UNIVERSIDAD CARLOS III DE MADRID working papers

Working Paper 06-66
Business Economics Series 20
November 2006

Universidad Carlos III de Madrid
Calle Madrid, 126
28903 Getafe (Spain)
Fax (34-91) 6249607

TECHNOLOGICAL COLLABORATION: BRIDGING THE INNOVATION GAP BETWEEN SMALL AND LARGE FIRMS

María Jesús Nieto [1] and Lluís Santamaria [2]

Abstract

This paper analyses technological collaboration as an input to the innovation processes of SMEs. Technological collaboration may be a useful mechanism to offset some of the weaknesses in SMEs' resource endowments and bring their innovation capabilities closer to that of their large counterparts. The results, based on a large longitudinal sample of Spanish manufacturing firms, show that technological collaboration is a critical factor in improving the capabilities and innovativeness of SMEs. While a general bridging of the gap between the innovativeness of SMEs and large firms was observed, the most significant advance was in product rather than process innovations.

Keywords*:* SMEs, technological collaboration, product innovation, process innovation

JEL code: O31; O32; L24

[1] Sección de Organización de Empresas. Tel: +34-91-6245826.; fax: + 34-91-6245707. *E-mail address:* *mnieto@emp.uc3m.es*
[2] Departamento de Economía de la Empresa. Tel.: +34-91-6248643; fax: + 34-91-6249607. *E-mail address:* *lsantama@emp.uc3m.es*

1. Introduction

Most current economies are largely composed of small and medium-sized enterprises (SMEs). In European Union, for instance, SMEs make up 99% of industry and account for more than 70% of employment[1]. Their innovative capability is a key driver of sustainable competitive advantage in today's rapidly changing markets. This situation has fuelled growing concern among managers and policy makers and has led to a strong commitment to use policy initiatives to support innovation within SMEs (Hoffman et al., 1998; Jones and Tilley, 2003).

This concern is also apparent in academic circles. In the economics of innovation and technological change literature, the relationship between firm size and innovation activity has received a good deal of attention (see Cohen, 1995; for an overview). The Schumpeterian debate over which firms – large or small – are more able and more likely to innovate is one of the oldest in political economics (Harrison, 1994), and has lost none of its relevance for today's world. Numerous studies have attempted to help boost the innovative capacity of smaller firms by trying to explain differences in innovation activity and pin down the key success factors (Acs and Audretsch, 1988a, b, 1990; Kleinknecht and Reijnen, 1991; Nooteboom, 1994; Rothwell and Dodgson, 1994; Bougrain and Haudeville, 2002; Narula, 2004; Hewitt-Dundas, 2006; among many others).

In general we can argue that SMEs have behavioural advantages over large firms, which in turn have material advantages over SMEs (Rothwell, 1989; Rothwell and

Dodgson, 1994). SMEs, however, tend to be less innovative than large firms and to dedicate less resources to the acquisition of external technologies (Bougrain and Haudeville, 2002). This is clearly the case in Spain. In our representative sample of Spanish SMEs only 36% claim to have introduced innovations compared to 65% of the large firms.

Despite the increasing attention being given to the role of SMEs and innovation, however, this is still an area that is under-researched (Edwards et al., 2005; O'Regan et al., 2006). Many of the weaknesses of small firms when innovating can still be observed and many questions remain unanswered. The research of Hewitt-Dundas (2006) took up this issue and examined the resources and capabilities that firms perceive to be constraining their innovation activity. One of the most conclusive findings of this research was that the lack of external partners was an important barrier to undertaking product innovation for small firms – this is a major difference between small and large firms. Although there is research that stresses the role of strategic alliances and collaboration as alternatives to undertaking innovation activities (Love and Roper, 1999; Rogers, 2004; Nieto and Santamaria, 2007), we need to delve more deeply into the specific role that innovation networking plays as a possible determining factor in developing the innovation capacity of SMEs (Edwards et al., 2005).

This study sets out to discover if collaboration, specifically technological collaboration, enables SMEs to overcome their lack of resources and capabilities, and thus boost their innovativeness. We consider that small firms have weaknesses that put them at a disadvantage compared to large ones when it comes to innovation and

---

[1] Based on data from the "Informe 2003/7 del Observatorio de la PYME Europea" elaborated by

that collaboration can go some way to levelling the playing field. We shall then proceed to analyse the potential effect of collaboration on innovation outcomes (in terms of process and product), and lastly go on to reveal if innovation networking can close the gap between SMEs and large firms.

In the next section we place our research in the context of the classic debate over firm size and innovation, paying particular attention to the innovation strengths and weaknesses of SMEs. After this we review the existing literature on technological collaboration, innovation and firm size. In the section on methodology we describe the data, variables and statistical techniques used. We then go on to analyse our results. The final section contains a discussion of the results and our conclusions.

2. Conceptual Foundations

2.1. Innovation strengths and weaknesses of SMEs

The large body of theoretical and empirical research on firm size and innovation reveals the interest there is in this relationship (see, for example: Acs and Audrestch, 1988a, b, 1990; Cohen, 1995). The contradictory nature of both the conceptual and empirical findings, however, does not provide clear guidance on what to expect in general (Stock et al., 2002: pp. 541). Although it has not been possible to establish a strong relationship between firm size and innovation *per se*, some empirical research has suggested that small and large firms have different determinants of innovation efforts (Van Dijk et al., 1997; Rogers, 2004) and do not pursue the same types of

---

Dirección General de la Pyme (Spanish Government). Firms with fewer than 200 employees are classified as SMEs.

innovation (Nooteboom, 1994; Vossen, 1999; Cohen and Klepper, 1996; Fritsch and Meschede, 2001).

These differences in innovation activity and innovation results can be explained by the various advantages traditionally ascribed to large and small firms. The main relative strengths of SMEs lie in behavioural advantages, while those of large firms reside in their resource advantages (Rothwell, 1989; Rothwell and Dogson, 1994). Smaller firms generally enjoy internal conditions that encourage innovativeness, such as entrepreneurship, flexibility and rapid response (Schumpeter, 1942; Penrose, 1959; Lewin and Massini, 2003). Shorter and more informal lines of communication allow SMEs to take decisions more quickly than large firms (Nooteboom, 1994; Narula 2004). Small firms may also find it easier to adjust employee incentives to provide optimal innovative effort thanks to their advantages in resolving agency problems (Holmstrom, 1989; Zenger, 1994). In addition, the closeness of SMEs to the market makes them faster at recognising opportunities (Rogers, 2004).

On the other hand, the relative weaknesses of small firms compared to large ones lie in the constraints they face on gaining access to critical resources and capabilities for innovation (Hewitt-Dundas, 2006). The advantages of scale and scope provided by the size of large firms make them better equipped for innovations that require large and specialised teams or sophisticated equipment (Cohen and Klepper, 1992). When licensing methods are not available, then, large firms have a greater incentive to pursue all types of innovation (especially process innovation), as their higher sales volumes allow them to spread the fixed costs of innovation over a larger sales base (Cohen and Klepper, 1996).

Large firms, in addition to their advantages of scale and scope, are more likely to possess the experience and financial resources required for capability development than small firms (Woo and Cooper, 1981). Studies of SME growth and innovation consistently stress that a lack of finance is the most important constraint on innovation (Vossen, 1998). Therefore, because of their lack of financial resources, SMEs are often disadvantaged in their ability to gather technological resources (Bougrain and Haudeville, 2002).

SMEs are also usually at a disadvantage when it comes to intangible resources, as they have access to a smaller range of knowledge and human capital skills than large firms (Rogers, 2004). While it is true that SMEs may be more efficient at retaining and motivating specialists through performance-contingent contracts (Zenger, 1994), they face greater problems to recruit highly skilled staff (Barber et al., 1989) and tend to invest less in on-going employee training than larger firms (Brown et al., 1990).

In summary, then, one would expect SMEs to face more constraints on their resource endowments and – despite their behavioural advantages – more obstacles to innovation than large firms. SMEs, however, have alternatives to internal development that may enable them to bridge the resource gap that exists with large firms. Searching for complementary resources outside of the firm through network relationships can be an efficient way to build up resource endowments (Choudhury and Xia, 1999; Gulati et al., 2000).

2.2. Improving innovation capabilities through technological collaboration

According to Duysters et al. (1999), alliances have shifted from being regarded as a peripheral aspect to a cornerstone of the firm's technological strategy. In fact, over the last two decades there has been a tremendous increase in the use of external networks by firms of all sizes (Hagedoorn, 1996, 2002). Their usefulness has been examined in various studies that have included *networking* to capture a contextual determinant of innovation. Becheikh et al. (2006) found that in studies including a variable to capture this *networking effect*[2], the relationship between innovation outcomes and networks (or external interactions with customers, suppliers, universities, research centres and other actors of a firm's environment) was either positive or insignificant, but never negative.

A possible explanation for this increase, apart from the declining costs of monitoring and exploiting networks, is the growing need for firms to possess multiple technological competences (Granstrand et al., 1997). In this way, technological collaboration is seen as a strategic mechanism to achieve several objectives (Cassiman, 1999; Hagedoorn et al., 2000; Bayona et al., 2001; Caloghirou et al., 2003; among others): 1) to increase the technological capabilities of the firm; 2) to gain access to new markets and to exploit new business opportunities; 3) to have access to public funding; and 4) to complete the innovation process.

Regarding small firms, external networks specifically create unique benefits and challenges, as a growing number of studies suggest (Powell et al., 1996; Zahra et al., 2000; Sarkar et al., 2001). Most recently, Hewitt-Dundas (2006) found that while a lack of partners for innovation had a negative impact on the ability of small firms to undertake innovation, it did not have a significant effect on the probability of innovating in larger firms. Her resource-based interpretation of this finding is that the external resources and capabilities that small firms can access through external

[2] In their survey of empirical research on innovation from 1993 to 2003.

innovation partnerships may provide them with the stimulus and capability to innovate that they would not otherwise have.

SMEs, then, have to use alliances astutely to overcome barriers to growth imposed by absolute limits to resources (Ahern, 1993; van Dijk et al., 1997). Networks allow SMEs to receive and decode flows of information. They reinforce SMEs' competitiveness by enabling them to access new knowledge, sources of technical assistance, expertise, sophisticated technology and market requirements; they also strategically reduce the irreversibility costs of the innovation process (Bougrain and Houdeville, 2002; Freel, 2005).

Rogers (2004) points out that SMEs may rely more heavily on external knowledge networks as an input to innovation than do large firms. Given that small firms seem to have potentially more to gain from innovative partnerships than larger firms, the very success of SMEs vis-à-vis their larger competitors may be due to their ability to use external networks more efficiently (Nooteboom, 1994; Rothwell and Dodgson, 1994).

Based on the preceding discussion, we conclude that technological collaboration may be a good way of strengthening and complementing the resource endowments and capabilities of SMEs and of improving their innovativeness. In the following sections we shall empirically examine how collaboration – along with other factors – helps to bridge the innovation gap between SMEs and large firms.

3. Methodology

3.1 Sample and Data

The source for our empirical analysis is the *Spanish Business Strategies Survey* (*SBSS*). This is a firm-level longitudinal survey 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 1,800 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 and industry sector (for more information on the sample see Huergo and Jaumandreu, 2004). 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 6,500 observations from 1,300 firms that have remained in the survey during the five-year period.

3.2 Model specification

We have taken the difficulties SMEs face to obtain the same innovation outputs as their larger counterparts as our starting point to specify the different models. Furthermore, technological collaboration – along with internal resources – is a key input to firms' innovation processes. Therefore, we specified two series of models to measure the impact of collaboration as an input to innovation processes on SMEs and large firms:

(1) The first series of models examine the relationship between SMEs and innovation outputs, in terms of process and product innovations. This relationship is analysed first by considering the category of SME and then by introducing the interaction effect between being a SME and to be engaged in technological agreements. These models will enable us to recognise how being a SME affects the probability of innovating, and if this *a priori* negative effect varies among the firms that collaborated.

Model 1A:

$$Innovation = \beta_0 + \beta_1 \cdot SMEs + \beta_2 \cdot Int\_resources + \beta_3 \cdot Industry + \varepsilon$$

Model 1B:

$$Innovation = \beta_0 + \beta_1 \cdot SMEs + \beta_2 \cdot SMEs \cdot Collaboration + \beta_3 \cdot Int\_resources + \beta_4 \cdot Industry + \varepsilon$$

(2) The second series of models look at how technological collaboration acts as an input to improving the innovation capacity of the firm. In this case, different models will be specified for a sub-sample of SMEs and a sub-sample of large firms.

Model 2A (Sub sample of SMEs):

$$Innovativeness\_improvement = \beta_0 + \beta_1 \cdot Collaboration + \beta_2 \cdot Int\_resources + \beta_3 \cdot Industry + \varepsilon$$

Model 2B (Sub sample of large firms):

$$Innovativeness\_improvement = \beta_0 + \beta_1 \cdot Collaboration + \beta_2 \cdot Int\_resources + \beta_3 \cdot Industry + \varepsilon$$

Dependent variables*:*

We considered innovation output indicators to estimate the first series of models. These were measured using two variables:

(1) *Product Innovation (PRODUCT-INN).* This is a dichotomous variable that takes the value 1 when the firm declares at least one product innovation in the survey year; otherwise its value is 0. A firm was considered to have achieved a product innovation if it replied positively to at least one of the following items: i) the product incorporated new functions; ii) the product had a new design and

appearance; iii) the product incorporated new materials and/or iv) the product incorporated new components.

(2) *Process Innovation (PROCESS-INN).* This is a dichotomous variable that takes the value 1 if the firm has achieved at least one process innovation in the survey year; otherwise its value is 0. A firm was considered to have achieved process innovations when: i) new machinery had been introduced; ii) new methods of organising production had been introduced; or iii) both of the above occurred.

To estimate the second series of models we had to construct an indicator that captured some type of improvement in innovation capacity. This improvement was measured via two variables (see the Appendix for a detailed description of their construction):

(1) *Improvement in product innovation capability (IMPROV-PD).* It is a dichotomous variable that takes the value 1 when the firm '*improves*', going from being a non-innovating firm in t-1 to an innovating one in t. It also takes the value 1 when the firm '*keeps*' its condition of innovating firm. It takes value 0 if the firm's situation has not changed and it continues to have no product innovations in year t. It also takes the value 0 when the firm "*gets worse*" going from being an innovating firm in t-1 to a non-innovating one in t.

(2) *Improvement in process innovation capability (IMPROV-PC).* This dichotomous variable is constructed in the same way than previous one, but considering process innovations instead of product innovations.

Independent and control variables

Given the objectives of our research, we tried to measure the potential innovative behaviour of SMEs, especially how this behaviour was affected by technological collaboration. To do this, we sorted the firms by size using a dichotomous variable (*SME*) that takes value 1 when the firm has fewer than 200 employees, and value 0 if there are 200 employees or more.

To take account of technological collaboration, we constructed a dichotomous variable that indicates whether firms have collaborated technologically with other firms or research organisations (*COLLABORATION*). This is included in the models as a lagged variable.

We also included a series of variables to measure the firm-level characteristics related to resource endowments: technological resources, financial resources, ownership, commercial resources, organisational resources and relative scale. These are important as they may have an effect on innovativeness.

Technological resources. To accurately measure the effect that technological collaboration has on innovativeness (and the improvement in innovation capabilities), we needed to take into account firms' internal resources, particularly their technological resources. For this reason we constructed a variable for R&D intensity, measured as the ratio of R&D expenditure to total sales (*R&D*). This is included in the models as a lagged variable.

Financial resources. Following Galende and Suarez (1999), we captured firms' financial autonomy and resources by introducing the level of debt – calculated by taking the ratio of Total Debts to Total Liability (*LEVERAGE*).

Ownership. Numerous studies have recognised the effect of ownership structure on innovation, capturing its influence by focusing on foreign ownership (see Becheikh et al., 2006). For this reason we included the percentage of foreign equity in a firm's capital (*FOREIGN*).

Commercial resources. A good indicator of reputation and commercial activities is the possibility that the firm exports part of its production to other markets (Galende and Suarez, 1999). Therefore, we used export intensity – calculated as the ratio of the firm's sales in foreign markets to total sales (*EXPORT*).

Organisational resources. The age of the firm is a possible measure of its organisational resources (*AGE*). It is a variable commonly used to measure the experience and the learning of the firms in empirical studies of innovation (Kumar and Saqib, 1996).

Relative scale. In addition to classifying firms as SMEs or large firms based on number of employees, we felt that it was prudent to include sales figures (*SALES*) to control for the relative scale of their activities. We also included these figures squared to capture possible non-linear effects of the variable (*SALES2*).

Industry characteristics. Industry effects are critical control variables for innovation. Because of size, firms can be more or less productive depending on the industrial sector they are operating in (Nooteboom, 1994; Acs and Audrestsch, 1988b); the knowledge requirements will also vary from sector to sector (Rothwell, 1991). 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 (*SUPPLIER*); 2) scale-intensive sectors (*SCALE*); 3) sectors with specialised suppliers (*SPECIALISED*); and 4) science-based sectors (*SCIENCE*).

Lastly, year dummy variables were included in the models (*YEAR*). Table I contains the descriptive statistics and correlations of the independent and control variables used in this study.

[Table I about here]

3.3 Estimation techniques and data analysis

First, we performed a series of Tests of difference between means; the results of these Tests are presented in Table II. The results reveal that small firms are much less likely to collaborate than large ones: less than one out of five small firms decides to collaborate, compared to almost three out of four large firms. Significant differences in the measures of innovation outcomes can also be observed in both process and product innovations.

[Table II about here]

The differences in these variables for the sub-sample of collaborating firms are far smaller for the two measures of innovation outcome; in fact, for product innovations they are not significant. The percentages of innovating firms, both for the full sample and the sub-sample of collaborating firms, are presented in Figure I.

[Figure I about here]

To test the robustness of these differences between SMEs and large firms, and observe the effect of collaboration on both types of firm, we specified a series of models. As we have already mentioned, the first series of models analyse the impact of collaboration on different types of innovation (product and process), while the second series of models explore the effect of collaboration on improvement in innovativeness. As our dependent variables are dichotomous, estimation models such as *logit* or *probit* (Aldrich and Nelson, 1984; Greene, 2000) would normally be appropriate. Given that product and process innovations may be related to each other (Martínez-Ros, 2000; Fristch and Meschede, 2001), the error terms of the two models are likely to be correlated. Thus, 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):

$$Z_{i1} = \beta_1' x_{i1} + \varepsilon_{i1}; \quad y_{i1} = 1 \text{ si } z_{i1} > 0, \; y_{i1} = 0 \text{ si } z_{i1} \leq 0$$

$$Z_{i2} = \beta_2' x_{i2} + \varepsilon_{i2}; \quad y_{i2} = 1 \text{ si } z_{i2} > 0, \; y_{i2} = 0 \text{ si } z_{i2} \leq 0$$

$$(\varepsilon_{i1}, \varepsilon_{i2}) \sim \text{N}(0,0,1,1,\rho)$$

This model produces estimates of the coefficient vectors β_1 and β_2 for the two equations, of ρ (the correlation between the error terms εij 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[3]. The *bivariate probit* model was estimated using the Stata 8 routine, based on the method of simulated maximum likelihood.

4. Empirical findings

Table III gives the results of the models measuring the impact of a series of variables on the likelihood of process and product innovations. The Wald test indicates high joint significance of the variables for both models. The ρ parameter is highly significant in both models, signalling that the error structures of the equations are correlated. This suggests that product and process innovation are not independent and the *bivariate* model is the correct specification.

The models corroborate the results of the Tests of difference between means. The negative effect that being a small firm has on the likelihood of achieving both types of

[3] If the correlation is not significant, separate (*univariate*) *probit* estimation of the equations is preferable as *bivariate probit* is less efficient than estimating separate models when the error terms are not correlated (Greene, 2000: 853-4).

innovations (Model 1A) is substantially reduced for firms that are engaged in technological collaboration (Model 1B). For process innovations the negative effect drops from -0.565 to -0.212 (considering the joint effect between the variable *SME* and its interaction with technological agreements, *SME*COLLABORATION*), while maintaining the significance of the parameters. In the case of product innovations the effect is greater, changing from -0.507 to +0.057. Thus, in the case of product innovations, we observe a change in the trend of SMEs due to the impact of technological collaborations.

[Table III about here]

The impact of R&D intensity on both types of innovations is positive and significant for both models. It is, however, less pronounced on the model where the collaboration effect is included. This may support the idea that firms that collaborate use this type of technological arrangement to complete their resource endowments. This variable is also more important for product rather than process innovations, which seems logical given the nature of both types of innovations.

The variables controlling for size indicate that this factor has a positive and significant, though not linear, effect. Environmental factors, such as the industrial sector a firm operates in, also affect the probability of achieving process and product innovations.

Age, level of debt and foreign ownership are not relevant variables in the analysis. Export intensity, though, exerts a positive and significant impact. As was the case with R&D intensity, however, its effect is weaker on the model where the collaboration effect is considered.

The models in Table IV are designed to analyse the impact of collaboration on the likelihood of developing innovation capacity for both SMEs (Model 2A) and large firms (Model 2B). The *biprobit* models specify if the improvement in innovation capacity corresponds to process or product innovations. As in the previous models, the Wald test indicates high joint significance of the variables for both models. The ρ parameter is highly significant in both models, signalling that the error structures of the equations are correlated. Once again, this suggests that the *bivariate* model is the correct specification.

[Table IV about here]

We observe a positive effect of collaboration on the likelihood of improving innovation capacity – for product and process innovations – both for SMEs than for large firms. For process innovations the effect of collaboration is slightly greater in large firms (0.606 versus 0.506). However, this effect is superior for SMEs in the case of product innovations (0.816 versus 0.645). This is evidence of the greater benefit that SMEs obtain from technological collaboration. It also helps to explain our preliminary results, which revealed a narrowing of the gap between average levels of innovativeness for SMEs and large firms, especially in the case of product innovations.

Apart from collaboration, another important variable in these models that demands attention is R&D intensity. The R&D variable shows that internal technological resources, along with collaboration, are vital inputs for the innovation processes of SMEs. Higher investment in R&D increases the likelihood of developing innovation capability for process and particularly product innovations.

We did not find a relevant effect on the likelihood of improving innovation capabilities for the rest of the variables related to firm-level characteristics (with the exception of export intensity on product innovations and sales on SMEs innovation capability) and contextual controls (industry and year dummies).

5. Discussion and conclusions

The classic Schumpeterian debate over firm size and innovation undoubtedly reflects a complex relationship that may be influenced by several factors (Becheikh et al., 2006). There is, in fact, a large body of work that ascribes advantages and disadvantages to size and suggests that SMEs and large firms differ in their innovative behaviour and outcomes (Nooteboom, 1994; Cohen and Klepper, 1996; Rogers, 2004; among others). SMEs may enjoy some behavioural advantages, but certainly face weaknesses in regard to large firms' material advantages (Rothwell and Dodgson, 1994). Hewitt-Dundas (2006) took this line when she pointed out that small firms' disadvantages can be put down to certain constraints that block access to resources and basic capabilities for innovation. The same author went further when she highlighted the absence of external partners as one of the key factors to explain the poor innovative performance of small firms compared to large firms. With this in mind, this paper aims to contribute to the literature on the relationship of innovativeness and firm size and our understanding of SMEs' innovation processes. The paper specifically analyses how collaboration acts as an input to the innovation process and allows SMEs to bridge the gap in innovativeness with their larger counterparts.

Using a firm-level longitudinal survey for the period from 1998 to 2002, we have observed that technological collaboration does indeed contribute to improving the innovativeness of SMEs compared to that of large firms. These findings are in line with those obtained by Feldman (1994) for the US and Audretsch and Vivarelli (1996) for Italy; both studies showed how external technological infrastructure appears to benefit the innovative activity of small firms more than that of larger firms. The central idea in both studies is that small firms tend to benefit more from spillovers from research undertaken in their local university laboratories. The peripheral effect of these spillovers is not so decisive for large firms as they have more capabilities and internal resources. In the same way, our research confirms that collaboration is a critical input for the innovation processes of SMEs, one that enables them to get closer to the levels of innovativeness of their larger counterparts.

This result was observed for both product and process innovations. We should point out, however, that the narrowing of the gap between SMEs and large firms is more significant for product innovations (see Figure II). One possible explanation for the different impact of collaboration on product and process innovations can be found in research by Cohen and Klepper (1996) and Fritsch and Meschede (2001). These papers show that SMEs are more oriented towards product than process innovations. As process innovations are less saleable than product innovations, large firms receive scale benefits because of the indivisibility of the innovation activities: a larger volume of sales implies that the fixed costs of innovation can be spread over a larger sales base. In addition, licensing methods are not available or are less effective for process innovations (Roger, 2004). Although collaboration helps to bring SMEs' levels of innovativeness closer to those of large firms, then, it is not surprising that the difference continues to be larger for process innovations, which are inherently less attractive for SMEs (Hoffman et al., 1998).

[Figure II about here]

These findings are reinforced by the effect that collaboration has on improving the innovation capabilities of SMEs. We have found evidence of how collaboration contributes highly significantly to changing the status of non-innovating SMEs, helping to turn them into innovating firms. Even more, we have observed how this effect is greater than that of the large firms in boosting innovation capabilities, especially in product innovations.

This paper does not aim to present a new model of innovation. Our research has contributed empirical evidence in line with Mytelka's (1991) finding that a firm's competitiveness may in fact be determined more by its external network than its size. Indeed, our main finding shows how technological collaboration can boost SMEs' capabilities and innovativeness, tempering the material disadvantages linked to smaller size that *a priori* existed in comparison with larger firms.

We have seen, however, that SMEs are less likely to collaborate than large firms. One possible explanation, as other studies have pointed out, may lie in the greater difficulty that SMEs seem to have reaching technological agreements. Rothwell (1991) showed how SMEs may be at a disadvantage with their counterparts when it comes to setting up lines of communication with external sources of scientific and technological experience. Narula (2004) also found that SMEs tend to prefer to use outsourcing rather than alliances. This may be because of the high risks and costs of managing an alliance along with their understandable wariness about choosing a partner, as there may be fewer opportunities to rectify a bad choice.

Given the benefits that collaboration brings in bridging the gap between SMEs and large firms, future research should try to understand the problems and reluctance of SMEs to become involved in technological collaborations. And once this has been resolved, the effectiveness of the varying mechanisms and policies to strengthen technological collaboration and boost the competitiveness and innovativeness of SMEs should be analysed from an institutional and managerial point of view.

References

Acs, Z. and D.B. Audretsch, 1988a, 'Innovation in large and small firms: An empirical analysis', *American Economic Review* **78**(4), 678-690.

Acs, Z. and D.B. Audretsch, 1988b, 'Innovation and firm size in manufacturing', *Technovation* **7**, 197-210.

Acs, Z. and D.B. Audretsch, 1990, *Innovation and small firms, Cambridge, MA: MIT Press.*

Ahern, R., 1993, 'Implications of strategic alliances for small R&D-intensive firms', *Environment and Planning* **25**, 1511-1526.

Aldrich, J.H. and F.D. Nelson, 1984, *Linear Probability,Logit and Probit Models*, Beverly Hills, California: Sage.

Audretsch, D.B. and M. Vivarelli, 1996, 'Firms size and R&D spillovers: Evidence from Italy', *Small Business Economics* **8**, 249-258.

Barber, J., J. Metcalfe and M. Porteous, 1989, 'Barriers to growth: the ACARD study', in: Barber, J., J. Metcalfe and M. Porteous, (eds.), *Barriers to growth in small firms,* Routledge, London.

Bayona, C., T. Garcia-Marco and E. Huerta, 2001, ‘Firms’ motivations for co-operative R&D: an empirical analysis of Spanish firms’, *Research Policy* **30**, 1289-1307.

Becheikh, N., R. Landry and N. Amara, 2006, ‘Lessons from innovation empirical studies in the manufacturing sector: A systematic review of the literature from 1993-2003’, *Technovation* **26**, 644-664.

Bougrain, F. and B. Haudeville, 2002, ‘Innovation, collaboration and SMEs internal research capacities’, *Research Policy* **31**, 735-747.

Brown, C., J. Hamilton and J. Medoff, 1990, *Employers Large and Small*, Cambridge, MA: Harvard. University Press.

Breen, R., 1996, *Regression Models. Censored, sample selected, or truncated data*, Sage Publications.

Caloghirou, Y., S. Ioannides and N. Vonortas, 2003, ‘Research Joint Ventures’, *Journal of Economic Surveys* **17**(4), 541-570.

Cassiman, B., 1999, ‘Cooperación en Investigación y Desarrollo: Evidencia para la Industria Manufacturera Española’ *Papeles de Economía Española* **81**, 143-154.

Choudhury, V. and W. Xia, 1999, ‘A resource-based theory of network structures’, in Venkatraman, N. and J. C. Henderson, (Eds), *Research in Strategic management and information technology*, v. 2, JAI Press.

Cohen, W. M, 1995, ‘Empirical studies of innovative activity’, in Stoneman, P., (eds.), *Handbook of the Economics of Innovation and Technological Change*, Oxford: Blackwell, 182-264.

Cohen, W.M. and S. Klepper, 1992, ‘The Anatomy of Industry R&D Intensity Distributions’, *American Economic Review* **82**, 773-799.

Cohen, W. M. and S. Klepper, 1996, ‘Firm size and the nature of innovation within industries: the case of process and product R&D’, *Review of Economics and Statistics* **78**(2), 232-243.

Duysters, G., G. Kok and M. Vaandrager, 1999, ‘Crafting successful strategic technology partnerships’, *R&D Management* **29**(4), 343-351.

Edwards, T., R. Delbridge and M. Munday, 2005, ‘Understanding innovation in small and medium-sized enterprises: a process manifest’, *Technovation* **25**, 1119-1127.

Feldman, M. P, 1994, ‘Knowledge complementary and innovation’, *Small Business Economics* **6**, 363-372.

Freel, M.S., 2005, ‘Patterns of innovation and skills in small firms’, *Technovation* **25**, 123-134.

Fritsch, M. and M. Meschede, 2001, ‘Product innovation, process innovation, and size’, *Review of Industrial Organization* **19**, 335-350.

Galende, J. and I. Suárez, 1999, ‘A resource-based analysis of the factors determining a firm’s R&D activities’, *Research Policy* **28**, 891-905.

Granstrand, O., P. Patel and K. Pavitt, 1997, ‘Multi-technology corporations: why they have “distributed” rather than “distinctive core” competences’, *California Management Review* **39**(4), 447-465.

Greene, W., 2000, *Econometric Analysis*, Prentice Hall.

Gulati, R., N. Nohria and A. Zaheer, 2000, ‘Strategic network’, *Strategic Management Journal* **21,** 203-215.

Hagedoorn, J., A. Link and N. Vonortas, 2000, ‘Research partnerships’, *Research Policy* **29**, 567-586.

Hagedoorn, J., 1996, ‘Trends and patterns in strategic technology partnering since the early seventies, *Strategic Management Journal* **14**, 371-385.

Hagedoorn, J., 2002, ‘Inter-firm R&D partnerships –an overview of pattern and trends since 1960’, *Research Policy* **31**, 477-492.

Harrison, B., 1994, ‘Lean and mean’, Basic Book, New York.

Hewitt-Dundas, N., 2006, ‘Resource and Capability Constraints to Innovation in Small and Large Plants’, *Small Business Economics* **26**, 257-277.

Hoffman, K., Parejo, M., Bessant, J. and Perren L., 1998, ‘Small firms, R&D technology and innovation in the UK: a literature review’, *Technovation* **18**(1), 39-55.

Holmstrom, B., 1989, ‘Agency costs and innovation’, *Journal of Economic Behavior and Organization* **12**, 305-327.

Huergo, E. and J. Jamandreu, 2004, ‘How does probability of innovation change with firm age?’, *Small Business Economics* **22**, 193-207.

Jones, O. and F. Tilley, 2003, *Competitive advantage in SMEs: Organizing for innovation and change*, Wiley, Chichester.

Kleinknecht, A. and J. Reijnen, 1991, ‘More evidence on the undercounting of small firm R&D’, *Research Policy* **20**, 579-587.

Kumar, N. and M. Saqib, 1996, ‘Firm size, opportunities for adaptation and in-house R&D activity in developing countries: the case of Indian manufacturing’, *Research Policy*, **25**(5): 713-22.

Lewin, A.Y. and S. Massini, 2003, ‘Knowledge Creation and Organizational Capabilities of Innovating and Imitating Firms’, in H. Tsoukas and N. Mylonopoulos (eds.), *Organizations as Knowledge Systems*, Palgrave, 209–237.

Love, J.H. and S. Roper, 1999, ‘The determinants of innovation: R&D, technology transfer and networking effects’, *Review of Industrial Organization* **15**, 43-69.

Martínez-Ros, E., 2000, ‘Explaining the decisions to carry out product and process innovations: the Spanish case’, *Journal of High Technology Management Research* **10**, 223-242.

Mytelka, L., 1991, ‘Crisis, technological change and the strategic alliance’, in Mytelka, L., (eds.), *Strategic partnerships and the world economy,* Pinter, London, 7-34.

Narula, R., 2004, ‘R&D collaboration by SMEs: new opportunities and limitations in the face of globalisation’, *Technovation* **24**, 153-161.

Nieto, M.J. and L. Santamaria, 2007, ‘The importance of diverse collaborative networks for the novelty of product innovation’, *Technovation* (forthcoming).

Nooteboom, B., 1994, ‘Innovation and diffusion in small firms: Theory and evidence’, *Small Business Economics* **6**, 327-347.

Pavitt, K., 1984, ‘Sectoral patterns of technical change: Towards a taxonomy and a theory’, *Research Policy* **13**, 343-373.

Powell, W., K. Koput and L. Smith-Doerr, 1996, ‘Interorganizational collaboration and the locus of innovation: Networks of learning in biotechnology’, *Administrative Science Quarterly* **41**(1), 116-145.,

O’Regan, N., A. Ghobadian and M. Sims, 2006, ‘Fast tracking innovation in manufacturing SMEs’, *Technovation* **26**, 251-261.

Penrose, E.T, 1959, *The theory of the growth of the firm,* Wiley, New York.

Rogers, M., 2004, 'Networks, firm size and innovation', *Small Business Economics* **22**, 141-153.

Rothwell, R, 1989, 'Small firms, innovation and industrial change', *Small Business Economics* **1**, 51-64.

Rothwell, R., 1991, 'External networking and innovation in small and medium-sized manufacturing in Europe', *Technovation* **11**(2), 93-112.

Rothwell, R. and M. Dodgson, 1994, 'Innovation and size of firm', in Dodgson M. and R. Rothwell, (eds.), *The Handbook of Industrial Innovation,* Aldershot Hants: Edward Elgar.

Sarkar, M.B., R. Echambadi, S.T. Cavusgil and P.S. Aulakh, 2001, 'The influence of complementarity compatibility and relationship capital on allliance performance', *Journal of the Academy of Marketing Science*, **29**(4): 358-373.

Schumpeter, J.A., 1942, *Capitalism,socialism and democracy,* Harper and Row, New York.

Stock, G. N., N.P. Greis and W.A. Fischer, 2002, 'Firm size and dynamic technological innovation', *Technovation* **22**, 537-549.

Van Dijk, B., R. Den Hertog, B. Menkveld and R. Thurik, 1997, 'Some new evidence on the determinants of large- and small-firm innovation', *Small Business Economics* **9**, 335-343.

Vossen, R.W., 1998, 'Relative strengths and weaknesses of small firms in innovation', *International Small Business Journal* **16**(3), 88-93.

Woo, C.Y.Y. and A.C. Cooper, 1981, 'Strategies of Effective Low Share Businesses', *Strategic Management Journal*, **2**: 301-318.

Zahra S.A, R.D. Ireland, M.A. Hitt, 2000, 'International expansion by new venture firms: International diversity, mode of market entry, technological learning, and performance', *Academy of Management Journal* **43**(5): 925-950.

Zenger, T.R., 1994, 'Explaining organisational diseconomies of scale in R&D: Agency problems and the allocation of engineering talent, ideas and effort and ideas by firm size', *Management Science* **40**(6), 708-729.

TABLE I

Means, Standard Deviations, and Correlations of the independent and control variables

		Mean	St. Dev.	1	2	3	4	5	6	7	8	9	10	11	12
1.	*SME*	0.714	0.451												
2.	*COLLABORATION*	0.337	0.472	-0.48											
3.	*R&D*	0.007	0.024	-0.17	0.34										
4.	*LEVERAGE*	0.561	0.226	0.07	-0.08	-0.01									
5.	*FOREIGN*	18.72	37.711	-0.41	0.28	0.05	-0.04								
6.	*EXPORT*	0.198	0.264	-0.38	0.36	0.17	-0.05	0.33							
7.	*AGE*	25.21	20.935	-0.32	0.21	0.10	-0.18	0.20	0.11						
8.	*SALES*	9.34E+06	4.17E+07	-0.31	0.18	0.06	-0.01	0.25	0.14	0.10					
9.	*SALES2*	1.83E+15	2.80E+16	-0.10	0.05	0.01	0.01	0.12	0.09	0.01	0.89				
10.	*SUPPLIER*	0.294	0.455	0.14	-0.18	-0.09	0.06	-0.19	-0.13	-0.08	-0.09	-0.04			
11.	*SCALE*	0.424	0.494	-0.10	0.02	-0.05	-0.05	0.02	0.02	0.03	0.10	0.06	-0.55		
12.	*SPECIALISED*	0.152	0.358	0.01	0.12	0.13	0.02	0.08	0.09	-0.01	-0.02	-0.02	-0.27	-0.36	
13.	*SCIENCE*	0.13	0.336	-0.04	0.09	0.07	-0.03	0.03	0.03	0.06	0.01	-0.01	-0.25	-0.33	-0.16

N = 6 500

TABLE II

Technological collaboration and Innovation results

Percentage of firms	Total Sample (6500 observations)				Collaborative firms (2181 observations)			
	TOTAL	SMEs	LARGE	Difference [a]	TOTAL	SMEs	LARGE	Difference
Technological Collaboration	33.5	18.9	70.1	-51.2 ***				
Product Innovation	24.6	18	41.2	-23.2 ***	48.2	47.5	48.7	1.2 (n.s.)
Process Innovation	34.9	27.1	54.4	-27.2 ***	57	47.9	63.1	-15.2 ***

[a] Student's t-test on the difference between means, *** denote samples are significantly different at the 0.01 level

TABLE III

Bivariate Probit Analysis: Innovation results, Size and Technological collaboration

	Model 1A		Model 1B	
	PRODUCT-INN	PROCESS-INN	PRODUCT-INN	PROCESS-INN
Independent variables				
SME	-0.507*** (-8.94)	-0.565*** (-10.41)	-0.852*** (-13.63)	-0.752*** (-12.99)
*SME*COLLABORATION*			0.909*** (14.63)	0.540*** (9.25)
R&D	7.668*** (4.62)	4.846*** (3.76)	4.947*** (4.29)	3.129*** (3.04)
LEVERAGE	-0.132 (-1.47)	0.093 (1.11)	-0.077 (-0.83)	0.129 (1.53)
FOREIGN	-0.001 (-1.32)	-0.001 (-1.18)	-0.001** (-2.09)	-0.001* (-1.70)
EXPORT	0.473*** (5.78)	0.362*** (4.67)	0.266*** (3.12)	0.230*** (2.93)
AGE	0.001 (1.14)	-0.001 (-1.42)	0.001 (0.79)	-0.001* (-1.95)
Control variables				
SALES	0.338*** (2.81)	0.329*** (2.61)	0.314*** (2.68)	0.313** (2.53)
SALES2	-0.490*** (-2.68)	-0.293* (-1.76)	-0.448** (-2.53)	-0.265 (-1.62)
SCALE	-0.126** (-2.53)	0.126*** (2.74)	-0.157*** (-3.06)	0.113** (2.43)
SPECIALISED	0.215*** (3.30)	0.042 (0.69)	0.126** (1.97)	-0.011 (-0.18)
SCIENCE	0.168** (2.44)	0.209*** (3.29)	0.124* (1.77)	0.181*** (2.82)
Intercept	-0.604*** (-6.24)	-0.381*** (-4.07)	-0.416*** (-4.19)	-0.267*** (-2.83)
$LR \sim \chi^2 : \rho = 0$	278.724***		237.359***	
Wald test of full model: χ^2	707.66***		1037.08***	
Log pseudo-likelihood	-5431.07		-5301.67	

Unstandardized regression coefficients are shown (robust standard errors). T-values are between parentheses. Time controls are included in both models.
* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

TABLE IV

Bivariate Probit Analysis: Improvement of innovativeness, Size and Technological collaboration

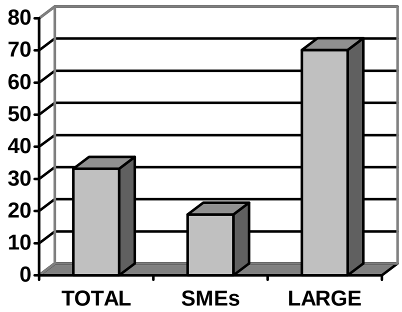
	Model 2A (SMEs)		**Model 2B (Large firms)**	
	IMPROV-PD	IMPROV-PC	IMPROV-PD	IMPROV-PC
Independent variables				
COLLABORATION	0.816***	0.506***	0.645***	0.606***
	(10.96)	(7.80)	(8.02)	(7.82)
R&D	6.283***	3.586**	2.215**	1.479
	(2.69)	(2.28)	(2.01)	(1.23)
LEVERAGE	-0.091	0.163	0.136	0.086
	(-0.78)	(1.63)	(0.81)	(0.52)
FOREIGN	-0.002**	-0.001	-0.001	-0.001***
	(-2.34)	(-0.20)	(-1.47)	(-2.63)
EXPORT	0.492***	0.086	-0.304**	0.163
	(4.12)	(0.80)	(-2.35)	(1.25)
AGE	-0.001	-0.004***	-0.001	-0.001
	(-0.26)	(-2.66)	(-0.69)	(-0.75)
Control variables				
SALES	6.521**	7.464***	0.112	0.256**
	(2.29)	(2.98)	(0.96)	(2.07)
SALES2	-101.480	-252.686	-0.184	-0.165
	(-0.58)	(-1.60)	(-1.10)	(-1.02)
SCALE	-0.243***	0.138**	-0.052	-0.034
	(-3.81)	(2.52)	(-0.56)	(-0.38)
SPECIALISED	0.081	-0.108	0.185	0.046
	(1.05)	(-1.45)	(1.52)	(0.38)
SCIENCE	0.098	0.189**	0.044	-0.043
	(1.11)	(2.45)	(0.36)	(-0.35)
Intercept	-1.289***	-1.054***	-0.727***	-0.483***
	(-12.86)	(-11.36)	(-4.52)	(-3.02)
$LR \sim \chi^2 : \rho = 0$	100.719***		117.213***	
Wald test of full model: χ^2	566.73***		180.72***	
Log pseudo-likelihood	-3387.81		-1822.511	

Unstandardized regression coefficients are shown (robust standard errors). T-values are between parentheses. Time controls are included in both models.
* p < 0.10; ** p < 0.05; *** p < 0.01.

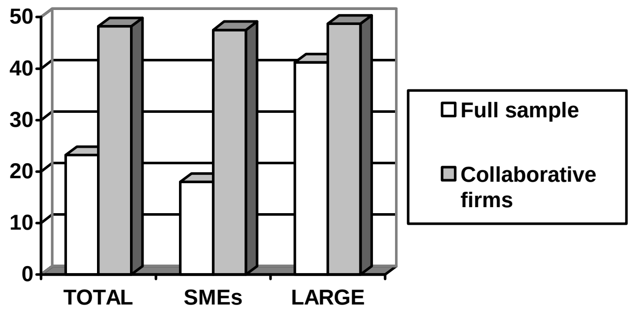
FIGURE I

Technological collaboration and innovation results by size

Percentage of collaborative firms



Percentage of firms with product innovation



Percentage of firms with process innovation

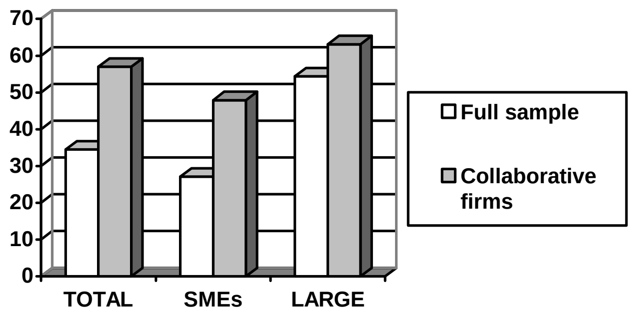
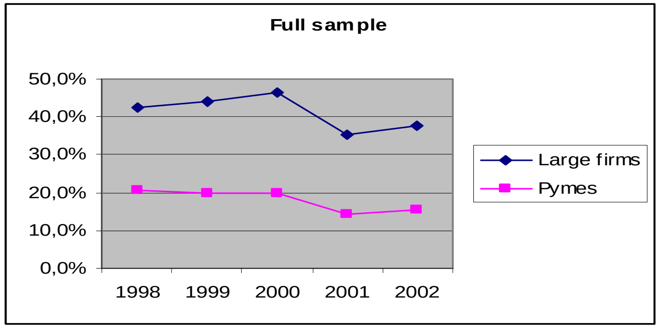
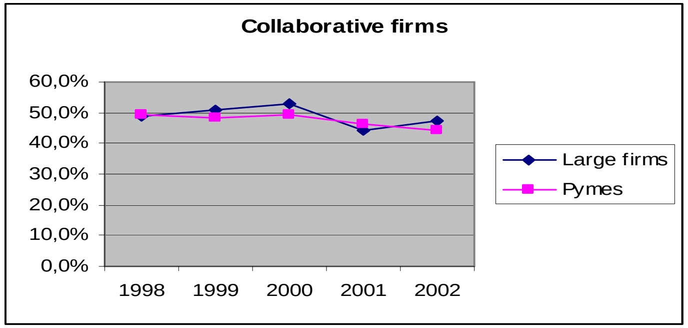


FIGURE II

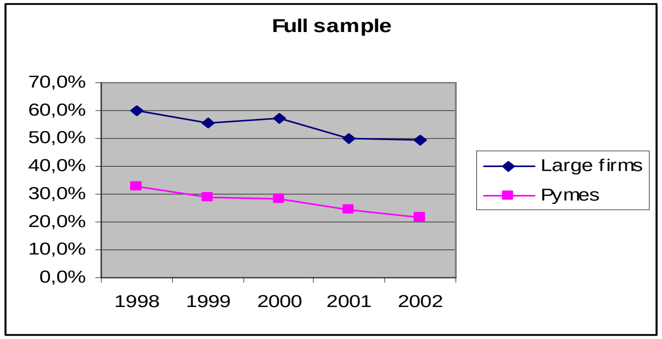
Evolution of innovation gap and the effect of technological collaboration

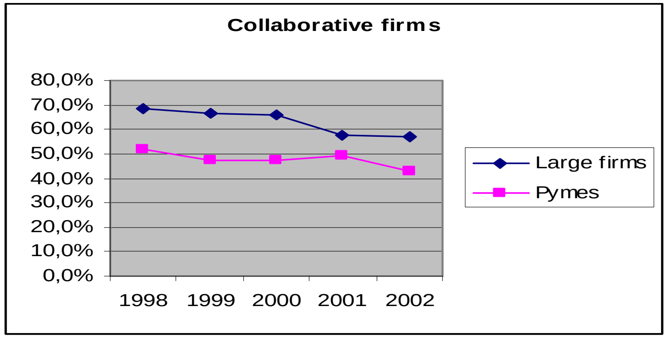
Evolution of product innovation gap





Evolution of process innovation gap





APPENDIX

Construction of the variable "*Improvement in innovativeness*"

This dichotomous variable takes value 1 when the firm "*keeps*" its condition of innovating firm or when "*improves*", going from being a non-innovating firm in t-1 to an innovating one in t. It takes value 0 when the firm has a "*passive*" behaviour and it continues to have no innovations or when it "*gets worse*" going from being an innovating firm in t-1 to a non-innovating firm in t. In the next table we show its construction:

	Innovative behaviour of the firm:					***Improvement in innovativeness***			
	1998	1999	2000	2001	2002	1999	2000	2001	2002
Firm 1	1	1	1	1	1	1	1	1	1
Firm 2	0	1	1	0	1	1	1	0	1
Firm 3	1	0	0	1	0	0	0	1	0
Firm 4	1	1	0	1	1	1	0	1	1
Firm 5	0	0	1	0	1	0	1	0	1

Descriptive of this variable in our sample:

All type of firms

Improvement in product innovation

Full Sample			
Improve	Stable	Passive	Get worse
379	874	3502	445
Collaborative firms			
211	624	702	200

Improvement in process innovation

Full sample			
Improve	Stable	Passive	Get worse
515	1229	2798	658
Collaborative firms			
209	760	521	247

Large firms

Improvement in product innovation

Full Sample			
Improve	Stable	Passive	Get worse
164	443	694	182
Collaborative firms			
127	375	401	135

Improvement in process innovation

Full sample			
Improve	Stable	Passive	Get worse
165	622	488	208
Collaborative firms			
108	521	255	154

SMEs

Improvement in product innovation

Full Sample			
Improve	Stable	Passive	Get worse
215	431	2808	263
Collaborative firms			
62	248	309	96

Improvement in process innovation

Full sample			
Improve	Stable	Passive	Get worse
350	607	2310	450
Collaborative firms			
77	232	289	117