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García-Vega, María; López, Alberto

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Determinants of Abandoning Innovative Activities: Evidence from Spanish Firms *

Determinantes del abandono de actividades de innovación: Evidencia para la empresa española *

María García-Vega **
Alberto López ***

Summary: 1. Introduction. 2. Related Literature. 3. Data and Sample of Firms. 4. Obstacles to Innovation: A Descriptive Analysis. 5. Econometric Analysis of the Determinants of Abandoning Innovative Activities 6. Summary and Concluding Remarks. 7. References. 8. Appendix A. 9. Appendix B.

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ABSTRACT: We empirically analyse the effect of firms' barriers to innovation on the probability of abandoning innovation projects. Specifically, we study factors related to the availability of finance, knowledge and market conditions. We use a sample of more than 8,300 innovative Spanish firms for the period 2005-2007. We find that all obstacles to innovation have a positive effect on the probability of abandoning innovative activities. Results show that market-related factors seem to be the most important determinants of innovation failure. Analyzing results by firm size, we find that, for small-medium firms, the main factors that lead to abandoning innovative projects are competition from established firms and market uncertainty. In contrast, for large firms, the most important barriers are the lack of qualified personnel and the availability of external finance. These results might suggest that large and small-medium firms differ in the scale and complexity of their innovative projects.

Key words: Innovation failure, Barriers to innovation, Firm heterogeneity.
JEL Classification: O31, O32, D22

RESUMEN: En este artículo analizamos empíricamente los efectos de los factores que dificultan la innovación sobre la probabilidad de abandonar actividades de innovación. Específicamente, estudiamos factores relacionadas con restricciones financieras, factores de cono-

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** School of Economics. University of Nottingham. GRIPICO (Group for Research in Productivity, Innovation and Competition). *maria.garcia-vega@nottingham.ac.uk*

*** Departamento de Fundamentos del Análisis Económico I. Facultad CC. Económicas y Empresariales. Universidad Complutense de Madrid. Campus de Somosaguas. 28223, Madrid. Spain. Phone: +34 913943158. Fax: +34 913942561. *alberto.lopez@ccee.ucm.es*

cimiento y condiciones de mercado para una muestra de más de 8.300 empresas innovadoras españolas para el periodo 2005-2007. Los resultados muestran que todos los obstáculos a la innovación tienen un efecto positivo sobre la probabilidad de abandono de las actividades de innovación. Para el conjunto de la muestra, los resultados indican que los condicionantes más importantes para el abandono son los relacionados con factores de mercado. Diferenciando los resultados por tamaño de empresa, encontramos que para las empresas pequeñas o medianas, los principales factores que inducen el abandono son los relacionados con la alta competencia por parte de empresas establecidas en el mercado y la incertidumbre en el mercado. Sin embargo, para las empresas grandes, los obstáculos mas importantes son la falta de personal cualificado y la disponibilidad de financiación. Estos resultados se pueden deber a las diferencias en escala y complejidad que existen entre las actividades de innovación llevadas a cabo por las empresas grandes y las empresas pequeñas o medianas.

Palabras clave: Innovacion, abandono, barreras a la innovacion, heterogeneidad empresarial.

Clasificación JEL: O31, O32, D22

1. Introduction

A central feature of successful firms is their engagement in innovative activities that can improve the quality of their products, reduce their production cost or increase their productivity[1]. Acs and Audretsch (1987, 1988) and Scherer (1983), for example, emphasize the role of firm and industry characteristics as determinants of relative advantages for achieving innovations and patent applications. However, also important, and often less studied, is the failure of research projects, meaning the abandoning of innovation activities to develop product or process innovations.

In this paper, we contribute to the empirical literature on innovation by analyzing the determinants of abandoning innovation activities. We focus on the importance of different obstacles to innovation reported by firms. Specifically, we study the effect of three different types of barriers on the probability of abandoning innovations: the lack of finance within and outside the firm, knowledge factors, and factors related to market conditions faced by the firm. We analyze the different effect of these factors on small-medium firms and on large firms.

Failure can be an unavoidable part of the innovation process. When firms start a new research project, they might not know the future profitability of the project or the difficulties that they might face while carrying out their research activities. In this paper, we try to find empirical firm-level regularities in order to understand why firms decide to abandon innovation projects. Identifying the determinants of failures will be useful for designing public policies and business practices that are likely to reduce their occurrence.

The data used in this paper comes from the *Panel de Innovación Tecnológica* (PITEC). PITEC is a new firm-level panel data base for innovative activities of Spanish firms based on the Community Innovation Survey (CIS). It contains

[1] See, for example, Mairesse and Sassenou (1991) for a survey of the early literature, or more recent studies by Klette (1996), Hall and Mairesse (1995), and Huergo and Jaumandreu (2004).

unique information related to innovation activities. In this paper, we use data from 2005 to 2007 for the manufacturing and service sectors. This gives us a total sample of more than 8,300 firms having reported positive expenditures on innovation during the reference period.

We find that all obstacles to innovation increase the probability of abandoning innovative activities. Our results show that market-related factors seem to be the most important determinants of innovation failure. Analyzing results by firm size, we find that there is firm heterogeneity: for small-medium firms, the main factors that lead to abandoning innovative projects are competition from established companies and market uncertainty. In contrast, for large firms, the most important barriers are the lack of qualified personnel and the availability of external finance. These findings suggests that there are differences in the type of research activities that small-medium and large firms undertake, and that, consequently, they encounter different potential problems that can induce them to abandon innovative projects.

The rest of the paper is organized as follows. Section 2 introduces the related literature. Section 3 describes the data and the sample of firms. Section 4 presents the descriptive analysis of the obstacles to innovation. Section 5 introduces the empirical methodology and presents the results of the estimations. Finally, Section 6 concludes.

2. Related Literature

In what follows, we present some related literature. Although this revision does not aim to be comprehensive, we present the most relevant empirical findings. We can distinguish between four different strands of empirical literature dealing with innovation failure and obstacles to innovation: (i) Studies which focus on the determinants of innovation failure; (ii) Literature which studies the factors that are associated with barriers to innovation; (iii) Studies which focus on analyzing complementarities between obstacles to innovation; and (iv) Literature which studies the effect of hampering factors for innovation on innovative activity.

2.1. Determinants of innovation failure

The evidence about the determinants of innovation failures is scarce. The study of Mohnen et al. (2008) mainly analyzes the impact of financial constraints on firm decisions to abandon, prematurely stop, slow down or not start innovation projects. These authors obtain that financial constraints have a positive effect on prematurely stopping, slowing down and not starting a project, but not on abandoning a project. A second study in this line of research is Landry et al (2008). These authors analyze innovation failure by drawing on the resource-based theory of the firm. They propose a wide number of determinants affecting the failure of innovation projects, including variables related to creation of knowledge assets through R&D, firm strategies, external sources of knowledge, funding, obstacles to innovation, vulnerability and degree

of novelty of innovation. Regarding results on obstacles to innovation, these authors find that financial obstacles and obstacles related to innovation development are the most important ones. On an aggregate level, Canepa and Stoneman (2002) report country-level evidence on the effect of financial constraints on innovation failure.

2.2. Factors associated with barriers to innovation

There are several studies that have dealt with the relationship between obstacles to innovation and firms' characteristics. Some examples are Baldwin and Lin (2002), Galia and Legros (2004), Mohnen and Rosa (2002) and Tourigny and Le (2004). These studies consider several firm characteristics, including both general characteristics of the firm (such as size, sector, age, competitive environment, group membership, among others) and variables related to innovation activity (such as technological intensity, financial support for innovation, externalization of R&D activities, R&D expenditures, introduction of technological innovations and novelty of innovation, among others). These studies show that there is firm heterogeneity that needs to be taken into account in order to evaluate the firms´ perception of obstacles to innovation.

2.3. Complementarities between obstacles to innovation

There is a set of influential studies that analyze complementarities between obstacles to innovation. These articles are closely related to the previous literature. A first approach tests correlations between obstacles conditional on a certain number of common explanatory variables. In this sense, Mohnen and Rosa (2002) find that obstacles related to cost factors and to risk seem to go together, and also problems of internal and external governance. Galia and Legros (2004) find evidence supporting the existence of important complementarities between obstacles to innovation in postponed projects, while complementarities are less important when analyzing abandoned projects. Mohnen and Röller (2005) propose a different approach to studying complementarities using a discrete test of supermodularity. These authors analyze the complementarity and substitutability between obstacles to innovation for both the probability of becoming an innovator and the intensity of innovation. They find that the results depend on the phase of innovation that they are analyzing (propensity or intensity). In this sense, it is shown that some obstacles are substitutable in the propensity to innovate, while complementing the intensity of innovation.

2.4. Obstacles to innovation and innovation activity

Some articles analyze the impact of hampering factors on innovation, which is measured as R&D, innovation activities or innovation output. Several studies find the following counterintuitive result: obstacles to innovation have a positive effect on innovation (see, for example, Mohnen and Röller (2005) and Lööf and

Heshmati (2006)). However, this result can be explained by a problem of endogeneity of hampering factors (i.e., there are common factors affecting both innovation and perception of obstacles). A complete treatment for endogeneity has been done by Savignac (2008), Hajivassiliou and Savignac (2008) and Tiwari et al. (2008). These papers focus on the effect of financial constraints, and find that, accounting for its endogeneity, this obstacle has a negative effect on innovation.

This paper is closely related to the previous literature, particularly with the studies analyzing the determinants of innovation failure. Our results for Spanish firms are consistent with the existing work. In this sense, we also find that the lack of funding increases the probability of abandoning. However, we obtain new insights on this topic, analyzing the effects of the different barriers according to firm size.

3. Data and Sample of Firms

Our dataset comes from a survey of innovating Spanish firms (*Panel de Innovación Tecnológica, PITEC*)[2] for the years 2005, 2006, and 2007. PITEC contains information for a panel of more than 11,000 firms every year. In this survey, each company provides information on some of its economic data, such as sales or number of employees. The firm also answers numerous questions about its innovation activities. As we said in the introduction, the main aim of this paper is to analyze the determinants of abandoning innovations and PITEC provides necessary information for this analysis. Regarding information on abandoned innovation activities, each firm answers the following question:

During the current and previous two years*, "did your enterprise have any innovation activities to develop product or process innovations that you had to abandon?"*[3].

PITEC also has information about variables that can affect the probability of abandoning innovations. In particular, the firm reports data related to its economic characteristics (size, exports, sector, group membership, among others), and variables related to innovation activity (importance of obstacles to innovation,

[2] The Spanish National Institute of Statistics (INE) constructs this database on the basis of the annual Spanish responses to the Community Innovation Survey (CIS). PITEC is placed at the disposal of researchers on the Fundación Española de Ciencia y Tecnología (FECYT) web site:

http://icono.fecyt.es/contenido.asp?dir=05)Publi/AA)panel.

The questions we quote below are the English version from the CIS questionnaire. These questions are the exact equivalent of the Spanish questionnaire.

[3] For example, the 2005 questionnaire refers to abandoned innovations for the period 2003-2005. A product innovation is defined in the survey as: "*The market introduction of a new good or service or a significantly improved good or service with respect to its capabilities, such as quality, user friendliness, software or subsystems. The innovation must be new to your enterprise, but it does not need to be new to your market.* A process innovation is defined as: *"the use of new or significantly improved methods for the production or supply of goods and services. The innovation must be new to your enterprise, but it does not need to be new to your industry."*

R&D expenditures, innovation expenditures and public financial support for innovation, among others)[4].

Our analysis is conducted for firms with positive expenditures in innovation activities for at least one year during the period 2005-2007. Hence, this work is focused on the analysis of firms engaging in innovation activities to develop and/or implement a product or process innovation[5]. The final sample used includes 8,728, 8,666 and 8,318 firms for the years 2005, 2006 and 2007, respectively.

Table 1 shows the percentage of firms that have either product or/and process innovations, as well as the percentage of firms with abandoned innovations. Approximately 85% of the firms in the sample have introduced some product or process innovations, and around 25% of firms with successful innovations have also abandoned some of their research projects. Depending on the period analyzed, between 85.5% to 90.9% of firms with abandoned innovative activities also have successful innovations. Hence, Table 1 shows that most firms with abandoned innovation activities also have other successful innovative projects, but the percentage of innovating firms with abandoned innovation activities is remarkably lower.

TABLE 1.—*Sample statistics (number and percentage of firms)*

	2003-2005	**2004-2006**	**2005-2007**
Firms (total sample)	8,728	8,666	8,318
Innovating firms[1,2]	7,393 (84.70%)	7,381 (85.17%)	7,065 (84.93%)
***with abandoned innovations*[3]**	26.06%	25.31%	26.10%
Firms with abandoned innovations[2]	2,119 (24.27%)	2,159 (24.91%)	2,155 (25.90%)
***being an innovating firm*[4]**	90.93%	86.56%	85.56%

[1]Innovating firms are defined as those that report having introduced product and/or process innovations.

[2]The percentage value shown in parentheses is the percentage of firms with respect to the total number of firms in the sample.

[3]The percentage value shown in parentheses is the percentage of firms with respect to the number of innovating firms in the sample.

[4]The percentage value shown in parentheses is the percentage of firms with respect to the number of firms with abandoned innovation activities in the sample.

[4] Section 5.1 details the set of explanatory variables that we use in explaining abandoned innovation activities, while detailed definitions of all employed variables can be found in Appendix A.

[5] All the econometric analysis that we have conducted in the following sections have also been done for firms with a ratio of innovation expenditures over turnover larger than 1%. The main results are not significantly different than those that we present in this paper.

In Table 2, we present the percentage of firms with abandoned innovations, differentiating between manufacturing and service firms. On average, this percentage is higher in the manufacturing sector than in the service sector. In Table 3, we distinguish by firm size (following the OECD classification, see, for example, OECD 2000). The descriptive statistics indicate that, on average, firms with fewer than 250 employees (i.e., small-medium firms) abandon less than large firms (firms with 250 or more employees).

TABLE 2.—*Firms with abandoned innovation activities by period and sector (% with respect to total sample)*

	Mean of periods	**2003-2005**	**2004-2006**	**2005-2007**
Manufacturing	27.16	26.82	27.19	27.50
Services	21.62	20.25	21.33	23.37

TABLE 3.—*Firms with abandoned innovation activities by period and size (% with respect to total sample)*

	Mean of periods	**2003-2005**	**2004-2006**	**2005-2007**
Firms with fewer than 250 employees	24.70	23.95	24.92	25.26
Firms with 250 or more employees	26.60	25.90	24.85	29.15

4. Obstacles to Innovation: A Descriptive Analysis

As we said in the introduction, the aim of this paper is to analyze the determinants of innovation failure, focusing mainly on the importance of obstacles to innovation. This section describes how Spanish firms perceive the importance of different obstacles to innovation. In the survey, firms are asked to rate the importance of several factors that could have hampered their innovation activities during the current and previous two years.

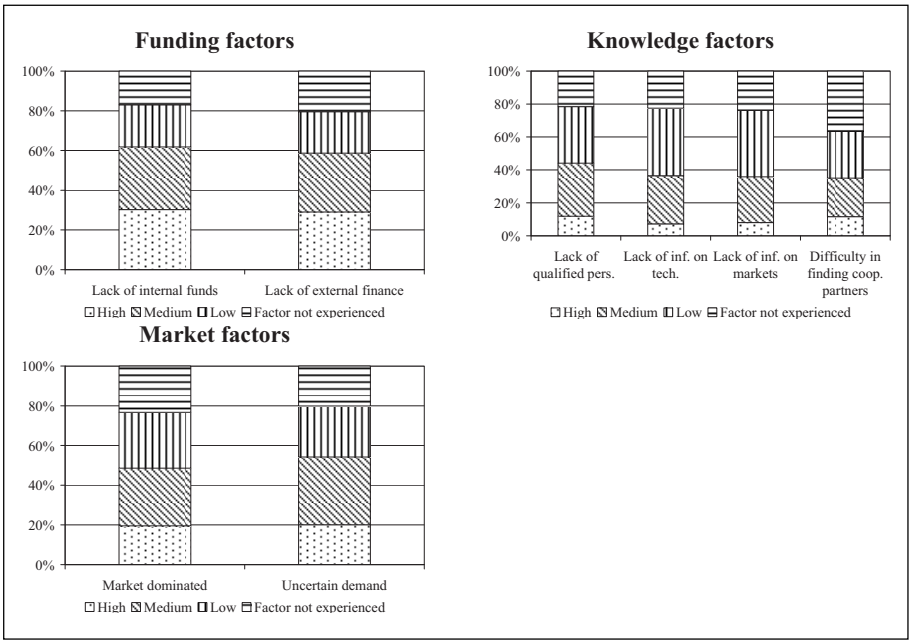
In particular, firms are asked: *"How important were the following factors for hampering your innovation activities or projects or influencing a decision not to innovate?"* These factors are classified into three groups: (i) *Funding related factors*. This group includes the *lack of funds within the enterprise or business group* and the *lack of finance from sources outside the enterprise*; (ii) *Knowledge related factors*. In this set of barriers, firms are asked about the *lack of qualified personnel*, the *lack of information on technology and on the markets* and the *difficulty in finding cooperation partners for innovation*; (iii) *Market-related factors*. This group refers to the importance of a *market dominated by established enterprises* and *uncertain demand for innovative*

goods or services. For each of these factors, firms are asked to rate their importance on a Likert scale of 1 to 4, where 1 represents high importance, 2 represents intermediate importance, 3 represents low importance and 4 represents factor not experienced. In doing the descriptive analysis showed in this section, we use the answers arranged in this four-point scale. For the econometric analysis shown in the next section, we rescale the importance of obstacles to innovation between 0 (factor not experienced) to 1 (high) (see Cassiman and Veugelers, 2002). Detailed definitions of these variables can be found in Appendix A.

Figure 1 summarizes the importance of the obstacles to innovation for all firms. We compare the average value of the different barriers. We obtain the mean of the obstacles for the period 2003-2007, calculating the average of the three-year periods analyzed (2003-2005, 2004-2006 and 2005-2007, which correspond to the 2005, 2006, and 2007 questionnaire, respectively)[6]. The descriptive statistics suggest that the *lack of internal* and *external finance* are the main factors hampering innovation. Around 60% of the firms perceive that these obstacles have a high or medium importance. The second main group of obstacles hampering innovation are *market factors*, especially the existence of an *uncertain demand* for innovative goods or services. *Knowledge factors* are comparatively less important than the other two types of barriers. In general, less than 40% of firms report that these obstacles have high or medium importance. Moreover, Figure 1 shows that, for each obstacle considered, around 20% of firms report that the factor is not experienced.

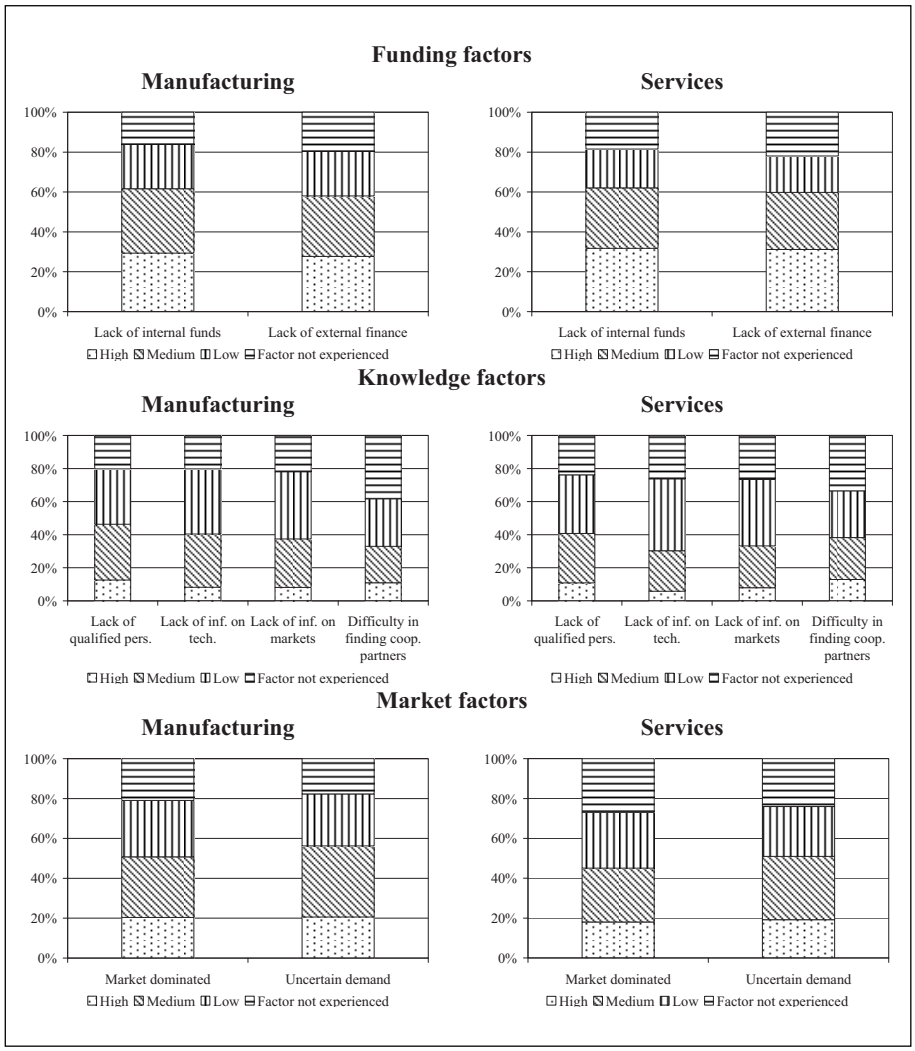
[6] Results for each period are very similar to those in Figure 1. Hence, for simplicity, we only show the mean of the periods.

FIGURE 1.—*Obstacles to innovation. Mean of the periods*



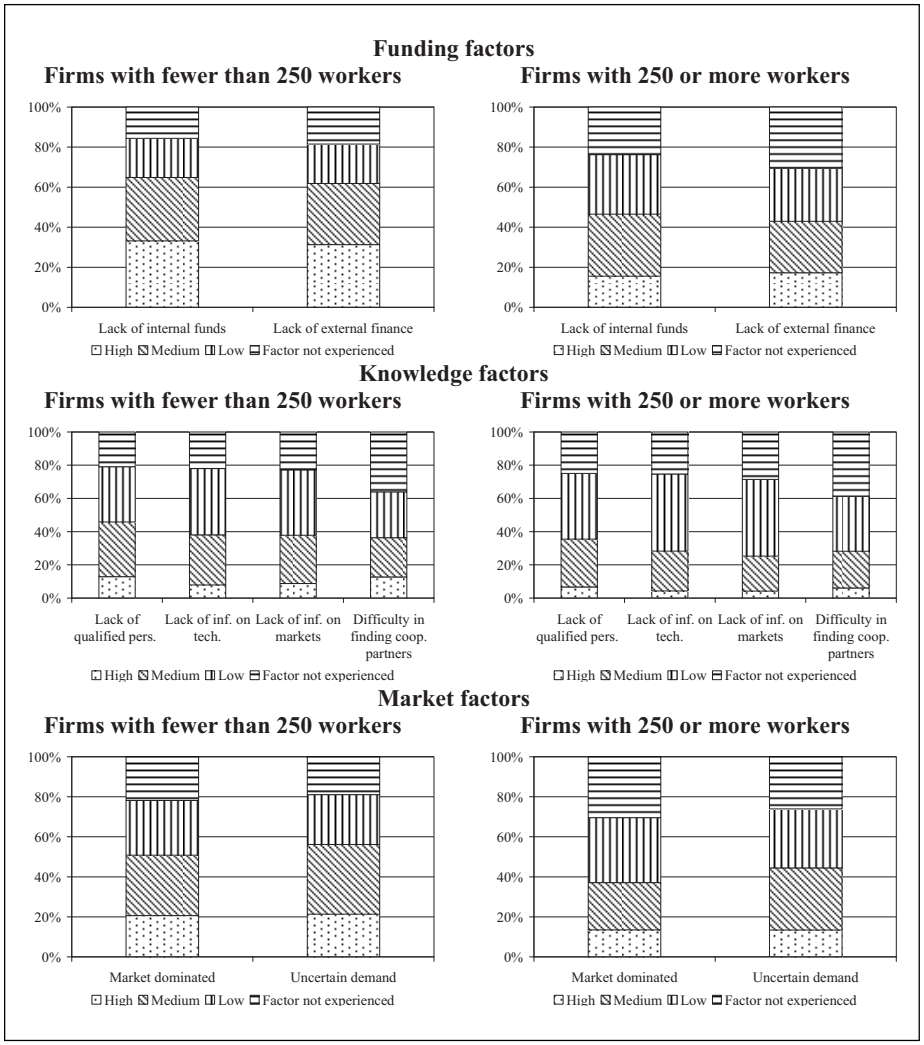
Finally, Figure 3 shows differences between barriers by firm size. We distinguish between small-medium firms, i.e., firms with fewer than 250 employees, and large firms, i.e., firms with 250 or more employees. We find that, on average, obstacles to innovation affect small-medium firms more than large firms. This difference is especially important for *funding*-related factors. In this case, the percentage of small-medium firms reporting that these obstacles have high or medium importance is around 65%, while for large firms this percentage is around 45%. The difference is approximately 20% for the factor that measures the importance of *uncertainty in the demand*. As in the previous figures, both for small-medium firms and large firms, the ranking of obstacles to innovate is, firstly, *funding factors*, secondly, *market factors*, and finally, *knowledge factors*.

FIGURE 2.—*Obstacles to innovation by sector. Mean of the periods*



In summary, the descriptive analysis supports the idea that the importance of the barriers to innovation depends on firm size. These obstacles may hamper the innovation activity of the firm, but not necessarily influence the decision to abandon an innovation activity, since, as shown in Table 1, only 25% of firms that innovate also abandon. In the next section, we analyze the effect of obstacles to innovation on the probability of abandoning innovation projects econometrically by controlling for potential covariates, and distinguishing by firm size.

FIGURE 3.—*Obstacles to innovation by size. Mean of the periods*



5. Econometric Analysis of the Determinants of Abandoning Innovative Activities

5.1. Econometric specification

We now turn to examining the determinants of abandoning innovative projects at the firm level. We estimate a probit equation by maximum likelihood for the probability that a firm abandons innovative activities during the period 2005-2007:

$$\mathrm{P}(Abandon_{i,(05-07)}=1) = \Phi\left(\gamma' x_{i,05} + \beta' Factors\ hampering\ innovation_{i,(03-05)} + \varepsilon_{i,05}\right),$$

where Φ is the normal standard c.d.f.

The dependent variable $Abandon_{i,(05\text{-}07)}$ is equal to one for those firms that have abandoned innovation activities during the period 2005-2007. Given that many variables refer to a three-year period, we consider the abandoned innovation activities from 2005 to 2007 (which correspond to the answers from the questionnaire of the year 2007) as dependent variable, and those that come from the questionnaire of the year 2005 as independent variables. This reduces our sample to a cross-section with 8,311 firms. In this way, we explain abandoned innovation activities in terms of current or past firms' characteristics. In particular, the right-hand side variables are the previously described factors that hamper innovation for the period 2003-2005, and a set of control variables for the year 2005. As controls, denoted by $x_{i,05}$ in the above equation, we include: *internal R&D intensity* of the firm, which is measured as the logarithm of internal R&D expenditures over the number of employees, *sectoral R&D intensity*, measured by the degree R&D intensity of the sector where the firm operates (this data comes from the OECD. See Appendix A for details about the construction of this variable, as well as the data source). We also include, as control variables, five dummies that indicate whether: the firm has fewer than 250 employees, it is part of a group, it is an exporter, it has received public support for innovation, and it is a manufacturing firm. Finally, $\varepsilon_{i,05}$ is the error term, which is normally distributed with mean equal to zero and standard deviation σ. Table B.1 in Appendix B gives descriptive statistics on the main variables used in our empirical analysis.

5.2. Results

In order to get a first approximation of the determinants of abandoning innovative activities, we aggregate the influence of barriers to innovation into three main groups: *funding*, *knowledge*, and *market factors*. The results are presented in column (i) in Table 4. In all tables, we report the marginal effects of the probit model.

TABLE 4.—*Determinants of the probability of abandoning innovation activities Baseline specifications*

	(i)		(ii)	
	dy/dx	**S. E.**	**dy/dx**	**S. E.**
Factors hampering innovation for all firms				
Funding factors	0.046**	(0.017)		
Knowledge factors	0.059**	(0.024)		
Market factors	0.080***	(0.019)		
for small-medium firms				
Funding factors			0.038**	(0.019)
Knowledge factors			0.048*	(0.026)
Market factors			0.077***	(0.021)
for large firms				
Funding factors			0.080*	(0.044)
Knowledge factors			0.126*	(0.066)
Market factors			0.098**	(0.048)
Small-medium firm (d)	-0.070***	(0.016)	-0.007	(0.029)
R&D intensity	0.015***	(0.002)	0.015***	(0.002)
Belonging to a group(d)	0.037***	(0.011)	0.037***	(0.011)
Being an exporter(d)	0.048***	(0.011)	0.048***	(0.011)
Sectoral R&D intensity	0.025**	(0.011)	0.025**	(0.011)
Public support for innovation(d)	-0.017*	(0.010)	-0.017*	(0.010)
Log likelihood	-4611		-4608	
Pseudo R2	0.030		0.030	
Observations	8,311		8,311	

All regressions include a dummy that indicates whether the firm is a manufacturing firm.
Marginal effects (dy/dx) from the probit model (at sample means) are reported.
S. E.: Estimated standard error.
*Significant at 10%, ** significant at 5%, *** significant at 1%.
The symbol (d) denotes dummy variable.

We can see that firms with fewer than 250 employees and those that have received public support for innovation are less likely to abandon innovation activities. In contrast, firms that are more R&D-intensive, firms from R&D-intensive sectors, and exporters have a higher probability of abandoning. All barriers to innovation increase the probability of abandoning. In particular, *market related factors* seem to have the highest impact on the abandon decision. In column (ii), we present factors that hamper innovation for small-medium and large firms separately. These results suggest that for small-medium firms, *market factors* are the most important obstacles that induce them to abandon, while for large firms, *knowledge factors* increase the probability of abandoning relatively more than other obstacles.

Next, we turn to the detailed analysis of the different barriers on the probability of abandoning. First, we analyze *funding factors* in more detail. Table 5 shows the

results of this analysis. We distinguish between the *lack of internal funding* and the *lack of external funding*. We find that the *lack of external funding* increases the probability of abandoning by 4.8%, while the impact of the *lack of internal funding* is not significant (see column (i)). In column (ii), we distinguish between small-medium and large firms. The results indicate that the *lack of external funding* increases the probability of abandoning by 13.7% but only for large firms. One possible explanation for this result is that large firms undertake extensive innovative projects. These projects might require a larger amount of funds than the type of projects that small-medium firms start (Baumol 2003). In this line, Acemoglu and Linn (2004) document that market size influences innovation in the pharmaceutical industry, and Görtz (1999) shows theoretically that large firms have more incentives to invest in big technological projects than small-medium firms.

TABLE 5.—*Determinants of the probability of abandoning innovation activities Disaggregation by funding factors*

	(i)		(ii)	
	dy/dx	**S. E.**	**dy/dx**	**S. E.**
Factors hampering innovation				
Funding factors				
for all firms				
Lack of internal funding	-0.003	(0.020)		
Lack of external funding	0.048**	(0.019)		
for small-medium firms				
Lack of internal funding			0.001	(0.022)
Lack of external funding			0.031	(0.021)
for large firms				
Lack of internal funding			-0.032	(0.052)
Lack of external funding			0.137**	(0.049)
Knowledge factors	0.058**	(0.024)	0.058**	(0.024)
Market factors	0.082***	(0.019)	0.081***	(0.019)
Small-medium firm (d)	-0.070***	(0.016)	-0.034	(0.025)
R&D intensity	0.015***	(0.002)	0.015***	(0.002)
Belonging to a group(d)	0.037***	(0.011)	0.037***	(0.011)
Being an exporter(d)	0.048***	(0.011)	0.047***	(0.011)
Sectoral R&D intensity	0.025**	(0.011)	0.025**	(0.011)
Public support for innovation(d)	-0.017*	(0.010)	-0.018*	(0.010)
Log likelihood	-4611		-4608	
Pseudo R2	0.030		0.030	
Observations	8,311		8,311	

All regressions include a dummy that indicates whether the firm is a manufacturing firm.
Marginal effects (dy/dx) from the probit model (at sample means) are reported.
S. E.: Estimated standard error.
Significant at 10%, ** significant at 5%, *** significant at 1%.
The symbol (d) denotes dummy variable.

In Table 6, we distinguish between different types of *knowledge factors*. The main finding is that the *difficulty in finding cooperative partners* increases the

probability of abandoning by 3.9%. However, there are some differences depending on firm size. For small-medium firms, the influence of *knowledge factors* on the probability of abandoning is negligible, while for large firms the *lack of qualified personnel* increases the probability of abandoning by 12.6%. This result again suggests that large firms are undertaking different and probably more complex innovative projects than small-medium firms.

TABLE 6.—*Determinants of the probability of abandoning innovation activities Disaggregation by knowledge factors*

	(i)		(ii)	
	dy/dx	**S. E.**	**dy/dx**	**S. E.**
Factors hampering innovation				
Funding factors	0.044**	(0.017)	0.042**	(0.017)
Knowledge factors				
for all firms				
Lack of information	-0.006	(0.026)		
Lack of qualified personnel	0.026	(0.017)		
Lack of cooperation partners	0.039*	(0.021)		
for small-medium firms				
Lack of information			-0.011	(0.028)
Lack of qualified personnel			0.026	(0.022)
Lack of cooperation partners			0.027	(0.018)
for large firms				
Lack of information			0.016	(0.070)
Lack of qualified personnel			0.126**	(0.057)
Lack of cooperation partners			0.023	(0.046)
Market factors	0.082***	(0.019)	0.082***	(0.019)
Small-medium firm (d)	-0.070***	(0.016)	-0.017	(0.026)
R&D intensity	0.015***	(0.002)	0.015***	(0.002)
Belonging to a group(d)	0.038***	(0.011)	0.038***	(0.011)
Being an exporter(d)	0.048***	(0.011)	0.048***	(0.011)
Sectoral R&D intensity	0.025**	(0.011)	0.025**	(0.011)
Public support for innovation(d)	-0.017*	(0.010)	-0.017*	(0.010)
Log likelihood	-4611		-4607	
Pseudo R2	0.030		0.031	
Observations	8,311		8,311	

All regressions include a dummy that indicates whether the firm is a manufacturing firm.
Marginal effects (dy/dx) from the probit model (at sample means) are reported.
St. Dev.: Estimated standard error.
Significant at 10%, ** significant at 5%, *** significant at 1%.
The symbol (d) denotes dummy variable.

Finally, in Table 7, we analyze the influence of *market factors* on the probability of abandoning in more detail. The results shown in column (i) indicate that *demand uncertainty* is more important than being in a *market dominated by established firms*. However, an analysis of the results shows that there is firm heterogeneity. For small-medium firms, *demand uncertainty* and the *effect of established firms* increase the probability of abandoning innovative projects (column (ii)). However, we find that for large firms, *market uncertainty* increases the probability of abandoning by 17.2%, while the presence of other established firms does not affect their decision to abandon.

TABLE 7.—*Determinants of the probability of abandoning innovation activities Disaggregation by market factors*

	(i)		(ii)	
	dy/dx	**S. E.**	**dy/dx**	**S. E.**
Factors hampering innovation				
Funding factors	0.046**	(0.017)	0.045**	(0.017)
Knowledge factors	0.057**	(0.024)	0.057**	(0.024)
Market factors				
for all firms				
High competition	0.022	(0.017)		
Demand uncertainty	0.060***	(0.018)		
for small-medium firms				
High competition			0.031*	(0.019)
Demand uncertainty			0.039*	(0.020)
for large firms				
High competition			-0.025	(0.042)
Demand uncertainty			0.172***	(0.044)
Small-medium firm (d)	-0.070***	(0.016)	-0.028	(0.026)
R&D intensity	0.015***	(0.002)	0.015***	(0.002)
Belonging to a group(d)	0.037***	(0.011)	0.037***	(0.011)
Being an exporter(d)	0.048***	(0.011)	0.047***	(0.011)
Sectoral R&D intensity	0.025**	(0.011)	0.025**	(0.011)
Public support for innovation(d)	-0.017*	(0.010)	-0.018*	(0.010)
Log likelihood	-4611		-4607	
Pseudo R2	0.030		0.031	
Observations	8311		8311	

All regressions include a dummy that indicates whether the firm is a manufacturing firm.
Marginal effects (dy/dx) from the probit model (at sample means) are reported.
St. Dev.: Estimated standard error.
Significant at 10%, ** significant at 5%, *** significant at 1%.
The symbol (d) denotes dummy variable.

6. Summary and Concluding Remarks

One major strand of empirical innovation literature focuses on analyzing the factors determining innovation successes, basically measured by the introduction of technological innovations (i.e., product or process innovations) and patent applications. However, innovation failure is also a possible outcome. Innovation involves the utilization of information, knowledge, technologies, and human and financial resources, and it is associated with uncertainty over the outcome of innovation activities.

In spite of its importance, literature on innovation failure is much less developed. This paper contributes to filling this gap. Literature on this issue focuses on analyzing the determinants of innovation failure, the factors that are associated with barriers to innovation, complementarities between obstacles to innovation and the effect of hampering factors for innovation on innovation activity. Specifically, the aim of this paper is to empirically analyze the determinants of abandoning innovation activities, focusing on factors related to the availability of finance, knowledge and market conditions. Designing effective public policies and business practices to reduce innovation failures requires knowledge of the factors that lead innovation projects to be abandoned. In doing this, we use a unique dataset of more than 8,300 Spanish innovating firms for the period 2005-2007. In this dataset, firms answer several questions about their economic data and innovative activities, including whether they have abandoned innovations.

We analyze innovation failure along two (related) dimensions: a descriptive and an econometric analysis. Descriptive analysis gives us a "general picture" about the incidence of innovation failure and on how Spanish firms perceive the importance of different obstacles to innovation. Econometric analysis of the determinants of abandoning innovative projects allows us to measure the effect of one factor controlling for (or holding fixed) the rest of the factors.

Firstly, we find that around 25% of firms in our sample have abandoned innovation activities. Interestingly, most of these firms also have other successful innovation projects, i.e., only a few firms fail in undertaking all their innovative projects.

Regarding the descriptive analysis of the obstacles to innovation, we find that firms perceive *funding related factors* as the most important hampering factors for innovation. As pointed out by Hall (2002), in the case of innovation activities, financial problems are especially important due to some of their inherent characteristics (high uncertainty and risk associated with its output, appropriability problems, importance of tacit knowledge, etc.). The second and third main perceived types of factors are *market factors* and *knowledge factors*, respectively. Results by sector show that there are no important differences between manufacturing firms and services. Finally, in our descriptive analysis, we find that, on average, small-medium firms perceive higher obstacles to innovation.

Secondly, the main results of the econometric analysis of the determinants of abandoning innovation are as follows. First of all, results for the whole sample of firms show that all obstacles to innovation increase the probability of abandoning innovation projects and *market related factors* seem to have the highest effect.

In addition, results by firm size show that, for large firms, the lack of qualified personnel and the lack of funds are the main obstacles that induce firms to abandon innovation activities. We show that small-medium firms perceive the lack of finance as one of the most important obstacles to innovation. However, this is not the main factor that increases their probability of abandoning. We obtain that, for small-medium firms, the presence of established companies and market uncertainty are the main factors to abandon innovation projects.

To sum up, our findings suggest a positive effect of all the obstacles considered (*funding related factors, market factors* and *knowledge factors*) on the probability of abandoning innovation projects. However, the importance of these factors varies with firm size. Differences between small-medium firms and large firms may be given by differences in the scale and complexity between the innovation projects that firms undertake or by own-firm characteristics. In this sense, the importance of the lack of funds on the probability of abandoning for large firms may be driven by the fact that these firms undertake extensive innovation projects which involve a larger amount of funds. The main factors affecting innovation projects undertaken by small-medium firms are those related to their relatively small weight in the market that they are operating.

One implication of our study is the need of different public policies to reduce innovative failures depending on firm size and on the economies of scale of the research project. Our analysis also indicates that firms that try to innovate but fail also manage to succeed in other research projects that they undertake. This result may suggest that there can be a learning or spillover effect associated with failure. In this sense, knowledge generated by failed projects may be used in other projects, and in this way failure may finally have a positive effect on firm innovativeness and performance. This analysis is left for future research.

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APPENDIX A: VARIABLE DEFINITIONS

Abandoning innovation activities: Dummy variable that takes the value one if the firm reports having abandoned innovation activities.

Being a manufacturing firm: Dummy variable that takes the value one if the firm is a manufacturing firm.

Being an exporter: Dummy variable that takes the value one if the firm reports a positive amount of exports.

Belonging to a group: Dummy variable that takes the value one if the firm belongs to a business group.

Demand uncertainty: Importance of uncertain demand for innovative goods or services to innovation process (number between 1 (high) and 4 (factor not experienced)). Rescaled between 0 (factor not experienced) and 1 (high).

$$\text{Demand uncertainty} = 1 - \frac{\text{Score of uncertain demand} - 1}{3}$$

Funding factors: Sum of the scores of importance of the following obstacles to innovation process (number between 1 (high) and 4 (factor not experienced)): Lack of funds within the enterprise or group; Lack of finance from sources outside the enterprise. Rescaled between 0 (factor not experienced) and 1 (high).

$$\text{Funding factors} = 1 - \frac{\text{Score lack internal funds} + \text{Score lack of external finance} - 2}{6}$$

High competition: Importance of market dominated by established enterprises to innovation process (number between 1 (high) and 4 (factor not experienced)). Rescaled between 0 (factor not experienced) and 1 (high).

$$\text{High competition} = 1 - \frac{\text{Score market dominated} - 1}{3}$$

Knowledge factors: Sum of the scores of importance of the following obstacles to innovation process (number between 1 (high) and 4 (factor not experienced)): Lack of qualified personnel; Lack of information on technology; Lack of information on markets; Difficulty in finding cooperation partners for innovation. Rescaled between 0 (factor not experienced) and 1 (high).

$$\text{Knowledge factors} = 1 - \frac{\text{Score lack qual. pers.} + \text{Score lack inf tech.} + \text{Score lack inf. mark.} + \text{Score difficulty coop.} - 4}{12}$$

Lack of cooperation partners: Importance of the difficulty in finding cooperation partners for innovation to innovation process (number between 1 (high)

and 4 (factor not experienced)). Rescaled between 0 (factor not experienced) and 1 (high).

$$\text{Lack of cooperation partners} = 1 - \frac{\text{Score difficulty coop.} - 1}{3}$$

Lack of external funding: Importance of the lack of finance from sources outside the enterprise to innovation process (number between 1 (high) and 4 (factor not experienced)). Rescaled between 0 (factor not experienced) and 1 (high).

$$\text{Lack of external funding} = 1 - \frac{\text{Score lack of external finance-1}}{3}$$

Lack of information: Sum of the scores of importance of the following obstacles to innovation process (number between 1 (high) and 4 (factor not experienced)): Lack of information on technology; Lack of information on markets. Rescaled between 0 (factor not experienced) and 1 (high).

$$\text{Lack of information} = 1 - \frac{\text{Score lack inf tech.} + \text{Score lack inf. mark.} - 2}{6}$$

Lack of qualified personnel: Importance of the lack of qualified personnel to innovation process (number between 1 (high) and 4 (factor not experienced)). Rescaled between 0 (factor not experienced) and 1 (high).

$$\text{Lack of qualified personnel} = 1 - \frac{\text{Score lack qual. pers.} - 1}{3}$$

Lack of internal funding: Importance of the lack of funds within the enterprise or group to innovation process (number between 1 (high) and 4 (factor not experienced)). Rescaled between 0 (factor not experienced) and 1 (high).

$$\text{Lack of internal funding} = 1 - \frac{\text{Score lack of internal funds} - 1}{3}$$

Large firm: Dummy variable that takes the value one if the firm has 250 or more employees.

Market factors: Sum of the scores of importance of the following obstacles to innovation process (number between 1 (high) and 4 (factor not experienced)): Market dominated by established enterprises; Uncertain demand for innovative goods or services. Rescaled between 0 (factor not experienced) and 1 (high).

$$\text{Market factors} = 1 - \frac{\text{Score market dominated} + \text{Score uncertain demand} - 2}{6}$$

Public support for innovation: Dummy variable that takes the value 1 if the firm has received any kind of public financial support for innovation activities from local, national or European sources.

R&D intensity: Logarithm of internal R&D expenditures over the number of employees.

Sectoral R&D intensity: For each sector, this variable is the ratio of R&D expenditures over value added by industry. Source: Analytical Business Enterprise Research and Development (ANBERD) and STAN Industry. STAN database for structural analysis (OECD). Data available at:

http://www.oecd.org/document/6/0,3343,en_21571361_33915056_39146886_1_1_1_1,00.html

Small-medium firm: Dummy variable that takes the value one if the firm has fewer than 250 employees.

APPENDIX B: ADDITIONAL TABLE

TABLE B.1.—*Descriptive statistics*[1]*. Year 2005*

	Sample mean (N=8,311)	**Mean non-abandoning firms**[2] (N=6,160)	**Mean abandoning firms**[3] (N=2,151)
Factors hampering innovation			
Funding factors	0.564 (0.333)	0.549 (0.337)	0.606 (0.317)
Lack of internal funding	0.575 (0.353)	0.562 (0.357)	0.613 (0.338)
Lack of external funding	0.553 (0.367)	0.536 (0.370)	0.600 (0.353)
Knowledge factors	0.398 (0.248)	0.386 (0.251)	0.431 (0.236)
Lack of information	0.399 (0.269)	0.388 (0.272)	0.431 (0.258)
Lack of cooperation partners	0.356 (0.339)	0.342 (0.337)	0.395 (0.342)
Lack of qualified personnel	0.436 (0.311)	0.425 (0.313)	0.469 (0.306)
Market	0.494 (0.306)	0.477 (0.309)	0.543 (0.291)
High competition	0.481 (0.350)	0.465 (0.351)	0.527 (0.342)
Demand uncertainty	0.507 (0.341)	0.488 (0.344)	0.560 (0.326)
Control variables			
Small-medium firm	0.833 (0.372)	0.839 (0.367)	0.817 (0.386)
R&D intensity	6.413 (3.561)	6.180 (3.687)	7.080 (3.078)
Belonging to a business group	0.335 (0.472)	0.322 (0.467)	0.372 (0.483)
Being an exporter	0.569 (0.495)	0.545 (0.497)	0.638 (0.480)
Sectoral R&D intensity	0.125 (0.444)	0.117 (0.428)	0.150 (0.488)
Being a manufacturing firm	0.615 (0.486)	0.601 (0.489)	0.657 (0.474)
Public support for innovation	0.480 (0.499)	0.473 (0.499)	0.500 (0.500)

[1]Standard deviations in parentheses.
[2]Mean of firms without abandoned innovation activities in 2005-2007.
[3]Mean of firms with abandoned innovation activities in 2005-2007.