														
2. HIGH	0.124	0.330	0.14	1													
3. COOP1	0.337	0.472	0.19	0.30	1												
4. COOPRO1	0.077	0.266	0.04	0.02	0.40	1											
5. COOPCLI1	0.018	0.133	0.03	0.04	0.19	0.03	1										
6. COOPSUP1	0.038	0.191	0.10	0.06	0.28	0.05	0.02	1									
7. COOPCOM1	0.001	0.019	0.02	0.00	0.02	0.00	0.00	0.00	1								
8. MULTPART1	0.203	0.402	0.13	0.29	0.71	0.14	0.06	0.10	0.00	1							
9. R&D	0.005	0.015	0.12	0.23	0.34	0.04	0.06	0.04	0.00	0.36	1						
10. SALES	0.093	0.417	0.02	0.09	0.18	0.02	0.00	0.00	0.00	0.20	0.04	1					
11. EXPORT	0.198	0.264	0.11	0.14	0.36	0.09	0.03	0.07	0.00	0.33	0.18	0.14	1				
12. SUPP DOM	0.294	0.455	0.03	0.11	0.18	0.07	0.05	0.00	0.00	0.15	0.11	0.10	0.13	1			
13. SCALE	0.423	0.494	0.05	0.02	0.01	0.05	0.04	0.00	0.00	0.00	0.08	0.10	0.03	0.55	1		
14. SPEC DOM	0.151	0.358	0.01	0.12	0.11	0.02	0.05	0.02	0.00	0.13	0.19	0.02	0.09	0.27	0.36	1	
15. SCIENCE	0.130	0.336	0.02	0.06	0.10	0.05	0.07	0.02	0.00	0.07	0.07	0.00	0.03	0.24	0.33	0.16	1

This table does not show descriptive statistics and correlations of the variable CONTIN, because it is a combination of other variables and is only available for the year 2002.

in both models, signaling that the error structures of the equations are correlated. This suggests that the *bivariate* model is the correct specification. The Wald test also indicates high joint significance of the variables for both models.

We used Model 1 to test the impact of collaboration with data from the 5-year period (1998–2002). As expected, collaboration has a positive and significant impact on the likelihood of achieving product innovations, both with a low ($\beta = 0.575$, $p < 0.01$) and high degree of novelty ($\beta = 0.774$, $p < 0.01$). Moreover, comparing both coefficients shows us that the impact of collaboration on the degree of novelty is positive since its effect on the likelihood of achieving more novel product innovations is larger than that on achieving less novel product innovations.

The effect of the control variable for size on the likelihood of achieving innovations is only significant in the case of more novel innovations, while the variable for export intensity only has a positive and significant effect on the likelihood of achieving less novel innovations. Coherent with the idea of absorptive capacity, internal R&D exerts a positive and significant effect on the achievement of product innovations (both low and high degree of novelty). Of the control variables for industry, operating in a SUPP-DOM sector decreases the likelihood of achieving innovations with a higher degree of novelty. In the case of incremental innovations the effect is the opposite.

As expected, the results of Model 1 offer empirical evidence supporting the positive relationship between collaboration and product innovations, particularly innovations with a high degree of novelty.

We estimated Model 2 to test the impact of continuity of collaboration on product innovation. To identify the collaborative evolution of the firm we analyzed the observations for 2002, as well as taking into account the collaborative trend of the firm from 1998 to 2001. Continuity of collaboration has a positive and significant impact on the likelihood of achieving both more and less novel innovations, though the impact is larger for innovations with a greater degree of novelty ($\beta = 0.238$, $p < 0.01$). The effect of the control variables is similar to Model 1.

4.2. Effects according to type of partner and diversity of network

Table 4 presents the estimated results for the impact of each type of partner on the degree of novelty of product innovation. As before, the ρ parameter is highly significant in both models, implying that the *bivariate* model is the correct specification, and the Wald test indicates high joint significance of the variables for both models. These results suggest that the effect of collaboration depends on the type of partner.

Table 3
Bivariate probit analysis: the effects of collaboration and continuity on the degree of novelty

	Model 1		Model 2	
	LOW	HIGH	LOW	HIGH
Explanatory variables				
COOP1	0.575***	0.774***		
CONTIN			0.187***	0.238***
Controls				
R&D	2.626*	6.349***	6.089**	5.975**
SALES	0.007	0.547***	0.539	1.385**
SALES2	0.067	0.737***	2.435	6.518
EXPORT	0.281***	0.097	0.328*	0.037
SCALE	0.308***	0.105*	0.200*	0.093
SPEC SUPP	0.249***	0.399***	0.268*	0.298**
SCIENCE	0.212**	0.264***	0.189	0.211
Intercept	1.380***	1.801***	1.511***	1.422***
LR $\sim\chi^2$: $\rho = 0$	474.819***		47.736***	
Wald test of full model: χ^2	939.9***		302.30***	
Log pseudo likelihood	3339.53		764.71	
Number of observations (period)	5200 (1998 2002)		1300 (2002)	

Unstandardized regression coefficients are shown. Time controls are included in the model 1.
*$p < 0.10$; **$p < 0.05$; ***$p < 0.01$.

Table 4
Bivariate probit analysis: the effects of different types of partner and network diversity on the degree of novelty

	Model 3	
	LOW	HIGH
Explanatory variables		
COOPRO1	0.319***	0.231***
COOPCLI1	0.313**	0.276*
COOPSUP1	0.681***	0.502***
COOPCOM1	0.947	0.540***
MULTPART1	0.499***	0.756***
Controls		
R&D	2.692*	6.119***
SALES	0.028	0.544***
SALES2	0.118	0.751***
EXPORT	0.332***	0.153**
SCALE	0.287***	0.147**
SPEC SUPP	0.221***	0.408***
SCIENCE	0.179**	0.334***
Intercept	1.381***	1.772***
LR $\sim\chi^2$: $\rho = 0$	393.477***	
Wald test of full model: $\chi2$	4054.24***	
Log pseudo likelihood	3337.03	
Number of observations (period)	5200 (1998 2002)	

Unstandardized regression coefficients are shown. Time controls are included in the model.
*$p < 0.10$; **$p < 0.05$; ***$p < 0.01$.

Model 3 shows that suppliers are the partners with the most significant effect on both less ($\beta = 0.681$, $p < 0.01$) and more ($\beta = 0.502$, $p < 0.01$) novel product innovations. Collaboration with ROs also has a positive and significant impact on the likelihood of achieving product innovations; the impact is slightly greater on less novel innovations ($\beta = 0.319$, $p < 0.01$ versus $\beta = 0.231$, $p < 0.01$). Collaboration with clients is another factor that positively impacts on achieving both types of innovation, though it is less significant than the previous two ($\beta = 0.313$, $p < 0.05$ versus $\beta = 0.276$, $p < 0.1$). As expected, meanwhile, the results for collaborating with competitors revealed no significant impact on the probability of achieving incremental innovations and a negative and significant effect on the likelihood of achieving more novel innovations ($\beta = -0.540$, $p < 0.01$).

The variables we have considered so far measure the effects of homogeneous networks composed of only one type of partner. The variable MULTPART, however, addresses this limitation by identifying partner diversity and capturing the effect of heterogeneity of the network: the different situations where firms have collaborated with more than one type of partner. Our findings show that collaboration with diverse partners has the largest effect on the likelihood of achieving more novel innovations ($\beta = 0.756$, $p < 0.01$). The impact of partner diversity is smaller, though, when it comes to achieving less novel innovations. In this case it is the second most important factor ($\beta = 0.499$, $p < 0.01$), after collaboration with suppliers. Once again, the effect of the control variables is very similar to the previous models.

5. Discussion and conclusions

Economic growth is increasingly connected with the generation and application of new knowledge. Firms are subject to rapid technological changes and a constant need to innovate more quickly and in more novel ways than their competitors. These demands are what make communication, networking, and collaboration among knowledge producers and users so important.

This study finds that technological collaboration, its continuity and the diversity of partners impact positively on product innovation. This finding follows in the footsteps of earlier studies that showed that collaboration is a good method of improving firms' innovation capabilities (Miotti and Sachwald, 2003; Becker and Dietz, 2004; Faems et al., 2005). While collaboration plays an important role in generating new products, its role in achieving innovations with a greater degree of novelty is even more central. Given that resources and capabilities are needed to innovate successfully, and that these are not always available inside the firm and cannot be obtained efficiently in the market, collaboration offers a good solution to the problem (Das and Teng, 2000; Belderbos et al., 2004b). This is even truer when more novel innovations—which are complex and usually require additional information—are being sought, as getting hold of the necessary resources and knowledge is much more difficult.

Our results suggest that two aspects should be highlighted when considering how far collaboration contributes to the success of the innovation strategy. First, we have seen how experience in the management of alliances is reflected in better results in terms of degree of novelty of product innovation. The inherent difficulties of technological collaboration are gradually overcome as the firm learns to collaborate, thanks to the development of its alliance management skills and its reputation over time. If we also throw in the fact that the firm is accumulating knowledge from its partners, it will be better placed to innovate on account of the boost to its resource endowment and innovation capabilities.

Second, the choice of partners in the collaborative network may be a make-or-break decision for the success of innovation. The literature on technological collaboration has analyzed the effect of different types of partners on the innovation process (Miotti and Sachwald, 2003; Belderbos et al., 2004a). Our study moves beyond this by exploring the potential impact that different partners (clients, suppliers, ROs, and competitors) may have on the degree of novelty of product innovation. As far as we know, Amara and Landry (2005) are alone in providing empirical evidence on this, though their study focuses on the effect of different sources of information on the novelty of innovations. Our findings show how diversity in the make-up of collaborative networks favors innovation novelty more than collaboration with a single type of partner does. Being integrated in a heterogeneous network promotes access to diverse sources of information and enables firms to transfer and apply that knowledge. When this happens firms find themselves in a better position to achieve more novel innovations.

By considering the individual impact of each type of partner, our results show that suppliers are the single partners who most impact on the achievement of product innovations with less or more degree of novelty, followed by clients and ROs in order of importance. This is consistent with the arguments set out in previous studies. Langfield-Smith and Greenwood (1998) state that this type of collaboration helps to develop new products and processes, improves quality and productivity, and reduces lead times. Peters and Becker (1998) continue this theme by pointing out that collaborating with suppliers helps to bring products to market more quickly.

These results are not overly surprising if we bear in mind Spanish firms' long history of collaborating with suppliers and clients and lack of tradition of working with ROs. This evidence backs COTEC's (Fundación para la innovación tecnológica, Spain, 1999) opinion that Spanish firms consider ROs to be valuable sources of information to acquire basic knowledge, but lack confidence in the potential of these institutions to achieve radical innovations. This situation is mirrored in a large number of

European countries, where collaboration between private firms and public research institutions is much less frequent than firm-to-firm collaborations (DeBresson et al., 1998; Drejer and Jørgensen, 2005). Authors such as Drejer and Jørgensen (2005) make this point when they stress the need for policy-makers to promote this type of public–private collaboration. Our analysis also reveals that this relationship may be highly advantageous when it comes to improving innovation performance.

Collaborating with competitors turns out to be the least fruitful way of producing innovations. In fact, its impact is negative for more novel innovations. This result is plausible as developing a more novel product may be crucial for maintaining a competitive advantage over the competition. Thus, fear of helping a rival and lack of trust—given the increased risk of opportunistic behavior—are what stop competitors from being seen as an instrument to achieve more novel innovations. Competitors, however, may be good partners when there are other objectives. Recent studies (Tether, 2002; Bayona et al., 2003) that highlight performing basic research and establishing standards as reasons for collaborating with competitors make this clear.

In summary, the main contribution of this paper is to shed light on how collaboration and the composition of networks can explain or facilitate product innovation achievements as well as increase their degree of novelty. Firms improve their knowledge base by looking for suitable partners to collaborate with. Collaborative R&D opens firms' eyes to the need to access ideas and information from a variety of sources (diversity) to improve innovation performance. In addition, experience (continuity) of collaboration is necessary to manage a diverse portfolio of ties.

Our findings may provide useful managerial implications. In the current competitive environment the achievement of innovations with a greater degree of novelty is becoming increasingly important. In this paper we show that different types of collaborative networks can be a critical success factor to achieve such innovation. The practical value of these findings lies in a better understanding of how the configuration of a collaborative network affects its own performance. Therefore, managers must be aware of the importance of partner suitability, network heterogeneity and continuity of collaboration strategy as these are determining factors for superior alliance performance in innovation and the further development of the firm's competitive advantage.

From the point of view of policy-makers—given the positive effect of collaborative networks—the need for mechanisms that promote the creation of technolo gical networks is clear. There are indeed national and international programs (e.g., PROFIT in Spain, ESPRIT or EUREKA in Europe, and SEMATECH in the USA) whose mission is to support R&D collaboration, either through funding or by setting up research consortia.

This work is not free from limitations. It would be desirable to have more complete information on the degree of novelty of the innovations—either via a richer category of novelty or via quantitative measures of innovation performance. Future studies may extend the instrumentalization of this concept, using other methodologies and sources of information. The inclusion of process innovations in order to offer a more comprehensive picture of firms' innovation processes may also offer another avenue for future research. From the point of view of collaboration, it would also be interesting to analyze the dimension of depth (how deep or close the collaboration with partners is).

Lastly, we would like to point out the generalizability of these findings. Although our data are limited to Spain, we have already noted that the patterns of collaboration are similar to those of the majority of European countries. Despite this, however, we should make some qualifications. The negative effect of competitors on innovation results may be due to the traditional profile of Spanish industry. As previously mentioned, this type of collaboration is usually more directed at the basic research typical of the high technology sectors. It seems reasonable to postulate that in a heavily science-based economy the impact of competitors would be more positive. An in-depth analysis of both high- and low-technology sectors would make it possible to see if significant differences exist between them.

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