Firm-Level Evidence on Innovation in Spain*

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Abstract

Using a new database based on a survey on innovation, this paper aims at identifying the determinants of firms' R&D investment and innovation decisions. The descriptive statistics confirm the evidence that the percentage of firms investing in R&D is substantially lower than the percentage of firms introducing innovations. The econometric analysis allows us to identify the geographic distribution of sales as an important determinant of both R&D investment and innovation.

Keywords: innovation, investment, microeconometrics
JEL Classification numbers: D21, 031.

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1 Introduction

On the theoretical and policy points of view, innovation has become a central theme for growth at the level of the firm and for the economy as a whole. In growth theory, innovation had not always been recognized as an important engine of growth because innovation did not fit in the competitive general equilibrium framework. Schumpeter was one of the rare economists at the time to consider innovation at the center of economic activity but his ideas remained for long out of mainstream economics. Two decades ago, endogenous growth theory proposed new growth models integrating the old ideas of Schumpeter and considered innovations, such as the introduction of new goods, new production processes or qualitative changes in assets, as a necessary condition for long-term growth (Romer 1990; Lucas 1988; Aghion and Howitt 1992). However, the enormous development of the theoretical literature on this subject still remains unmatched by the development of empirical evidence. The main reasons are the difficulties in defining innovation and measuring innovative inputs and outputs (Rogers 1998). In the last twenty years, surveys at the firm level have been suggested as a complementary method to the R&D and patents data to identify other potential measures of innovative inputs and outputs. Despite all the legitimate caveats on the accuracy and objectivity of qualitative data, surveys have contributed to investigating innovation activity of firms that do not invest in R&D, such as small firms or even the sector of services, which accounts for a large part of industrial countries' economic activity.

The present paper adopts the survey method to study the determinants of innovation at the firm level. A questionnaire was sent to more than 26 000 firms of more than 10 employees in Spain in 2006 and 2007. This survey resulted in a usable random sample of 516 enterprises of all sectors. Traditionally, empirical studies have focused on the manufacturing sector. Even though this paper's sample contains a large fraction of manufacturing firms, it also includes firms of other sectors. The main questions were whether the enterprises realized R&D investment in 2005 and introduced innovations in 2004 or 2005. In the survey, innovation was defined as "the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations." (OECD (2005), p.46). This definition is broad and generally lead to a high rate of innovating firms in empirical studies, as is the case in this paper. However, the use of R&D or patents data discards too many firms which do not need them to introduce innovations, such as enterprises in the sector of services.

Although innovation has been difficult to define and measure, some stylized evidence have been produced in the empirical literature. The frequent cross-section result is the positive relationship between productivity and R&D activity at the firm level (Hall 1996; Griliches 1998). However, this result is not statistically significant in longitudinal analyses. The role of firm size has been also very much investigated. It seems that R&D expenditure per employee is independent of the size of enterprise but large firms are reported to display a more than proportionally R&D effort (Cohen 1995; Cohen and Klepper 1996). Griliches

(1990) notes that the latter result could be influenced by the fact that small firms tend not to report R&D investment, as they realize informal R&D. Acs and Audretsch (1988) argue that small and large firms respond differently to innovation determinants. Another important innovation determinant that will not be covered in this paper due to the lack of data is market structure. The empirical studies have produced mixed results. Theoretically, strong competition may incite firms to innovate to gain a competitive advantage but competition tends to reduce market power that is necessary to invest in R&D. The Schumpeterian hypothesis states that monopolistic competition is needed for firms to appropriate the returns of their innovation investments. The empirical studies have not produced a consensus over this issue (Cohen 1995; Symeonidis 1996). The relationship between competition and market structure could be in fact in the shape of an inverted-U (Aghion, Bloom, Blundell, Griffith, and Howitt 2005).

The objective of this section is to identify the relevant variables of our database that are likely to account for the probability for an enterprise to invest in R&D and to introduce new products. This objective is motivated by two facts. First, it is difficult to measure innovation in terms of output units and evaluate its impact on enterprise performance. Thus, we do not know whether innovating enterprises grow faster than non-innovating enterprises or have a higher probability of surviving. Second, no all firms declare innovating and some claim that they need not innovate to make profits. Then, why to innovate? Both facts incite the investigator to look into variables that may affect firm behavior in order to identify innovating and non-innovating profiles by their determinants.

The paper is organized as follows. Section 2 presents the survey and the data. Some descriptive statistics are discussed in Section 3. Section 4 analyzes the econometric results. Finally, section 5 concludes.

2 Survey and data

Our sample consists of 516 Spanish enterprises that responded to a survey we realized in Spain in 2006-2007. Although there are existing data coming from Spanish surveys on innovation, such as the Encuesta sobre las Estrategias Empresariales (EEE) of the Spanish statistical institute (INE) or the Encuesta sobre Innovación Tecnológica of the SEPI foundation, we conducted our own survey to focus as much on non-innovating as innovating enterprises and include information that is not covered by the existing surveys. Our survey was sent electronically to all the Spanish enterprises of the Kompass database (around 26,600 enterprises with at least 10 employees) from November 2006 until April 2007. The Kompass database is a random sample of all the Spanish enterprises that have at least one enterprise as a client or as a supplier. All enterprises of the Kompass sample had an email address and thus received the survey. These enterprises had one month to voluntarily respond to the survey on a dedicated website on the internet. At the end of the process, the survey resulted in a cross-section dataset of 598 enterprises from all sectors. After removing the enterprises that responded partially to the questionnaire, we ended up with a sample of 516 enterprises.

Due to the selection method of our sample (random sampling), we used the INE's population database on Spanish firms (DIRCE database) and stratified sample focusing on innovation (EEE), depending on the variable under study, to identify potential biases of our sample (S1). We performed the Wilcoxon test for three characteristics (firm size, geographical location of firms and sectors of activity) to check whether the hypothesis of equality between the distribution of our sample and those of the INE's population and stratified sample could be statistically rejected. The results of the test show that the equality of distributions cannot be statistically rejected for all three characteristics (Tables 1, 2 and 3).

Table 1: Distribution of Spanish firms by size in the population (DIRCE database) and our sample (S1) and Wilcoxon test

Number of employees	DIRCE database (%)	Sample S1 (%)
$[10 - 50[$	85.4	68.7
$[50 - 200[$	11.7	22.9
$[200 - 500[$	2.1	6.0
$[500 - 1000[$	0.5	1.7
> 1000	0.4	0.7

Wilcoxon signed-rank test
H_0: Var(DIRCE) = Var(S1)
$z = -0.674 \quad Prob > \lvert z \rvert = 0.5002$

Source: authors' database

3 Descriptive statistics

Our sample include 598 Spanish enterprises localized throughout continental Spain, in the Balearic islands and in the Canary islands. Among these firms, 6% belonged to multinational enterprises at the date of the survey and 22% had at least another geographical location beyond the headquarters, either in Spain or abroad.

3.1 Enterprises and R&D

Among the 598 firms that responded to the survey, 58.5% declared having invested in R&D in 2005 while 41.5% declared having not. Some summary statistics on the whole

Table 2: Distribution of Spanish firms by region in the population (DIRCE database) and our sample (S1) and Wilcoxon test

Region in Spain	DIRCE database (%)	Sample S1 (%)
La Rioja	0.8	1.8
Cantabria	1.1	0.7
Extremedura	1.5	1.7
Navarra	1.6	2.0
Asturias	1.8	2.0
Baleares	2.5	2.5
Aragón	2.9	4.7
Murcia	3.3	2.2
Castilla-La Mancha	3.6	3.0
Castilla y León	4.2	4.5
Canarias	4.3	0.7
Galicia	5.2	5.2
País Vasco	5.6	12.7
Comunidad Valenciana	11.7	12.7
Andalucía	14.1	9.7
Madrid	15.6	10.4
Catalua	20.2	27.0

Wilcoxon signed-rank test
H_0: Var(DIRCE) = Var(S1)
$z = -0.142 \quad Prob > \|z\| = 0.8869$

Source: authors' database

sample and on the two subsamples (enterprises that did invest in R&D and enterprises that did not invest in R&D in 2005) are presented in Tables 4, 5 and 6. The mean year of foundation is 1978 for the whole sample and is slightly more recent for the group of firms without R&D. However, the median year (1982) is exactly the same for both subsamples (Table 4). The descriptive statistics on the distribution of enterprises by labor force size show a clear difference between both groups of firms. The mean or the median size of firms investing in R&D is much larger than those of firms without R&D investment (Table 5). This result is in line with all empirical studies on this issue. Other statistics stress the relevance of R&D as a criterion to identify firm behavior. Enterprises investing in R&D export much more and invest more in physical and human capital than enterprises that do not invest in R&D (Table 6). More than two-third of the enterprises that invest in R&D

Table 3: Distribution of Spanish firms by sector in the population (DIRCE database) and our sample (S1) and Wilcoxon test

Region in Spain	DIRCE database (%)	Sample S1 (%)
Mining and quarrying (NACE 10-14)	0.5	1.7
Manufacturing (NACE 15-37)	35.2	75.2
Electricity, gas and water (NACE 40-41)	0.5	1.2
Construction (NACE 45)	16.4	3.6
Wholesale, retail trade and accomodation (NACE 50-55)	21.1	7.4
Transportation (NACE 60-63)	4.2	1.7
Financial and insurance activities (NACE 65-67)	1.4	0.0
Computing (NACE 72)	2.2	2.4
Scientific research and development (NACE 73)	0.4	1.4
Other service activities (NACE 71, 74)	10.8	4.1
Public administration (NACE 80, 85, 90-95)	7.3	1.2

Wilcoxon signed-rank test
H_0: Var(DIRCE) = Var(S1)
$z = -0.142$ $\quad Prob > \lvert z\rvert = 0.8869$

Source: authors' database

export part of their production and less than 10% of them sell more than 50% in the local market. For the enterprises that do not invest in R&D, the corresponding figures are less than 50% and 36%. Another distinctive feature between both subgroups of enterprises is the distribution of qualifications in the labor force. The enterprises investing in R&D hire three times more PhD graduates and have a more qualified labor force than the other subgroup. Finally, the last three paragraphs of Table 6 are devoted to innovation.[1] The enterprises of our sample were asked whether they introduced new products or/and new production process or/and new organization methods in the last two years from the date of the survey. The answers to these questions must be treated with care since respondents may not be accurate or objective. In fact, innovation possesses a qualitative dimension for which there is no objective way to identify it. Due to this qualitative nature, innovation has been hard to measure. The traditional measurement method has relied on quantities such as R&D expenditures or patents but they are innovative inputs rather than innovative outputs. Even if innovative output must be correlated in some way with innovative inputs, the uncertain result of an innovation process should make us cautious about the interpretation of measures of innovative inputs. Moreover, enterprises can introduce innovations without spending on R&D and patents. They are likely small or incremental innovations but can be as profitable as breakthrough innovations for the individual firm.[2] The large spectrum of innovations has led the scientific community to use

[1]Innovation is defined as "the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations." (OECD 2005, p. 46)

[2]The impact of an innovation on an individual firm should be distinguished from the global impact. A firm may introduce an innovation that improves its market share without affecting the technological

Table 4: Descriptive statistics on the distribution of firms by age (year of foundation)

	All firms	Firms with R&D	Firms without R&D
Mean	1978	1976	1980
Median	1982	1982	1982
Maximum	2006	2006	2006
Minimum	1858	1858	1911
Standard deviation	20.9	23.8	16.6
Bias	-2.0	-2.1	-1.4
Kurtosis	9.2	8.9	6.0
Jarque-Bera test	1289.9	636.9	144.7
Prob	0.00	0.00	0.00
Observations	562	288	203

Source: authors' database

Table 5: Descriptive statistics on the distribution of firms by size

	All firms	Firms with R&D	Firms without R&D
Mean	90.3	125.7	42.5
Median	30	40	24.5
Maximum	4340	4340	800
Minimum	10	10	10
Standard deviation	308.4	403.2	76.0
Bias	10.4	8.0	7.1
Kurtosis	123.0	72.8	62.7
Jarque-Bera test	329434.5	63585.4	32947.9
Prob	0.00	0.00	0.00
Observations	533	297	210

Source: authors' database

survey to identify innovative and non-innovative firms. This is the method we adopted for this work, adding qualitative information to quantitative data. Table 6 summarizes some of this information. The results show that 56% of the firms having declared not investing in R&D nonetheless declared having introduced new goods or services in 2004 or in 2005. The figure is even higher for the organization methods (60%) and the production processes (62%). These results tend to confirm that innovation can occur without spending on R&D. Another explanation for these results is given by Griliches (1990) who stresses that small firms, due to financial or organizational constraints, realize informal R&D that is not easy to account for quantitatively and therefore do not report R&D expenditures. Although a majority of our sample's firms which do not report R&D spending declares having made innovations, the frequencies are still substantially lower than for the firms investing in R&D.

3.1.1 Enterprises investing in R&D

Focusing on the subgroup of firms investing in R&D, some summary statistics allow to identify interesting features of their behavior (Table 7). Most expenditure in R&D aims at developing new products (60% of the firms) and production processes to a lesser extent (30%). The clear expected benefit of their R&D investment is an increase in productivity

frontier of the entire economy.

Table 6: Descriptive statistics on enterprises and R&D

	Firms without R&D (%)	Firms with R&D (%)
Exporters	47.2	70.3
Exports > 30% of total sales	9.3	27.7
100% national sales	53.7	29.7
Local sales > 50% of total sales	36.0	7.6
Gross Fixed Capital Formation (GFCF) in 2005	57.9	72.6
GFCF in 2005 but not in 2002-2005	3.3	1.3
GFCF in 2002-2005	72.4	78.5
Investment type:		
CAD	30.4	48.8
Control instruments	43.5	67.0
Robotic	14.0	31.4
Flexible production systems	34.6	57.4
Other technology (internet)	50.5	62.7
Human capital:		
Enterprises with PhD graduates	4.7	15.2
Enterprises with university graduates	65.0	81.2
Enterprises with more than 10% of University graduates	26.2	35.0
Training:		
Enterprises that organized training	77.1	92.7
Computing training	55.6	75.6
Language training	27.6	58.7
Technical training	38.3	70.0
Enterprises that introduced new goods and services (NGS)	56.1	87.5
NGS realized by the enterprise	32.2	58.7
NGS realized in collaboration	11.2	23.6
NGS Realized by a provider	12.6	5.6
Enterprises that introduced new production processes (NPP)	62.6	87.1
NPP realized by the enterprise	42.5	61.7
NPP realized in collaboration	15.9	22.4
NPP Realized by a supplier	9.3	3.0
Enterprises that introduced new firm organization (NFO)	58.9	80.2
NFO realized by the enterprise	42.5	59.4
NFO realized in collaboration	13.6	18.5
NFO realized by a provider	2.8	2.3

Source: authors' database

for 70% of the firms and an improvement in product quality for 17%. Our data show that R&D investment is a risky business since only 25% of the firms declare that it is always successful. Among these R&D investments yielding successful innovations, 30% of the firms decide to patent them. Regarding the financing of R&D investments, a very large majority of firms use internal financial resources and 70% of them use their own cash to finance more than 50% of their R&D activity. A non-negligible fraction of firms (40%) use subsidies as external finance but for a marginal share of their R&D expenditures. Very few firms use banking credit but our survey does not allow to know whether the firms did not obtain banking credit or did not want to use banking credit to finance R&D investments. Another interesting information is the substantial fraction of firms (45%) that declare collaborating with other firms in their R&D activity. These firms may be joint ventures, suppliers or consultancy firms.

3.1.2 Enterprises that do not invest in R&D

Regarding the subgroup of firms that did not invest in R&D in 2005, 80% of them declared that they even never made R&D investment in the past (Table 8). Only 26% declare to plan to do it in the future. This gives some interesting information about firm behavior with respect to R&D activity: either the enterprise invest in R&D continuously (see Table 7) or never. The issue is then to identify the variables likely to explain this observed contrast in firm behavior. The descriptive statistics of Table 8 provide some insights about the factors that seem to explain why some firms decide not to invest in R&D. The main reasons cited by these firms are the large costs of R&D for 40% of them, the absence of market incentives to engage in R&D for 39%, the lack of qualified workers for 30% and the lack of financial resources for 25% of them. The lack of market incentives as one of the main factors for not investing in R&D is corroborated by the answer to the question whether R&D is related to firm's competitiveness. Only 20% of these firms agree with the statement that a lack of R&D implies a lack of competitiveness.

3.2 Enterprises and innovation

The enterprises of the survey were asked to answer the question whether they introduced in the last two years each of the three main types of innovations (product innovation, innovation in production process in innovation in organization methods). The frequencies of responses are presented in Table (9). Three main results may be highlighted. First, the percentage of innovating firms is large which is a confirmation of the existing literature and the fact that innovation is generally viewed in a broad sense. This means that a sizeable fraction of firms (56%) declares that they innovate while declaring that they do not invest in R&D. A firm may thus innovate without investing in R&D. Second, the frequency of firms innovating is much higher when they invest in R&D rather than not. Finally, the decision to innovate does not seem very sensitive to firm size as it is the case with the decision to invest in R&D.

Table 7: Descriptive statistics on enterprises investing in R&D

	%
R&D type:	
production processes	31.4
goods and services	59.7
organization	6.6
Expected benefits:	
increase in productivity	70.3
improvement in product quality	17.2
cost reduction	4.0
reduction in labor cost	2.0
reduction in energy use	0.3
improvement in environmental impact	2.0
Realization of R&D activity:	
continuously	74.9
intends to invest in the future	93.7
Result of R&D activity:	
always positive	25.4
almost always	49.2
sometimes positive	20.5
almost never positive	1.7
Positive results that lead to patents	28.7
Labor force in R&D:	
enterprises with researchers (PhD)	32.7
enterprises with more than 30% of PhD in R&D	18.2
enterprises with technicians	78.2
enterprises with research assistants	44.9
R&D financing:	
Internal resources	84.8
more than 50% from internal resources	68.0
External financing	20.1
more than 10% from external resources	18.8
more than 30% from external resources	11.2
more than 50% from external resources	6.9
Subsidies	40.3%
more than 10% from subsidies	31.0
more than 30% from subsidies	14.9
more than 50% from subsidies	5.3
Enterprises that used following financial support:	
subsidies	55.4
credit	7.3
desgravaciones	5.9
capital participation	0.3
public institutions' support	0.3
awards	0.3
no support	27.4
Source of financial support:	
local government	72.6
national Government	18.5
European Union	5.6
Exchange of information with:	
other enterprises	20.1
customers	38.0
suppliers	4.6
competitors	1.7
experts	15.5
labs	3.6
universities	8.6
public institutions	5.0
R&D activity with other enterprises	45.5

Source: authors' database

Table 8: Descriptive statistics on enterprises that do not invest in R&D

	%
Enterprises did not invest in R&D in 2005 because:	
they did not plan to invest in R&D that year	30.4
they did invest in R&D in the past	19.6
they plan to do it in the future	26.6
Reasons why enterprises did not invest in R&D:	
business risk	70.3
cost	40.2
lack of financial resources	24.8
organization difficulties	22.0
lack of qualified labor	29.9
lack of technological information	15.4
lack of market information	12.1
lack of flexibility	12.6
lack of market demand	24.3
market conditions do not require R&D	38.8
old R&D still good enough	15.4
Lack of R&D implies lack of competitiveness	20.1

Source: authors' database

Table 9: Descriptive statistics on innovation by firm size

	All firms	Firms with R&D	Firms without R&D
Firms having introduced new products (%)			
Firms < 50 employees	72.4 (348)	87.7 (179)	56.2 (169)
Firms [50,250] employees	76.3 (127)	86.5 (89)	52.6 (38)
Firms > 250 employees	87.0 (31)	89.3 (28)	66.6 (3)
All firm sizes	74.6 (516)	87.7 (302)	56.0 (214)
Firms having introduced new production processes (%)			
Firms < 50 employees	74.7	85.4	63.3
Firms [50,250] employees	81.1	88.7	63.1
Firms > 250 employees	93.5	96.4	66.6
All firm sizes	77.1	87.4	62.6
Firms having introduced new organization methods (%)			
Firms < 50 employees	70.6	81.0	59.7
Firms [50,250] employees	72.4	78.6	57.9
Firms > 250 employees	80.6	85.7	33.3
All firm sizes	71.5	80.4	58.8

Table 10: Descriptive statistics on enterprises by firm size

	All firms	Firms < 50 employees	Firms [50, 250] employees	Firms > 250 employees
Enterprises and R&D:				
Enterprises that invested in R&D in 2005 (% of each group size's observations)	58.5%	51.5%	70.0%	90.3%
Enterprises that did not invest in R&D in 2005 (% of each group size's observations) because:	41.5%	48.5%	30%	9.7%
they did not plan to invest in R&D that year	30.4%	33%	18%	n. a.*
they did invest in R&D in the past	19.6%	16.5%	21%	n.a.
they plan to do it in the future	26.6%	26%	31%	n. a.
R&D Financing:				
internal resources	84.8%	85%	88%	78%
more than 50% from internal resources	68.0%	67%	68%	71%
Reasons for not investing in R&D				
business risk	23.8%	26%	13%	n. a.
cost	40.2%	42%	37%	n. a.
market conditions do not require R&D	38.8%	40%	37%	n. a.
old R&D still good enough	15.4%	17%	9%	n. a.
Observations	516	348	127	31

* Not applicable
Source: authors' database

3.3 Descriptive statistics by firm size

We already mentioned that the R&D investment decision depends a lot on firm size as documented by the literature. The larger the enterprise, the higher the probability that this enterprise will engage in R&D investment. This result is confirmed by the frequency rates shown in Table (10). As the firm size increases, the percentage of firm declaring R&D investment in 2005 also increases. A slight majority of firms with less than 50 employees are R&D investors while 90% of large firms are. However, firm behavior characterized by the few questions that were asked is strikingly invariant across group sizes. For firms investing in R&D, the percentage of firms relying on internal resources to finance R&D investment is very similar across group sizes. As for the enterprises that do not invest in R&D, their behavior and the reasons mentioned by them are also very similar across group sizes. One exception is the percentage of firms mentioning the business risk as an obstacle to R&D investment. This reason is cited by 26% of the firms with less than 50 employees and only 13% of the firms hiring between 50 and 250 employees. ?????????% of fimrs that never invested in R&D:

3.4 Descriptive statistics by sector

The enterprise's decision to invest in R&D and to introduce new products may be influenced by sectoral characteristics, such as the technological content, the life expectancy

Table 11: Descriptive statistics on enterprises by sector

	All firms	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Enterprises that made product innovation:	74.6%	75%	74%	82%	67%	82%	82%	77%
Enterprises and in R&D:								
Enterprises that invested in R&D in 2005	58.5%	59.7%	64.3%	76.5%	55.9%	66.6%	44.1%	62.8%
Enterprises that did not invest in R&D in 2005 because:	41.5%	40.3%	35.7%	23.5%	44.1%	33.3%	55.9%	37.2%
they did not plan to invest in R&D that year	30.4%	36%	n.a.*	n.a.	40%	n.a.	n.a.	n.a.
they did invest in R&D in the past	19.6%	14.5%	n.a.	n.a.	11.1%.	n.a.	n.a.	n.a.
they plan to do it in the future	26.6%	30%	n.a.	n.a.	27%	n.a.	n.a.	n.a.
R&D Financing:								
internal resources	84.8%	88%	89%	92%	88%	92%	73.1%	83%
more than 50% from internal resources	68.0%	72%	74%	80%	72%	77%	72.7%	52%
Reasons for not investing in R&D								
business risk	23.8%	26%	n.a.	n.a.	31%	n.a.	n.a.	n.a.
cost	40.2%	46%	n.a.	n.a.	53%	n.a.	n.a.	n.a.
market conditions do not require R&D	38.8%	40%	n.a.	n.a.	22%	n.a.	n.a.	n.a.
old R&D still good enough	15.4%	19%	n.a.	n.a.	18%	n.a.	n.a.	n.a.
Observations		390	27	51	102	39	34	43

* Not applicable
Source: authors' database

(1) Manufacturing (1993 NACE: 15-37)
(2) Food (1993 NACE: 15-16)
(3) Chemical industry (1993 NACE: 24-25)
(4) Metallurgy (1993 NACE: 27-28)
(5) Machinery (1993 NACE: 29)
(6) Wholesale, retail and accomodation (1993 NACE: 50-55)
(7) Services to enterprises (1993 NACE: 71-74)

of the products, or the competition intensity of the sector. The firm behavior regarding innovation is relatively homogeneous across sectors (Table 11). The percentage of firms that made product innovations is high and very similar in the six sectors of the table. There is more heterogeneity in respect of R&D but this heterogeneity goes beyond the distinction between industry and services. Traditionally, it is considered that R&D investment is made by the industrial sector. As shown in Table (11), the sector of services to enterprises invests in R&D as much as the food industry or the sector of machinery. It is in the sector of wholesale, retail and accommodation that the percentage of firms investing in R&D is the lowest.

4 Econometric analysis

Innovation is widely considered as a way for enterprises to survive and to increase productivity. It is not the only way, as many successful enterprises do not innovate. Therefore, innovation is a choice variable for the firms. The objective of this section is to identify the relevant variables of our database that can account for this choice, i.e. the choice for an enterprise to invest in R&D and to introduce new products. From this exercise, we expect to learn more about firm behavior in respect of innovation.

4.1 The econometric model

Considering innovation as an engine of growth, we will define the growth rate of firm-level production as the result of any quantitative or qualitative change in the varieties of goods and services produced or in production technology. Formally,

$$\frac{dy(t)}{dt} = \frac{d}{dt}\int_1^n f_{i,t}[z(t)]di, \tag{1}$$

where $\frac{dy(t)}{dt}$ is the real output growth rate of the firm, $f_{i,t}$ is the production function of good i at time t, $z(t)$ is a vector of inputs and $n \geqslant 1$ is the number of varieties produced by the firm. The innovation may occur in the number of varieties produced, n, in the substitution of one variety by another one (f_j replacing f_i) or in the improvement in the technology ($f_{i,t=1}(.) > f_{i,t=0}(.)$). Even though the costs of innovations may be evaluated, the return of innovations are difficult to identify especially if they occur in the various possible areas, if they are incremental, and if they yield returns in the long run. Due to these difficulties, researchers have focused on $z(t)$, i.e. on measurable variables supposedly associated with innovation, such as R&D investment and patents. The latter can be considered as both an innovative input and output while the former is an innovative input. The drawback of both indicators is its limited scope. No all innovating firms invest in R&D and even less patent their inventions. Moreover, they may signal innovative behavior but they are not necessarily proxies for innovative output. In fact, investment realized by firms to innovate may be unsuccessful. The uncertainty and the innovation costs may explain why some firms renounce to innovation. Another way to study innovation is by using surveys to collect qualitative information on firm behavior with respect to innovation. The drawback of this method is the subjectivity of respondents and the too large number of firms declaring innovating. In this paper, we use both types of indicators: R&D investment decision and innovation decision. Formerly, we assume that

$$I(t) = g[x(t)], \tag{2}$$

where $I(t) \geqslant 0$ is the innovative output, $x(t)$ is a vector of factors including innovative inputs and other relevant variables and $g(.)$ is a function relating these innovation factors and the innovative output. The firm will decide to introduce $I(t)$ on the market if it expects a positive return. Formally, $I(t) > 0$ if

$$E[\pi(t)] = E\left\{y_{(t)}[I(t)]\right\} - C(t) \geqslant 0, \tag{3}$$

where $E[\pi(t)]$ is the expected profit of the firm, $E\left\{y_{(t)}[I(t)]\right\}$ is the expected sales of the innovative output and $C(t)$ is the cost of production. The expected profit of the firm can be interpreted as the expected performance of the enterprise or its survival probability. The expected profit may depend on different factors, such as firm characteristics, market structure, or sectoral idiosyncracies. As we already mentioned, it is hard to measure this expected profit, which will be considered here as the latent variable. If we consider the innovation decision as a binary variable, the decision rule can be defined as

$$I(t) = 1 \Rightarrow \frac{dE[\pi(t)]}{dX} > 0 \quad (4)$$

$$I(t) = 0 \Rightarrow \frac{dE[\pi(t)]}{dX} \leqslant 0. \quad (5)$$

The objective of this paper is to identify the vector of variables X, if any, in order to account for firm's innovative behavior. The general econometric model can thus be written as

$$I = X\beta + \epsilon, \quad (6)$$

where I is the firm's decision on R&D investment or on the introduction of a new product, i.e., a binary variable that take the value of 1 if the decision appears to be yes in the survey and 0 otherwise; the matrix X represents the matrix of explanatory variables that we selected from the ones available in the database; the vector β is the vector of the coefficients and ϵ is a continuously distributed variable independent of X and whose distribution is symmetric about zero.

Both dependent variables of this exercise are dichotomous qualitative variables and are generally estimated with the maximum likelihood method. For both types of estimation we will use the logit model implying the application of a logistic transformation of the linear specification $X\beta$. The error term ϵ has a standard logistic distribution.

4.2 Estimation results

4.2.1 Variables

The econometric analysis consists in estimating the conditional probability of innovating in 2004 or in 2005 and the conditional probability of investing in R&D in 2005. The dependent variables are therefore two dichotomous variables: "Innovation 2004-2005" and "R&D 2005" (see Table 12). The explanatory variables have been chosen according to data availability in the database and as to reflect firm characteristics, market structure and sectoral idiosyncracies. Among the firm characteristics, an important variable that is frequently investigated in the literature is firm "Size". Most studies conclude that R&D

Table 12: Description of variables

Variables	Description
R&D 2005	Binary variable for whether the firm made R&D investment in 2005 (= 1 if R&D done, 0 otherwise).
Innovation 2004-2005	Binary variable for whether the firm introduced new goods or services in 2004 or 2005 (= 1 if innovation done, 0 otherwise).
Age	Age in years of the firm in 2006.
Size	Firm size measured by the number of employees.
Local	Percentage of total sales that is sold on the local market in 2005.
DumExp	Dummy variable for whether the firm exports (= 1 export, 0 otherwise).
Export	Percentage of total sales that is exported in 2005.
College	Percentage of the labor force that has a college graduation in 2005.
Training	Dummy variable for whether the firm organized training for its labor force in 2005. (= 1 if training done, 0 otherwise).
College*export	Interaction variable
Size*export	Interaction variable
DumMC	Dummy variable for whether the firm belongs to the manufacturing or the construction sector in 2005. (= 1 if belongs to Manufacturing or Construction sectors, 0 otherwise).

is positively correlated with firm size. We will test this hypothesis on both R&D and innovation decisions. Another firm characteristics is its "Age". The expected result on the effect of age on R&D and innovation decisions is not clear. If innovation is a necessary condition for firm survival, then we should expect a positive correlation between R&D and innovation decisions and the years of age of enterprises. However, if innovations tend to take place in new firms, then the expected sign of the age coefficient should be negative. We added two more firm characteristics, one on the labor force ("College") and the other on "Training". We expect that a more highly qualified labor force is necessary to introduce or adopt innovations and an innovating firm should generally need to train its labor force to make the innovation successful. As for the market structure variables, we want to test the fact of exporting, the intensity of exports and the intensity of local sales on R&D and innovation decisions. We expect positive coefficients for the first two variables and a negative one for the latter. We finally include a dummy variable for the manufacturing and construction sector to investigate if sectoral idiosyncracies account for firm's innovation behavior.

4.2.2 The determinants of innovation decision

A large majority of enterprises declared in our survey that they introduced a new product in 2004 or in 2005 (see Table 9). The aim of this section is to identify a few determinants likely to account for the probability for a firm to introduce a new product. The results of the estimation are presented in Table (13). As a first comment, the results show that there is a big heterogeneity in firm behavior as only three variables are statistically significant. The dummy "R&D" is positive and very significant. This is obviously an expected result since firms investing in R&D do so in order to innovate. The descriptive statistics showed that an overwhelming majority of enterprises that invested in R&D in 2005 had introduced a new product in 2004 or in 2005. A more interesting result is about export. The dummy variable "DumExp" is not statistically significant implying that the fact of exporting or not is not a relevant variable to account for the probability of innovating. However, the export intensity, i.e. the percentage of production exported, is positive and significant at 5%. The variable "Local" standing for the percentage of production sold on the local market is not significant. The last significant variable is the interaction term between "College" and "Export". This variable is weakly significant and the coefficient is surprisingly negative. Therefore, the determinants that seem to be relevant to influence the probability of innovating are the R&D investment decision and the export intensity. Two other variables deserve some attention. First, the variable "age" is not statistically significant. The innovation decision does not seem to have an effect on the firm's survival. As mentioned in the previous section, if it had an effect, only the innovating firms would remain in the older cohorts. Our results show that it is not the case. Another interesting result is the absence of a statistical relationship between "size" and the innovation decision. This result contrasts with the positive correlation between size and R&D investment as documented by the empirical literature and our results of the next section. Finally, the sector dummy "DumMC" is not statistically significant either.

The estimation results on the probability of innovating did not allow us to construct from the independent variables at hand the profiles of innovating and non-innovating firms. One can conclude that there is a lot of heterogeneity across firms and within both types of firms. However, this econometric exercise could be improved by working further with the independent variables such as "Export" and "Size". Our results are based on cross-section estimations and some insights could be potentially interesting by looking at the longitudinal dimension of export intensity and firm size. Another way of refinement could be the inclusion of new variables such as the gross operating surplus per employee and its variation over time, detailed investment expenditures and its variation over time and competition indexes. From our estimation results, it is also possible to conclude that innovations are so different in magnitude that there should be some classification to distinguish small from bigger innovations. In fact, one way to do this is to consider that enterprises investing in R&D tend to produce bigger innovations than the other enterprises. This is the exercise we propose in the following section.

4.2.3 The determinants of the R&D investment decision

The distinction between enterprises investing in R&D and the others is a way to identify enterprises that have institutionalized innovation activities. Although this distinction does not coincide with the distinction between innovating and non-innovating firms, it may be interpreted as two different scales of magnitude of innovations. We therefore assume that enterprises investing in R&D tend to introduce larger-scale innovations than the other group of enterprises. We propose to estimate the impact of the same explanatory variables as previously on the probability of investing in R&D. The results are presented in Table (14). Many explanatory variables turn out to be statistically significant. As in the previous exercise, the dummy variable "DumExp" is not significant while the

Table 13: Estimation results : innovation decision in 2004-2005

Method of estimation: logit model
Dependent variable: Innovation 2004-2005

Variable	Coefficient (Std. Err.)
Age	-0.0002 (0.0060)
Size	0.0002 (0.0009)
Local	-0.0028 (0.0037)
DumExp	-0.0576 (0.2925)
Export	0.0199** (0.0098)
RD	1.5471*** (0.2548)
Training	-0.1825 (0.3209)
College	0.0088 (0.0083)
College*export	-0.0004* (0.0003)
Size*export	0.0000 (0.0000)
DumMC	-0.4851 (0.3304)
Intercept	0.6173 (0.4853)

Obs.	470
Log-likelihood	-233.1373
$\chi^2_{(11)}$	76.1287
Pseudo R^2	0.14
Percent correctly predicted:	
$y = 1$	91%
$y = 0$	31.4%

Significance levels : $*$: 10% $**$: 5% $***$: 1%

export intensity is very significant and its coefficient is positive. This time, the variable "Local" is significant and its coefficient displays the expected negative sign, implying that the more the firm sells locally, the lower the probability is for the firm to invest in R&D. Another similar result with the previous exercise is the effect of "Age" that is not statistically significant either. This means that investing in R&D is not a necessary condition for a firm to survive. Three other firm characteristics are statistically significant. The variable "Size" is one of them and confirms other empirical studies that conclude that R&D investment is positively correlated with firm size. Then, the variables "College" and "Training" have also a positive effect on the probability of investing in R&D. Finally, the dummy variable for the manufacturing and construction sector is significant and has a positive coefficient.

These results are interesting enough to design the profile of both groups of firms. Thus, enterprises that are large, belong to the manufacturing sector, sell little on local markets, export a great deal, hire highly qualified people and organize training for their labor force have a high probability of investing in R&D. However, this econometric exercise does not say much about the magnitude of the effect that these variables have on the probability of interest since the estimation model is non-linear. In other words, each predicted probability depends on the level of each estimated variable. One intuitive way to assess this magnitude is to draw conditional effects plots and make vary some relevant variables. For example, we consider the estimation of the probability of investing in R&D conditional on six independent variables (Export, College, Size, Local, Training, DumMC). The coefficients obtained are used to calculate the probability of investing in R&D conditional on sample mean values for "College" (11%) and "Local" (21%), the first quantile value for "Size" (18 employees), and 0 for both "Training" and "DumMC". We plot the predicted probabilities as a function of "Export" that varies from 0 to 100%. The result is the solid curve in Figure (3). The predicted probability is less than 20% when the percentage of exports is 0% while it is 30% when exports amount to 50% of sales. The impact of the variable "Export" on the predicted probability is substantial. The two other curves of the graph show that the variables "Training" and "DumMC" have also an important positive effect on the predicted probability. For instance, a firm of 18 employees exporting 30% of its output, that does not belong to the manufacturing or the construction sector and does not organize training for its labor force has a predicted probability of around 25% while the similar firm but belonging to the manufacturing or the construction sector and organizing training for its labor force has a predicted probability of around 65%. We can conclude that the statistically significant variables "Export", "Training" and "DumMC" have a sizeable effect on the predicted probabilities of investing in R&D.

We construct the same conditional effects curves with one modification: the size of enterprise is no longer 18 but 62 employees which is the number of employees of the third quantile (Figure 4). The predicted probabilities look very similar as in the previous graph. Although the variable "Size" is statistically significant, its impact on the predicted probabilities is very small. This can be explained by the distribution of sizes. Most of the

Table 14: Estimation results : R&D investment decision

Method of estimation: logit model
Dependent variable: R&D in 2005

Variable	Coefficient (Std. Err.)
Age	0.0027
	(0.0052)
Size	0.0050**
	(0.0020)
Local	-0.0170***
	(0.0038)
DumExp	0.0126
	(0.2660)
Export	0.0222***
	(0.0079)
Training	1.2065***
	(0.3168)
College	0.0226***
	(0.0076)
College*export	-0.0002
	(0.0003)
Size*export	-0.0001
	(0.0000)
DumMC	0.6159**
	(0.2988)
Intercept	-1.6959***
	(0.4701)
Obs.	470
Log-likelihood	-265.5375
$\chi^2_{(10)}$	108.1398
Pseudo R^2	0.16
Percent correctly predicted:	
$y = 1$	84.2%
$y = 0$	53.3%

Significance levels : $*$: 10% $**$: 5% $***$: 1%

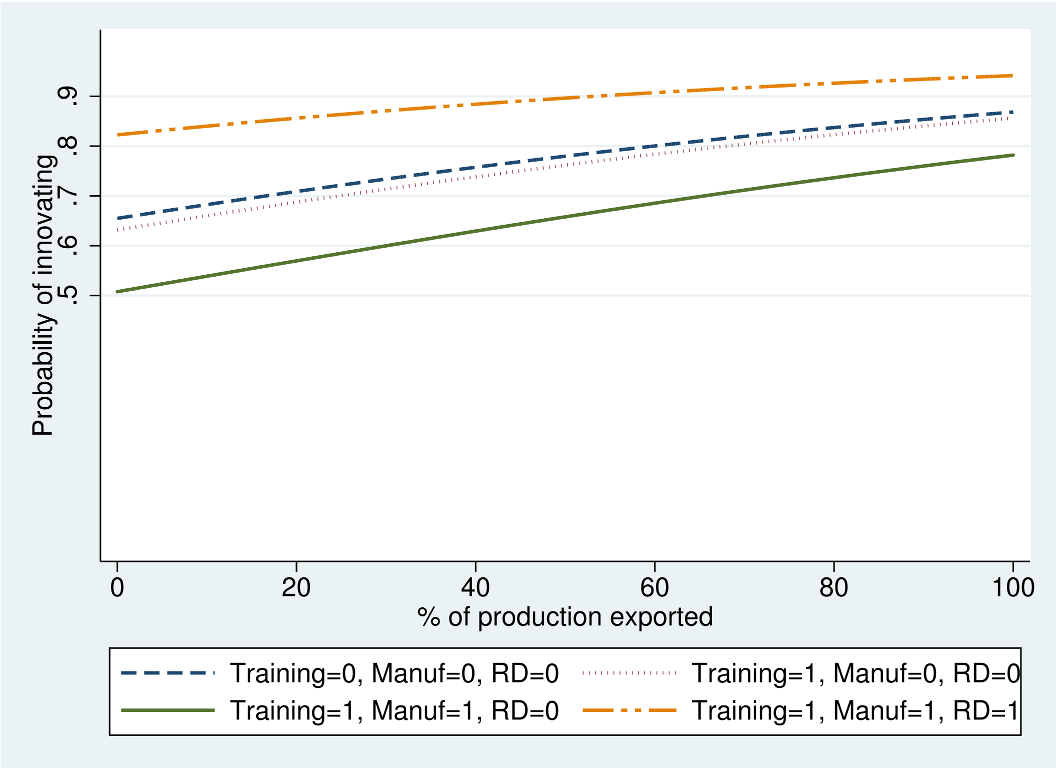

Figure 1: Conditional effects plot: innovation and export

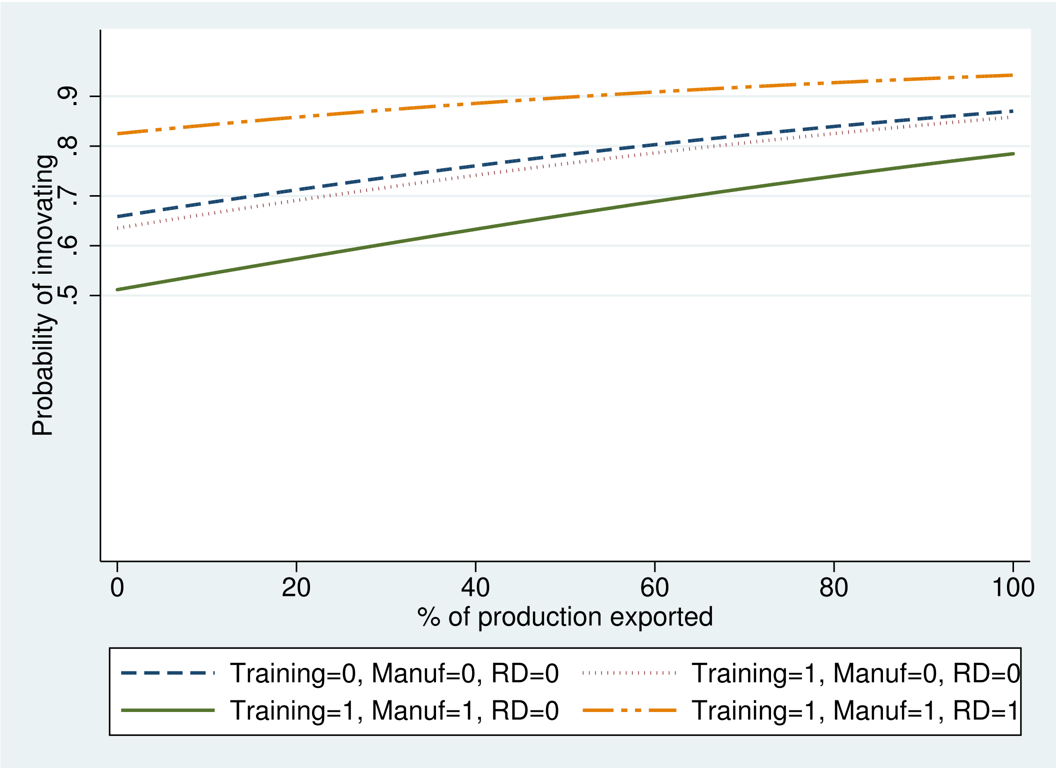

Figure 2: Conditional effects plot: innovation and export

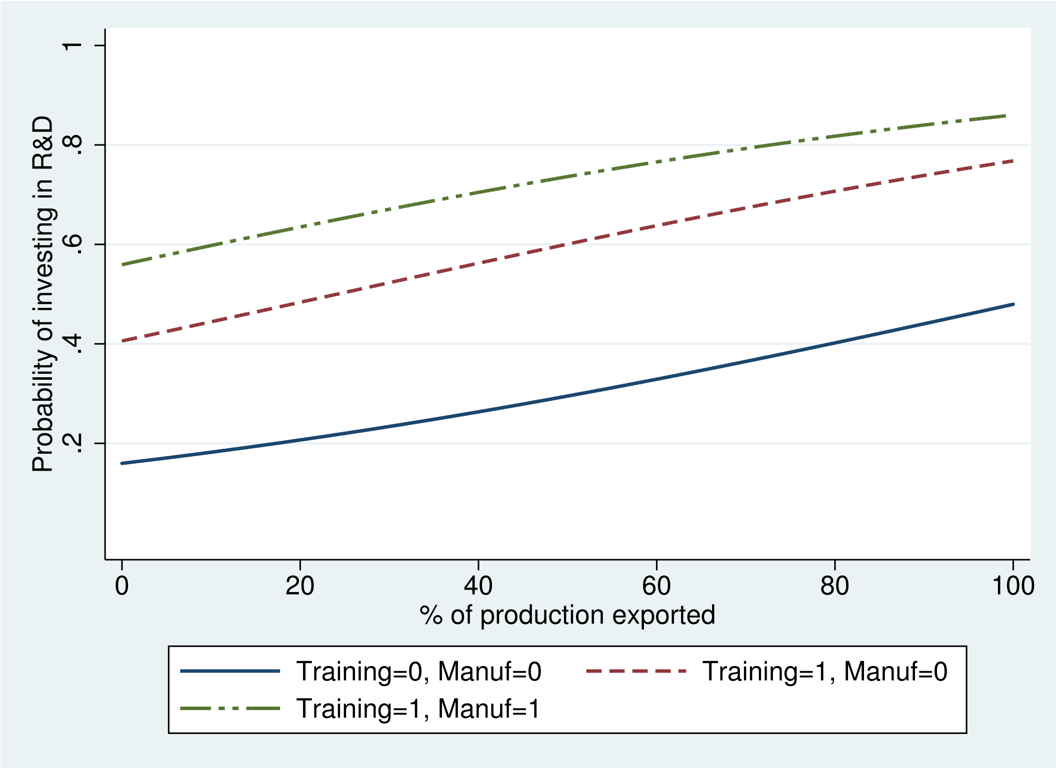

Figure 3: Conditional effects plot: R&D and export, firm size=18

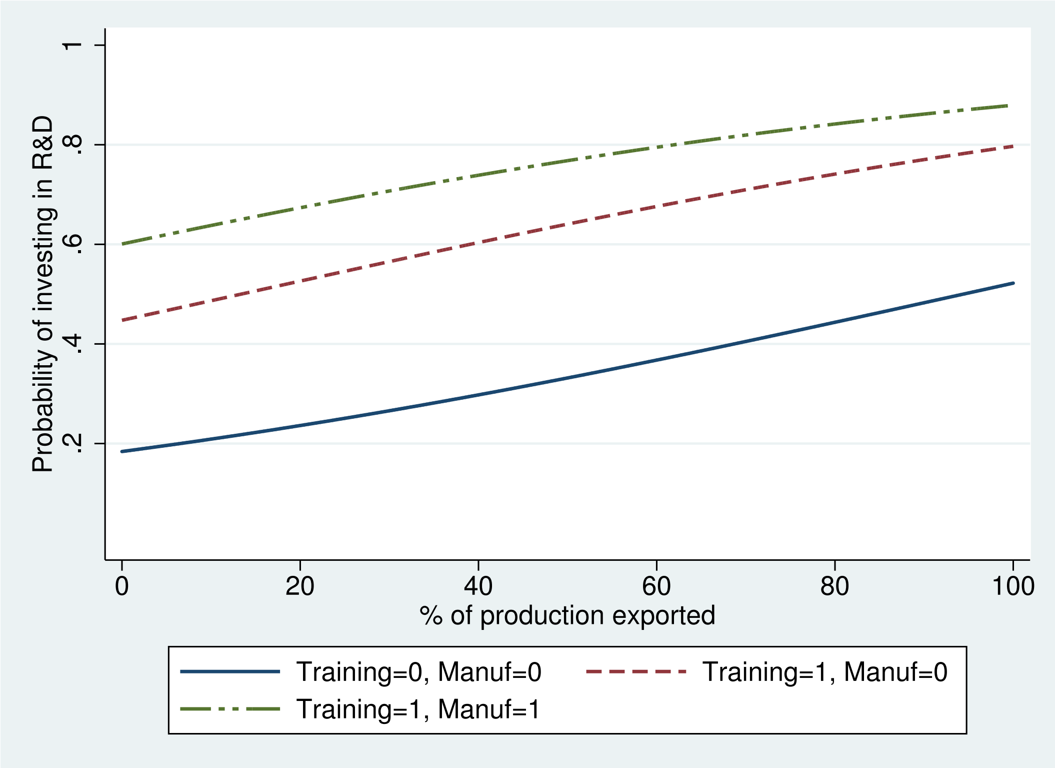

Figure 4: Conditional effects plot: R&D and export, firm size=62

firms of our sample and in the population of Spanish firms have less than 100 employees. The effect of the variable "Size" can be explained by extreme values of the sample. The conditional effects plot allows us to assess the real impact of that variable on the predicted probabilities (see also Figure 5).

5 Conclusion

The objective of this paper was to exploit econometrically the original data from a random sample obtained by a survey conducted by the authors in Spain in 2006 and 2007. The originality of the database comes from the inclusion of detailed data on export, on investment and human capital. The econometric exercises aimed at identifying the determinants of the firm's choice to invest in R&D and to introduce new products. The results are mixed. For the R&D dependent variable, the estimations confirm standard results of the literature on the subject and highlight the export intensity variable (percentage of sales exported) as a very important determinant of deciding whether to invest in R&D. The regression results regarding the firm's decision of introducing product innovation during the period 2004-2005 turn out to be disappointing. Very few explanatory variables available in our database, except the percentage of sales exported and R&D investment, are statistically significant. Therefore, this econometric exercise provides little insight on

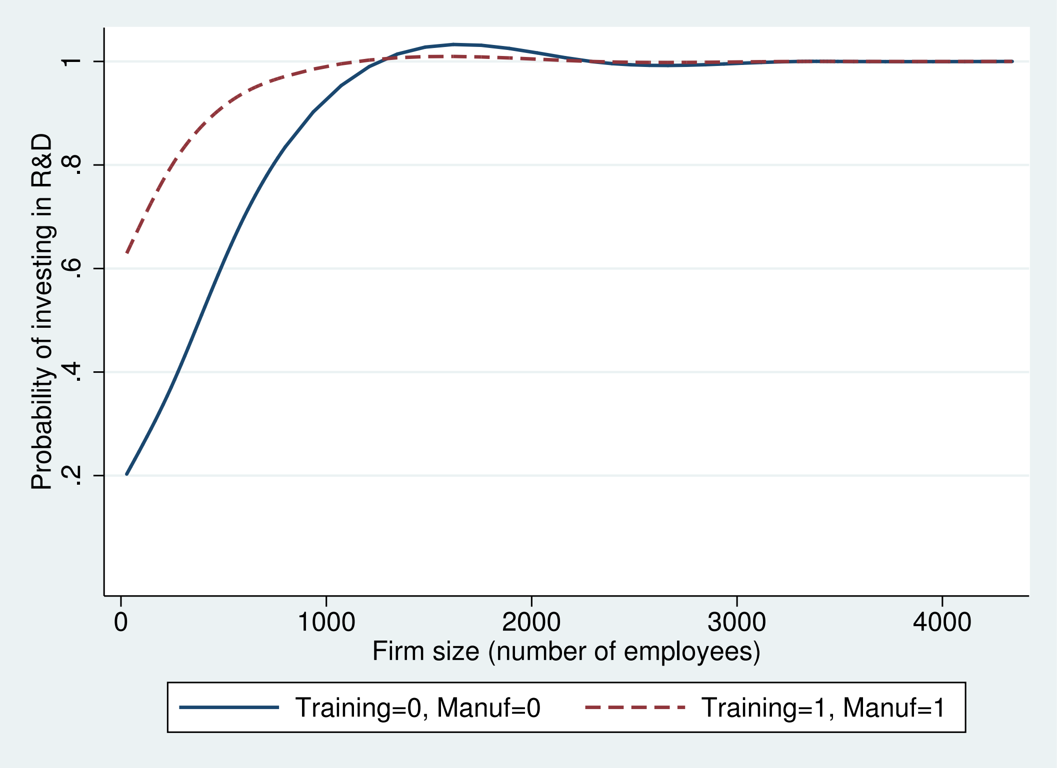

Figure 5: Conditional effects plot: R&D and firm size

firm behavior in respect of innovation. This can be explained by the presence of too much heterogeneity in innovative behavior so that no average innovative firm profile comes out. A more sensible explanation is the problem of definition and measure of innovation leading to measurement error. Innovation is a too broad concept and this causes too much inaccuracy and subjectivity in the surveys' responses. It may be possible to distinguish different scales of innovation, such as world innovation, national innovation, or firm-level innovation, but this will not eliminate subjectivity. A more promising route would be to identify innovative behavior by a combination of detailed data on investments in physical capital and human capital.

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