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HETEROGENEITY OF INNOVATION STRATEGIES AND FIRMS' PERFORMANCE

Giovanni Cerulli and Bianca Potì

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Heterogeneity of innovation strategies and firms' performance

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ABSTRACT. This work deals with two main issues: first, the possibility of identifying differences in firm economic returns (operating profit margins) for different groups of innovation strategy and second, the possibility of checking for factors explaining the probability of being within the best performers for each group of innovation strategy. It is an empirically based analysis using descriptive statistics (first part) and a probit econometric analysis (second part) where data are collected at firm level from two CIS surveys matched with economic accountability data for 902 Italian manufacturing firms for the period 1998-2000. The distribution analysis of profit margins by different populations of firms shows a better economic performance for groups characterized by more complex innovation strategies. Unexpectedly, the risk associated to economic returns is lower for groups where returns' mean is higher. In this case skewness is higher too suggesting that reaching "excellence" is more difficult. The probit regressions account for the role played by different (market and firm) factors on the probability of being the best positioned for each firm population. This work gives two main messages: first, when studying the impact of R&D activity (both on firm productivity or competitiveness) it is worth to distinguish among different kinds of innovation strategy rather than limiting the analysis to aggregated results and second, it appears quite clear that competition awards more complex innovation strategies than simple R&D intra-muros activity.

KEYWORDS: profitability, strategic heterogeneity, R&D and innovation, probit regression

JEL CODES: L60, L10, O30, C25

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CONTENTS

INTRODUCTION

Empirical studies exploring the relation between innovation and profitability are only a few. While there is a huge amount of study on the relation between R&D (or innovative input) and productivity, based on an extended production function[1], there are only a few studies on the effect of innovation on firms' economic results. This is probably due to the higher complexity of modelling the determinants of profitability, which have their roots in the industrial economics discipline (the studies on structure and performance, the theory of imperfectly competitive markets) and to the difficulty of combining innovation economics and studies on structure and performance. Difficulty lays in formulating a clear-cut empirical specification on the basis of pieces of theory and past empirical results in such a way that the design of the test doesn't neglect important aspects and at the same time allows for a clear interpretation.

Inter-industrial analysis of the relation between profitability and industrial structure, based on the microeconomics of price formation and market equilibrium, try to put in relation (different measures of) profitability and industrial concentration or entry barriers; they often found a positive effect of entry barriers on economic results, but of a limited statistical meaning.

The modern theory of markets is elaborated around the role of firm behaviour and strategy and their effect on performance and market structure (models with feedbacks or centred on strategic behaviours). Schumpeter gave an important contribution to the modern theory of markets by identifying a competition different from price and based on the introduction of innovations, by giving attention to potential competition and looking at dynamic efficiency. Empirical studies in the Schumpeterian tradition have been concentrated on testing the relation between innovation and market structure by considering the effect of innovation on industrial structure (stochastic models of firm growth, simulation models) or the role of market concentration and firm size on innovative behaviour. These last series of studies can bring to ambiguous results (Cohen and Levin, 1989), since inter-industrial differences in innovation depend on other determinants (structure of demand, technological opportunities and condition of return appropriability), the basic conditions on which the equilibrium market structure depends (Cohen, 1995). Following the results of a rich mass of empirical studies, technological opportunity and appropriability conditions differ among sectors and can be roughly identified with sectoral dummies. Generally speaking, sectoral heterogeneity can bring to ambiguous results when data are aggregated through cross-sections or when panel data analyses are developed for identifying the determinants of profitability. That's why it is important to follow a mixed strategy of empirical analysis: descriptive statistics and econometric analysis, where the first ones give richer information and the second identifies the few stronger relations operating on average.

Another relevant problem in this empirical literature is to deal with firm heterogeneity: even in the same industry, only some firms are able to capture the returns from their innovation. It can depend on specific firm capabilities, specific strategies within a same sector facing similar technological opportunities or on specific input combinations (Dosi, 1988; Marsili and Salter, 2005). In particular, the construction of technological capabilities indicators for econometric tests is particularly difficult. In general, empirical studies on profitability deal with firm heterogeneity indirectly, through exogenously built clusters of firms (by size, by sector) or directly, following econometric approaches that include or identify stochastic effects (Bayesian models, fixed or random effects in panel data).

Our paper explores the relation between firm profitability and innovation on the basis of a specific dataset, where the results of two Community Innovation Surveys (CIS II and III) are matched with firm accountability data for the Italian manufacturing industry. The dataset is a cross-section, given the type of the core data source, therefore it brings with it the limits/problems linked to cross-section analysis (see below). At the same time CIS surveys allow for two opportunities: an innovation-focused descriptive statistics and the opportunity of econometric analysis on different populations of innovative firms.

1. PROFITABILITY AND INNOVATION: A SHORT SURVEY

Recent studies on profitability and innovation are mostly of two types: a) analysis of the distribution of returns to innovation (Scherer, 1998; Marsili and Salter, 2005) whose relevant contribution is describing the characteristics of the uncertain economic return to innovation and the presence/absence of regularities associated to profit margins, and b) structural models (cross-section or panel data analysis) of the relation between profitability and innovation. Within these structural models "panel datasets make it possible in

[1] See, for example, the classical review by Mairesse and Sassenou (1991).

principle to control for or to study cyclical o secular disequilibria and to analyse directly the long run differences among industries. Industry averages over relatively long time periods shed more light on long run differences than observations for any single year" (Schmalensee, 2005).

These studies use different specifications of innovation: 1) patents (Scherer 1998; Cefis and Ciccarelli, 2005), which are at an intermediary stage between R&D and innovation and that can be used in cross-sector analysis with some difficulty given the sectoral different propensity to patent; 2) the number of (major) innovations (Geroski et al., 1993), which doesn't tell what happens to the larger population of innovative firms (with the risk to run into a sample bias); 3) innovation sales (Marsili and Salter, 2005), which do not allow to distinguish for innovation "quality", due to the fact that prices do not exhaustively reflect changes in product quality, but should reflect in principle market conditions and private returns.

We discuss briefly the main results of these studies. Scherer (1998) explored how much skewed is the distribution of profits from technological innovation and at what type of distribution (Paretian, log normal) it conforms[2]. Higher skewness (such as in the Pareto distribution) doesn't allow for a relation between the effort in R&D or innovation (input measures) and economic return. From a statistical point of view the distribution resulted closer to a log normal one, where the profit opportunities from innovation are roughly proportional to the size of the market. It should be possible for a firm to reduce risk by enlarging the innovation portfolio, a strategy only for a few companies.

Starting from these results Marsili and Salter (2005) investigated other behavioural implications and regularities in the distribution of returns: what do innovation features give rise to the observed distribution of return? The authors used the ratio "firm innovation sales to firm total sales" (from CIS II and III surveys) as the economic return variable for Netherlands and for two panels of innovative firms (total firms and persistent innovators). They observe the return distribution for different types of innovation and find out that it is more skewed in the case of radical innovations than for incremental ones. Novel innovations are more elitist. They also look for a relation between sectors and inter-firm diversity, advancing the hypothesis that firms' technological variety is lower in high-tech sectors[3]. The authors find out that sectoral factors matter in shaping the distribution of performance and selection across firms, but they don't alter the return distribution between different types of innovation.

Geroski *et al*. (1993) evaluated the effects of a major innovation (introduced on the market) on corporate profitability[4]. The empirical model is built upon a conventional "structure-performance" basis: profit margin is determined by industry variables (concentration, import intensity, labour unionisation) and firm variables (market share and the interaction between firm market share and concentration). The authors introduce three innovation variables: one for the number of innovation by firm and two for the *spillover* level in the industry in which the firm operates[5]. They find out that the number of produced innovations has a positive effect on profitability, even if only modest in size "on average"[6].

Moreover Geroski *et al*., by comparing innovators and non innovators, find out that innovative firms enjoy higher profit margins[7], but innovators enjoy also permanent return differences, even in years when they do not introduce innovation on the market. Innovative firms seem to have internal capabilities, which allow them to better enjoy external spillovers and to be insensitive to adverse macroeconomic situations. The authors find a confirmation of the fact that profitability is not linked to the output of an innovation process but to the process of innovation itself that transforms firm's capabilities.

Finally Cefis and Ciccarelli (2005) investigated the effect of innovative activities on corporate profitability for 267 UK manufacturing firms with a 5 years panel data for economic variables (from 1988 to 1992) and a

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2 The author used the royalties from US university patent portfolios and the quasi-rent from marketed pharmaceutical entities as return indicator.

3 "where successful innovation is more imperative for the firms" (Marsili and Salter, 2005, p. 87).

4 The database contains 721 UK manufacturing firms during the period 1972-1983 and the authors use two samples: the population (721 firms) and the innovators (117 firms that introduced at least one innovation during the period).

5 The relation is controlled for firm specific fixed effects (to take into account variation across firms in technological opportunities and appropriability) and for systematic time effects, through lagged profit margins. The authors argue that the lagged margin, while appropriate for reflecting cash flow influence on decisions for research expenditure level, doesn't influence the timing of the innovation output, since time between profits and new innovative output operates with very long lags.

6 Since other research using the same data had found that those innovations had had a greater effect on users' productivity than on innovation producers', authors assume that the same can be taken for profitability. The modest profits realized by innovators were only a fraction of the value that innovative activity produced. At the same time, since the selected innovations had commercial success, the total returns to (successful and unsuccessful) innovation could be thought lower that that found out.

7 Because of the innovation introduced and the larger market share firms have.

balanced panel of 14 years for patents[8]. The econometric specification includes firm heterogeneity using a Bayesian approach and assuming the parameters to be different across firms even if deriving from a common distribution. They found that the effect of innovation on profit is positive and better determined by estimating four empirical specifications and comparing their Bayesian approach with classical estimation methods (panel data with random effect, with fixed effect and pooled OLS). While in the classical model specifications the relation between profit margin and innovation has not a clear pattern (a negative relation for a one year lag and then a random and not cumulative pattern, positive or negative, in the different years), the Bayesian approach shows a more clear trend, being positive and stronger for the first three years and then decreasing smoothly.

The authors tested also if there are differences in profitability between innovators, non-innovators and persistent innovators (which are firms that did not remain without asking for a patent for more than 2 years). They observed that the persistent innovators show a higher mean, median ad maximum value. Finally the authors investigated “whether the implied average steady state of innovators is different from the implied average steady state of non-innovators” and find out that there is a long run persistence in profit differentials.

2. PROFITABILITY AND INNOVATION: OUR EMPIRICAL INVESTIGATION

Generally speaking, it is not at all obvious that innovation activity brings more profit margins to firms given at least cost and risk considerations. Risks act at three levels: from R&D to invention, from invention to innovation, and from commercialised innovation to economic return. Following some paths of the previous studies on the effect of innovation activity on firm profitability, we investigate for a different country and with a different specification of innovation:

- if there are differences in operating profit margins (OPM) among innovators, non innovators, persistent innovators and other specification of innovation strategies;
- if there is a relation between innovation output (share of total sales deriving from innovation) and operating profit margin and if the relation between R&D expenditure and economic return is confirmed for the different groups of innovative firms;
- which factors (and with which strength) do affect the probability of a firm to be the best performer within different population of innovation strategies.

3. METHODOLOGY AND RESULTS

3.1 Descriptive analysis

The sample collects data on 902 Italian manufacturing firms. It merges accounting economic data (firms’ civil budgets) from the Italian National Institute of Statistics with data coming from a matching of CIS 2 and CIS 3 (Community innovation surveys). Accounting data are collected from 1998 to 2003, whereas CIS data refer to 1996 (CIS 2) and 2000 (CIS 3). Within the firm sample, more than half (527) are innovators, i.e., firms that adopted innovative process or brought successfully (incremental or radical) innovations into the market during the three year period. Firms which failed or have on going project are not included.

For the average of OPM over 2001, 2002 and 2003 table 1 presents the main descriptive statistics for the pooled sample and for the sample split by innovators, non-innovators, persistent innovators and firms with other strategy specifications. Firstly, it is of worth to specify that high tech and low tech sector includes both innovators and non-innovators, while making intra-muros R&D includes only firms that are innovators; moreover, as it will be clearer later, the distinction between imitative and first-to-market innovators, as it is recorded by CIS, is a not clear-cut distinction. Our variable of interest is the “operating profit margin” (hereafter OPM) measured as “operating profits” (before taxes and interests payment) divided by “total sales”. OPM is calculated as the average value for the period 2001-2003.

We have investigated through the calculus of mean, median, coefficient of variation and skewness whether the distribution of OPM is similar among different populations of firms, that are: innovators and non-innovators (the pool of 902 firms), innovators (process and product), non-innovators, persistent innovators (firms that remained in the population of innovators during a six years period, from 1996 to 2000), patenting (firm which have presented at least one patent application in a three year period), persistent patenting (firms that remained in the population of inventors and patent applicants during a six years period, from 1996 to 2000), intra-firm R&D based innovators, jointly intra and extra firm R&D based innovators, firms operating in high tech sectors and in low tech sectors, product innovators, process innovators, product and process jointly innovators.

[8] The empirical specification is based on the conventional “structure-performance” frame and the profit margin is a function of costs at firm level (capital intensity and average labour cost), firm characteristics (size and market share) and market structure (industry concentration, interaction between shares and concentration and scale of industry, i.e., the industry sales divided by the number of firms in the industry).

Table 1. Main descriptive statistics for the average of operating profit margin (OPM) on 2001, 2002 and 2003 according to different sub-groups of firms in Italian manufacturing.
* = change of number of observations due to the CIS 3 questionnaire structure; the new number of observations is available in column 11.

Average operating profit margin (OPM) on 2001, 2002 and 2003	1 Number of observa-tion	2 Share on total observ. (%)	3 Mean	4 Std. Dev.	5 Min	6 Max	7 Median	8 Coeffi-cient of variation	9 Skewness	10 Average of Size	11 Number of Observ. for innovators	12 Average of R&D expen-diture inten-sity* (%)	13 Average of R&D em-ployment intensity* (%)
1.Pooled	902	100	0.041	0.104	-0.53	1.094	0.03	2.52	2.13	374	-	-	-
2. Innovators	527	58.43	0.044	0.101	-0.424	0.798	0.032	2.282	2.05	483	347	1.76	5.8
3. Non-innovators	375	41.57	0.037	0.108	-0.53	1.094	0.027	2.913	2.23	223	-	-	-
4. Persistent innovators	397	44.01	0.046	0.101	-0.424	0.798	0.031	2.183	2.67	577	294	1.76	6.0
5. Imitative	79	8.76	0.053	0.108	-0.08	0.798	0.034	2.037	4.39	474	56	1.83	6.1
6. First-to-market	328	36.36	0.04	0.088	-0.424	0.518	0.031	2.205	0.53	527	251	1.86	6.1
7. Patenting	243	26.94	0.055	0.118	-0.424	0.467	0.035	2.145	3.11	635	184	2.11	6.0
8. Persistent patenting	137	15.19	0.063	0.097	-0.529	0.518	0.042	1.539	2.43	759	116	2.19	6.8
9. Non-patenting	659	73.05	0.036	0.097	-0.53	0.518	0.026	2.701	1.39	278	175	1.4	5.8
10. Making R&D intra	341	37.8	0.042	0.108	-0.424	0.798	0.03	2.571	1.85	604	341	1.82	6.3
11. Persistent making R&D intra	233	25.83	0.043	0.107	-0.423	0.286	0.03	2.488	2.24	672	233	1.89	6.7
12. Persistent making R&D intra and extra (jointly)	57	6.31	0.082	0.138	-0.189	0.252	0.056	1.682	2.77	1330	56	2.46	8.0
13. High tech	317	35.14	0.044	0.118	-0.529	0.606	0.042	2.681	2.63	509	190	2.16	7.2
14. Low tech	585	64.85	0.039	0.094	-0.424	0.798	0.028	2.41	1.48	301	169	1.32	4.4
15. Product innovators (only)	116	12.86	0.038	0.094	-0.363	0.518	0.025	2.47	1.64	361	76	2.19	6.3
16. Process innovators (only)	120	13.3	0.049	0.125	-0.334	0.696	0.033	2.551	2.27	369	40	1.06	3.0
17. Product and process innova-tors (jointly)	291	32.26	0.043	0.091	-0.423	0.798	0.032	2.116	1.79	578	231	1.74	6.1

Note: (-) indicates that pooled and innovators firm are (roughly) coinciding when considering firms performing R&D expenditure

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The pooled sample of firms (innovators and non-innovators) is our benchmarking and it shows an average OPM of 0.041. It means that for any 100 euros got from sales the average firm gained 4.1 euros of profits (4.1%). Innovative firms are better positioned than non-innovative firms (with an average OPM of 4.4% instead of 3.7%). These result is strengthened for firms which are persistent innovators (4.6%). The best performance is reached by patenting (5.5%), persistent patenting (6.3%) and firms which have a persistent and jointly intra and extra R&D activity (8.2%). An intra-muros R&D activity, even when persistent (i.e. present in 1996 and in 2000) doesn't indicate a better performance than for an innovator (with or without R&D). This is coherent with the fact that, in our sample, a (only) process innovation strategy shows a better average economic result (4.9%) than a strategy based on (only) product innovations (3.8%) and a mix of process and product innovation (4.3%).

Table 1 shows also the average firm size and the average R&D intensity for each group. The groups of firms have been also ranked for each of these indicators (OPM's mean, coefficient of variation, skewness, average of size and R&D intensity) using the "pooled" group as benchmarking term. The rankings are visible in table 2.

By plotting the 17 firm groups considered in table 1 and standardizing them for their minimum and maximum value, so that each indicator (again: mean, coefficient of variation, skewness, average size and R&D intensity) varies between zero and one, we obtained a series of graphics representing: a) the relation between these indicators (patterns), and b) the relative position of each single group (ranking). Let us briefly comment them.

To begin with, figure 1 shows a positive relation between firm size and OPM mean showing clearly different groups' performances as function of their strategy. The group of firms making intra-muros R&D, whether in a persistent or in a not persistent way (number 10 and 11), has an average size similar to patenting firms (number 7), but with lower economic return. The same we find in the case of R&D intensity (see figure 2): even if the best performing groups have higher value of R&D intensity, some firms' groups with similar relative effort in R&D, such as product innovators (number 15) and firms operating in high tech sectors (number 13), have different average economic return.

Figure 1. Plots among mean, coefficient of variation, skewness and average size for the 17 sub-groups of Italian manufacturing firms of table 1. Each measure is standardized in order to vary between zero and one. The vertical and horizontal lines correspond to the overall sample ("pooled" in table 1)

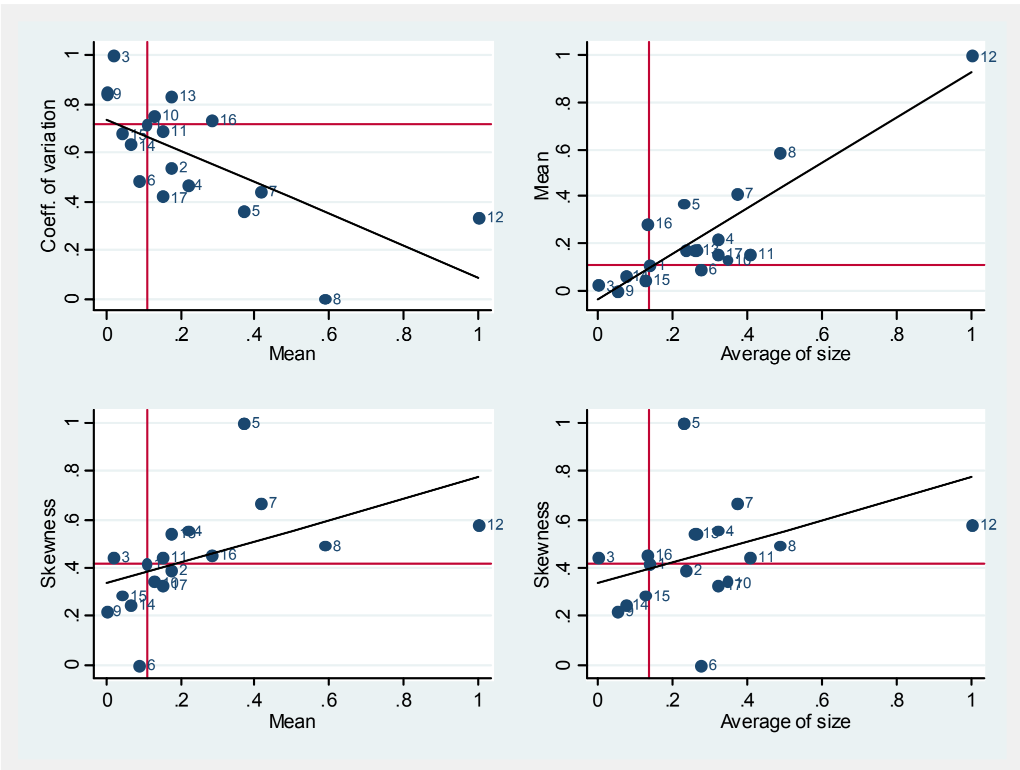


Table 2. Ranking for the groups of Italian manufacturing firms of table 1 according to its indicators

		Mean
12	Persistent making R&D intra and extra (jointly)	0.082
8	Persistent patenting	0.063
7	Patenting	0.055
5	Imitative	0.053
16	Process innovators (only)	0.049
4	Persistent innovators	0.046
2	Innovators	0.044
13	High tech	0.044
11	Persistent making R&D intra	0.043
17	Product and process innovators (jointly)	0.043
10	Making R&D intra	0.042
1	Pooled	0.041
6	First-to-market	0.04
14	Low tech	0.039
15	Product innovators (only)	0.038
3	Non-innovators	0.037
9	Non-patenting	0.036

		Coeff. of var.
3	Non-innovators	2.913
9	Non-patenting	2.701
13	High tech	2.681
10	Making R&D intra	2.571
16	Process innovators (only)	2.551
1	Pooled	2.52
11	Persistent making R&D intra	2.488
15	Product innovators (only)	2.47
14	Low tech	2.41
2	Innovators	2.282
6	First-to-market	2.205
4	Persistent innovators	2.183
7	Patenting	2.145
17	Product and process innovators (jointly)	2.116
5	Imitative	2.037
12	Persistent making R&D intra and extra (jointly)	1.682
8	Persistent patenting	1.539

		Skewness
5	Imitative	4.39
7	Patenting	3.11
12	Persistent making R&D intra and extra (jointly)	2.77
4	Persistent innovators	2.67
13	High tech	2.63
8	Persistent patenting	2.43
16	Process innovators (only)	2.27
11	Persistent making R&D intra	2.24
3	Non-innovators	2.23
1	Pooled	2.13
2	Innovators	2.05
10	Making R&D intra	1.85
17	Product and process innovators (jointly)	1.79
15	Product innovators (only)	1.64
14	Low tech	1.48
9	Non-patenting	1.39
6	First-to-market	0.53

		Average of size
12	Persistent making R&D intra and extra (jointly)	1330
8	Persistent patenting	759
11	Persistent making R&D intra	672
7	Patenting	635
10	Making R&D intra	604
17	Product and process innovators (jointly)	578
4	Persistent innovators	577
6	First-to-market	527
13	High tech	509
2	Innovators	483
5	Imitative	474
1	Pooled	374
16	Process innovators (only)	369
15	Product innovators (only)	361
14	Low tech	301
9	Non-patenting	278
3	Non-innovators	223

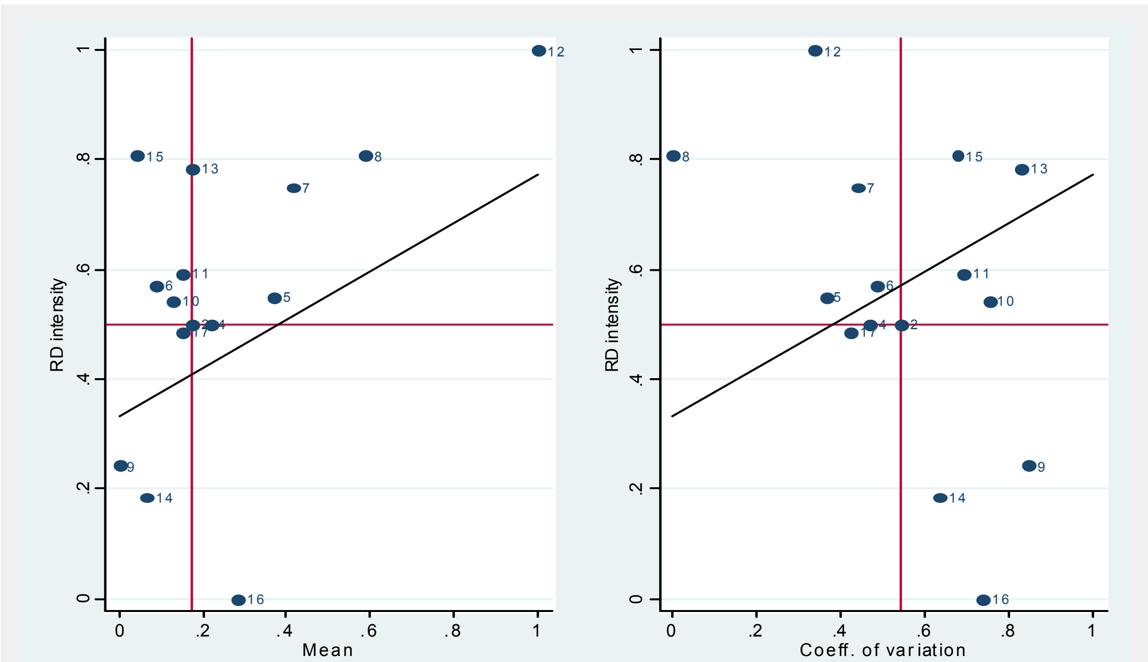
		R&D intensity
12	Persistent making R&D intra and extra (jointly)	2.46
8	Persistent patenting	2.19
15	Product innovators (only)	2.19
13	High tech	2.16
7	Patenting	2.11
11	Persistent making R&D intra	1.89
6	First-to-market	1.86
5	Imitative	1.83
10	Making R&D intra	1.82
2	Innovators	1.76
4	Persistent innovators	1.76
17	Product and process innovators (jointly)	1.74
9	Non-patenting	1.4
14	Low tech	1.32
16	Process innovators (only)	1.06
1	Pooled	n.a.
3	Non-innovators	n.a.

A specific case is that of process innovative firms (number 16), with low R&D intensity but high average economic return. A panel identifies the “excellent” firms (only 56 observations, 6.3% of all sample) with the highest OPM, the highest average size and R&D intensity: these firms have a complex and persistent R&D strategy (number 12), characterized by a combination of internal and commissioned/acquired research.

In terms of coefficient of variation table 1 shows that, by and large, in panels with an average better economic return there is a higher concentration of OPM value around the group mean value, i.e. a low dispersion of firms’ OPM values. Differently from what could be expected, the relation between OPM groups’ mean and the measure of economic risk (given properly by the coefficient of variation) is a decreasing one (see, again, figure 1). It seems like some structural characters make more performing strategies to be also the less risky.

The combination of mean and variation helps to identify the strongest groups: they are the ones with a persistent and complex R&D strategy (number 12) and the persistent patenting firms (number 8). This last group (15.2% of the sample) seems to be the one with the more concentrated OPM value. This result indicates the relevance of having a “persistent” behaviour, particularly in some competitive strategy such as patenting and combining a complex R&D strategy. There is a sort of self-selection, which makes those firms keeping within the most performing strategies less sensitive to business uncertainty. The larger dispersion of economic result is, consequently, in the non-innovative and non-patenting groups of firms.

Figure 2. Plots between mean, coefficient of variation, and R&D intensity for the 17 sub-groups of Italian manufacturing firms of table 1. Each measure is standardized in order to vary between zero and one. The vertical and horizontal lines correspond to the group of innovative firms (according to table 1).



By looking at the distribution of OPM (again, table 1) we can observe that the median value is always below the mean value for all the groups, denoting the presence of a general positive distributional asymmetry. Skewness indicator allows to measure how much asymmetrical is the distribution of profits: the higher and positive the skewness, the lower the number of firms with an OPM greater than the mean value, i.e. the more it is difficult to be “excellent” within the group. Generally speaking, within the better performing groups, being above the mean value is more difficult. Only in three cases, where OPM mean is above or around the benchmarking (at the right of the vertical axis in the figure 1), the asymmetry of OPM distribution is below the benchmarking (the horizontal axis): for innovators (number 2, representing 58.4% of the sample), product and process jointly innovators (number 17, representing 32.3% of the sample) and making intra-muros R&D innovators (number 10, representing 37.8% of the sample). For these groups the OPM distribution asymmetry is relatively low, i.e. it is easier to find firms with a better performance than the group average one.

We also performed a Kolmogorov-Smirnov test for identifying the existence of differences in the distribution of OPM (always averaged on 2001-2003) between the following couple of groups: innovators and non-innovators, imitative and first-to-market, firms in high tech and low tech sectors, patenting and non patenting and some others. Results, reported in table 2, show that in three cases we refuse (at least at the 10% of significance) the null hypothesis of identical distributions: for making (almost one type) of R&D versus non making (neither one type) R&D, for firms in high tech sectors versus low tech and for patenting versus non-patenting firms. The test simply suggests that groups' distribution is more different within these three couples (coloured in grey in table 2) than between innovators and non-innovators firms.

Table 2. Kolmogorov-Smirnov test [(*)]

	Kolmogorov-Smirnov test	P-value	
Innovators vs. Non-innovators	0.040	0.84	equal
Imitative vs. First-to market	0.118	0.33	equal
HT vs. LT	0.097	0.03	different
Patenting vs. Non-patenting	0.095	0.06	different
Making R&D vs. Non-making R&D	0.119	0.04	different
Making R&D intra vs. non-making R&D intra	0.091	0.20	equal
Product innovators vs. non-product innovators	0.026	0.99	equal
Process innovators vs. non-process innovators	0.047	0.67	equal

[(*)] Test for equality in distribution of the average of OPM (operating profit margin) over 2001, 2002 and 2003 according to specific sub-groups of Italian manufacturing firms. We use deviations from the industries' means to take into account sectoral differences. The null hypothesis is H_0: the two groups of firms come from the same statistical distribution. We accept difference in distribution at least at 10% of statistical significance.

Before introducing the structural model, we present two simple correlations of OPM with two critical variables: the "per employee turnover coming from product innovation" (INNT) derived from CIS 3, and the "per employee R&D expenditure" (REDEX). Table 3 shows the result of these simple correlations between OPM in 2001 and INNT in 2000 and REDEX in 2000 respectively, by firm groups.

Table 3. Simple correlation between OPM_{01} and $INNT_{00}$ and OPM_{01} and $REDEX_{00}$ [(*)]

	Correlation between OPM_{01} and $INNT_{00}$	Correlation between OPM_{01} and $REDEX_{00}$
Pooled	-0.016	0.169*
Innovators	-0.031	0.165*
Imitative	0,114	0.252*
First-to-Market	-0.098*	0.168*
Persistent innovators	-0.030	0.241*
HT	-0.035	0.217*
LT	-0.025	-0.038
Patenting	-0.022	0.312*
Non-patenting	-0.053	-0.039
Persistent patenting	-0.060	0.384*
Making R&D intra	-0.019	0.207*
Persistent making R&D intra	-0.036	0.262*
Marking R&D intra and extra (jointly)	-0.071	0.185*
Persistent marking R&D intra and extra (jointly)	-0.103	0.093

[(*)]Correlation between OPM_{01} (operating profit margin in 2001) and $INNT_{00}$ (per employee innovative turnover in 2000) and OPM_{01} and $REDEX_{00}$ (per employee R&D expenditure in 2000) in some sub-groups of Italian manufacturing firms. * = 10% of statistical significance.

While the relation between OPM and the level of R&D expenditure per employee is statistical significant (at least at 10% of significance) for all the groups of innovation strategy (except group 12), the relation between OPM and innovative turnover per employee is statistically non-significant for all the sub-groups (except group 6 with negative sign). There are important reasons why this innovation output variable is not related to economic profitability, and we'll discuss them in the conclusion. As a consequence, in our econometric specification we will come back to the "traditional" indicator of innovative capacity, i.e. the level of R&D expenditure, even if it doesn't identify well process innovation strategy and asked for a reduction of our sample to 497 observations[9].

3.2 The econometric model specification

In this section we present an econometric specification for the firm's probability of being successful. This variable is defined as the probability of obtaining an OPM greater than the overall sample mean. Our task is to inquire into the structural relation between this probability and: a) market and firm structure, b) costs considerations, and c) innovative capacity of firms, by taking into account strategic heterogeneity. The model specification takes the following form:

[9] That is, we excluded non-innovators, since CIS doesn't collect this information for them.

[1] $$Prob\,(OPM_{i,01} > \overline{OPM}_{01}) = f\,(MS_{i,00}\ ,\ CONC_{i,00}\ ,\ SIZE_{i,00}\ ,\ CAP_{i,00}\ ,\ ALC_{i,00}\ ,\ REDEX_{i,00}\ ,\ REDEX\_SECT_{i,00}\ ,\ \varepsilon_{i,01})$$

where $\overline{OPM}_{01}$ is the overall sample mean of *OPM* in 2001, *MS* is the firm market share using firm's turnover at the 2-digit industry level, *CONC* is the four-firms concentration ratio at 2-digit industry level using firm's turnover, *SIZE* is a measure of the firm absolute dimension in term of its number of employees, *CAP* is the capital intensity measured as the total capital stock at book value divided by the total number of employees, *ALC* is the average labour cost measured by the sum of total wages and social contributions divided by the number of employees, *REDEX* is the R&D expenditure per employee and *REDEX_SECT* is the sectoral R&D expenditure per employee at the 2-digit industry level and it has been introduced to take into account potential sectoral externalities.

3.2.1 Variables description

In the specification of our model we consider a set of three different groups of variables: 1) market variables (industry concentration), 2) firm variables (firm market share, firm size, productive factors' costs such as total labour costs per employee and capital intensity), and 3) variables linked to innovation (firm R&D expenditure per employee and sector R&D expenditure per employee). Measure and economic meaning of these variables is presented below.

OPM: the measure of *profitability* is a critical aspect of empirical works on the determinants of economic performance. Following recent applications we use the ratio accounting profits, that indicates the ability of firms to hold price above the average (or marginal) cost to total sales[10]. A relevant aspect in our application is related to the research and development expenditures, which in firm accounting are treated as "current expenditures", while they produce future cash flow and should be better treated as capital stock; the effect of this under-estimation of intangible investment could be an overstating of the return.

MS: ex-ante *market share*, measured as the ratio of firm sales to total industry sales, is a proxy of the firm capability of influencing the price-cost margin[11].

SIZE: firm's size is an indicator of the strength of the firm on the market and its possibility of sustain a more expensive and large portfolio of innovation projects. The size of resources available to a firm helps in diversifying risks and getting a relatively better performance.

CONC: to measure *industry concentration* we use the ratio of aggregated sales of the four largest sellers to the industry total sales. In the typical S-C-P approach high concentration implies the possibility of keeping an extra profit in the long run in a low competitive market. The justification is the association of concentration with high barriers to new entry. In our application these barriers could be build through R&D investments[12]. An ex-ante oligopolistic market structure makes rival behaviour more stable and predictable and, reducing uncertainty, increases the incentive to invent/innovate. In our case it could be inferred also a better capacity of choice in terms of time or type of innovation and a relatively better economic performance.

CAP: capital intensity. This variable is taken as a strategic choice of firms, which can build in this way a barrier to prevent that profit be eroded by the entry of competitors, but it represents also a cost for firms.

ALC: average labour costs. We take labour cost (total salaries divided by the number of employees) as a proxy of the quality of human resources instead of a strict indicator of efficiency. Some recent study on the Italian industry (Destefanis and Sena, 2005) have shown that the quality of human resources has a positive and relevant relation with firm productivity[13].

[10] As it is known accounting data can represent noisy measures of economic variables. At the same time accounting data are used by firms in decision making and are taken into account by the stock markets. The real problem is "the extent to which errors in accounting data are correlated with independent variables used in the regression analysis" (Schmalensee, 2005, p 962). If such correlation is not important, the statistic analysis doesn't miss the real relations involving economic profitability. Another problem can derive from the firm discretion in the accounting procedures. For avoiding this bias it should be better to use alternatives measure of profitability or to build sub-samples that differ in the possible bias (small versus large companies or other) and check for the stability of the results. We do not follow this procedure within our different populations of firms, not to complicate too much the interpretation of results.

[11] If ex-post market share were used it should represent a successful capacity of appropriating economic returns.

[12] The models of patent race allow for a strategic justification of R&D and innovation in oligopolistic industry with potential entry. Concentrated industry can be a favourable environment for protecting profits through innovation.

[13] It should be probably better to use a more specific variable for human resources quality and we plan to introduce them in future applications.

REDEX: firm R&D expenditure per employee. The intra and extra-muros R&D intensity at firm level is a key variable indicating the firm relative effort (given the firm amount of resources) in realizing, committing and acquiring research activity. It is a flow indicator representing in our model an input variable in the innovation process and, more generally, a measure of the firm's capability to innovate.

REDEX-SECT: sectoral R&D expenditure per employee is the intra-muros R&D expenditure by sector and it indicates the degree of externalities in the industry where the firm operates. It has a rather ambiguous meaning since it can represent a proxy for sectoral *spillovers* as well as an indicator of sectoral competition in R&D.

3.2.2 Model estimation

We introduce here some estimation problems, some limitations and specificity of our model. Limitations are essentially due to the temporal dimension of our sample. In fact, while other authors (Gerosky *et al*., 1993; Cefis-Ciccarelli, 2005) exploited a panel dataset, that is, a sample in which each firm is observed for different years, we can just use two single cross-sections for 1996 and 2000. This constraint is due to the fact that CIS variables are collected by a frequency of three years[14]. Moreover, given some lack of information in the firms accounting data source, we exploit CIS data with a single cross-section for the year 2000 (CIS 3), while using some data from 1996 (CIS 2) as instruments to take into account potential endogeneity problems.

Using a cross-section instead of a panel data structure rises various shortcomings. Three in particular seems to be the most important ones: first, by a single cross-section we cannot account for idiosyncratic effects at the firm level (as in the case of fixed or random effects estimation in a panel data setting); second, without a time series structure we cannot estimate the dynamics of the model such as, for example, the significance of short and long term effects of specific regressors (such as in the case of dynamic panel data); third, on the basis of just one year, the sample could not be enough robust to business cycle, so that the risk to run into an "odd" observation could not be completely prevented.

Nevertheless, making use of the CIS has its advantages: first, the CIS is an official and specialized survey on innovation with a really high quality of data and with a great deal of information that many other surveys are in general unable to provide; second, CIS is the only dataset available (at least in Italy) in order to tackle some specific research questions on heterogeneity, thank to the possibility of sub-grouping the sample according to different innovation strategies; third, the CIS allows for a good degree of data consistency (at least for the CIS 2 and 3 we use here).

Problems coming from estimating [1] are of a various kind. A first aspect concerns the cleaning of the dataset. We addressed potential biases coming from letting influential observations within the dataset by using a "Cook's d" truncation that eliminates the most influential observations combining both information on residuals (outliers) and leverage[15]. A second aspect regards problem of collinearity for which we performed an ordinary test by computing "variance inflation factors". A third aspect is the presence of heteroskedasticity: in order to take into account potential correlations in the observations' errors structure, we considered robust regressions with an estimated errors' covariance matrix clustered by industries.

Nevertheless, apart from traditional estimation problems, an other issue typically arising in microeconometric analysis (as well as in industrial econometrics) is the possibility of some regressors to be endogenous, namely, correlated with the error term of the model.

As known, problems of endogeneity could come from three different sources: simultaneity in variables specification, measurement errors in the proxy used to represent some specific theoretical concepts and, finally, the presence of omitted variables (see Wooldridge, 2002, p. 50-51). In order to address these estimation drawbacks we implemented the following strategy: first, in order to attenuate the simultaneity relations among the regressors and the dependent variable, we allow for one year of delay between the hypothetical causes (the covariates, all at their 2000 values) and the dependent variable (at its 2001 values); second, we identify a possible source of further endogeneity in the REDEX_SECT variable both because this variable is a very approximate and rough measure of the overall sectoral externalities arising at the 2-digit industrial level, and because it is probably correlated with many unobservable variables not specified in the model but probably contained in the error term.

Another problem arising in our model estimation is

[14] We can make use of just CIS 2 (based on 1996) and CIS 3 (based on 2000) for issues of consistency in our dataset (namely, we do not use the CIS 1).

[15] We calculate "Cook's d" truncation by running an OLS regression between the dependent variable OPM and the previously specified regressors.

due to the fact that our sample does not correctly represent the population it refers to. This derives, as we said before, directly from the way the sample has been drawn. In case like this, unfortunately, it is possible to run into a "sample selection bias" heavily affecting the goodness of the population parameters to be estimated. In order to address this issue two possible alternatives can be undertaken: the first is to use sampling weights according to the survey sample design chosen and run a weighted regression; the second is to build a "model controlled for design variables" (or "conditioned variables model") consisting of introducing the design variables as dummies in the model (Fazio *et al.*, 2005). We follow this latter alternative since, for the nature of our sample selection, the official weights provided by the CIS 3 could be highly misleading. Hence, we complete model [1] by introducing the three CIS stratifying variables: size (4 modalities), geographic area (10 modalities) and sector (20 modalities).

The method used to estimate equation [1] consists of a probit estimation with one endogenous regressor (IV Probit). Following the work of Rivers and Vuong (1988) a two step procedure can be implemented to obtain consistent estimation of such a model. Nevertheless, a more efficient estimation strategy can be obtained by implementing a conditional maximum likelihood estimation (CMLE) (see appendix A for technical issues). CMLE, however, is computationally more difficult than the two step procedure and since it has to be solved iteratively it can take a lot of time to obtain results. In our case, however, since we suppose just one endogenous regressor, computation is not particularly difficult and we can easily perform it. By using CMLE we also can carry out a test for the exogeneity of REDEX_SECT in 2000 choosing, as its own instrumental variables, REDEX_SECT in 1996 and SIZE in 1998. These variables, in fact, are: a) enough correlated with REDEX_SECT in 2000, and b) sufficiently lagged to be considered independent on the error term at 2001; hence, they seem to be good candidates to be used as instruments. Under standard assumptions, the CMLE test for exogeneity converges asymptotically to a t-distribution so that standard t-table can be easily utilized (Wooldridge, 2002, p. 472-477).

By starting from these premises, our estimation strategy will follow this simple two sequential steps: first, we run a CMLE estimation of model [1] augmented for design dummy variables; second, we calculate the test for exogeneity on REDEX_SECT in 2000 derived from the CMLE: if we accept exogeneity, we run an ordinary probit taking its results, whereas if we do not accept it, we get the results from the previous CMLE.

3.2.3 Results

Model results are presented in table 4. It includes robust probit regressions for five firm groups: Innovators, Persistent innovators, Patenting, Persistent patenting, Making intra-muros R&D, Intra and extra R&D performers and Innovators in high tech sectors[16]. As it can be drawn from the table just in the case of Patenting and Persistent patenting firms it has been necessary, according to the test results, to use a Robust probit regression with instrumental variables (IV-Probit).

For each probit regression table 4 provides the estimation of coefficients, their robust standard errors clustered on industries (in round brackets), the usual tests for the goodness of fit (wald-Chi2 and pseudo R^2), the first step results to control for the goodness on the instruments exploited, the diagnostic tests for the exogeneity of $REDEX\_SECT_{00}$ and, finally, the probability of succeeding for the average firm of each group (when all the variables are assumed to be fixed to their mean group value). Single coefficients represent elasticity computed by holding all the regressors fixed to their sample mean (average marginal effect).

The model specification is not statistically significant for the group of "innovators" (see the Wald-chi2 value). Firm's total R&D expenditure per employee (REDEX) is positively and (statistically) significantly related to the probability of getting better economic position in almost all the groups[17] and it is particularly influent for persistent patenting firms and even more for innovators operating in high tech sectors. In this last case, all other conditions equal, a firm doubling its total R&D expenditure per employee (a 100% positive variation) increases its probability of success of about 23%. This value is about 19% for Patenting, 15% for Persistent patenting and about 17% for Making intra-muros R&D firms.

[16] We didn't include groups where R&D variable is not worth, such as non-innovators and process innovators, neither imitative and first-to-market innovators, since CIS gives non trustable data on them.

[17] The "persistent making intra and extra-muros R&D" group is an exception. In this case, in fact, REDEX is non significant. This result can be probably due both to the fact that this group starts from an already very high average R&D intensity (see table 1) so that a further increase of R&D expenditure per employee could generate R&D scale diseconomies, and to the fact that the (strong) statistical significance of the market share can absorb part of the REDEX effect since higher level of R&D expenditure should be viewed, as we said at the beginning of this paper, also as a form of barrier to entry.

Table 4*

Dependent Variable: Prob $(OPM_{01} > \overline{OPM}_{01})$	Innovators	Persistent Innovators	Patenting	Persistent Patenting	Making R&D Intra	Persistent Making R&D Intra And Extra (Jointly)	Innovators High Tech
	Probit	Probit	IV-Probit	IV-Probit	Probit	Probit	Probit
$REDEX_{00}$	n.s.	0.066*	0.190*	0.151**	0.166*	n.s.	0.232**
		(0.046)	*(0.055)*	*(0.057)*	*(0.085)*		*(0.086)*
$REDEX\_SECT_{00}$ (▲)	-0.152**	n.s.	0.177**	0.305*	n.s.	0.896**	-0.172**
	(0.076)		*(0.108)*	*(0.174)*		*(0.169)*	*(0.059)*
MS_{00}	n.s.	n.s.	n.s.	0.378*	n.s.	1.111**	n.s.
				(0.210)		*(0.325)*	
CAP_{00}	-0.123*	-0.158*	-0.137*	n.s.	-0.253**	n.s.	n.s.
	(0.066)	*(0.098)*	*(n.a.)*		*(0.125)*		
ALC_{00}	n.s.	1.156**	n.s.	n.s.	n.s.	n.s.	n.s.
		(0.450)					
$CONC_{00}$	dropped	dropped	n.s.	-0.393**	dropped	dropped	dropped
				(0.186)			
$SIZE_{00}$	n.s.	n.s.	-0.366**	n.s.	n.s.	-0.374**	n.s.
			(0.187)			*(0.106)*	
Number of observations	497	367	191	112	301	43	208
Wald-Chi2	43.99 [0.169]	18.25 [0.01]	23.27 [0.00]	18.74 [0.00]	n.a.	25.61 [0.01]	n.a.
Pseudo-R^2	0.06	0.10	0.14	0.15	0.09	0.46	0.09
First step regression (F-test)	19.51 [0.00]	77.43 [0.00]	950.8 [0.00]	1799.7 [0.00]	34.26 [0.00]	312.45 [0.00]	318.13 [0.00]
Test of exogeneity (H_0: ρ =0)	0.08 [0.77]	0.20 [0.65]	4.99 [0.02]	5.17 [0.02]	0.15 [0.69]	3.01 [0.08]	1.72 [0.19]
Probability of succeeding	0.37	0.35	0.40	0.43	0.33	0.80	0.36

*Robust probit regressions with instrumental variables (IV-Probit) and ordinary robust probit regressions (Probit) for different groups of firms' probability of succeeding (defined as the probability of performing an operating profit margin (OPM) in 2001 greater than the sample OPM mean in 2001). Estimates are obtained by conditional maximum likelihood (CMLE). Coefficients represent elasticities computed by holding all the regressors fixed to their sample mean (i.e., average marginal effect). Robust standard errors clustered on industries are in round brackets. Tests' p-values are in square brackets. (▲) = variable instrumented by $REDEX\_SECT_{96}$ and $SIZE_{98}$; * = 10% and ** = 5% significance level for the T-test; n.s. = non-significant; n.a. = non-available.

The sectoral intra-muros R&D expenditure is positively and statistically significantly related to the probability of getting an OPM higher than the sample mean for three of the seven groups considered. The group of firms that can better implement its success probability, when in a sector with high technological opportunity and presence of R&D externalities, is that of firms with a more complex R&D strategy. This persistently making intra and extra-muros R&D firms have an increase of the probability of success about 90% when sectoral intra-muros R&D activity increases of 100%. They have a strong capacity of benefiting and absorbing sectoral externalities. For Patenting and Persistent patenting this absorptive capacity measure is about 18% and 30% respectively. The group collecting "persistent innovators" does not show the same pattern: the REDEX sectoral variable is, in fact, not significant. For innovators in high tech sectors, including R&D performers and not, a higher R&D presence in the sector have a negative impact, suggesting a competitive sectoral race difficult to be handled.

Firm market share (MS) is generally a non significant variable, except in two cases, the Persistent patenting and the firm persistently following a complex R&D strategy.

Efficiency or cost aspects influence the probability of being economically the best only in a few cases. CAP, the capital intensity, has always a negative sign and is statistically significant in the groups of Persistent innovators, Patenting and Making intra-muros R&D firms, while the more complex becomes the innovative strategy, the less relevant "efficiency" aspects seem to be.

The average labour cost (ALC), which we take as a human resources quality proxy[18], is positively and 10% statistically significantly related to the probability of being among the best ones in the group only in the case of "Persistent innovators", a more generic or less complex (non based on patent or on R&D) strategy.

The ex ante market CONC is generally a non significant variable, except for the Persistent patenting firm group, where it has a negative sign, indicating more the risk of a strong competition on the probability of being economically successful, than the opportunity given by a more clearly readable context. Moreover we found that CONC is a variable strongly correlated to the sectoral dummy (so that it is sometimes dropped out).

SIZE, finally, is often a non significant variable or significant with a negative elasticity coefficient: this is probably due to the fact that the group average size is enough high (see Table 1) and an increase in scale could probably bring decreasing returns.

Finally, the probit regressions also indicate that the probability of reaching an OPM higher than the sample mean (probability of succeeding) is higher in two groups of firms: the Persistent patenting (such as in Cefis and Ciccarelli work) and the firms with a complex R&D strategy. The "average firm" in the Persistent patenting group owns a 43% of success probability if the value of all the variables considered are held to their sample mean, while for the group of firms identified by a complex R&D strategy this probability reaches the really high value of about 80%.

4. DISCUSSION AND CONCLUSION

When looking at the literature on the impact of R&D or innovation expenditures on firm productivity or on the distribution of profits from technological innovation, a reader is stroked by two facts: the risk of not being remunerated is high and the asymmetry of the economic return is high. This relation needs to be better clarified distinguishing firm characteristics, beyond the sectoral level of aggregation. This can be an important aspects also for policy makers interested in resources allocation. Scholars studying the relation between R&D and productivity at firm level are more and more interested in finding a good indicator of something difficult to capture: the firm innovative capabilities, that could be defined as "what is not explained" by the traditional equations on the relation between R&D and firm productivity[19]. This difficulty is exacerbated in a country like Italy where, just by giving a rough look at the CIS data, it seems that there is one innovation strategy which is more largely diffused: process innovation. This strategy aims to reduce production costs by introducing technological innovations giving to R&D activity a relatively low weight.

We were interested in looking at the final result of firm innovative activity, i.e. its economic return, to understand if something else than "size", and its related meaning of a "larger range of innovation projects", could explain differences in firm economic performance and if there is a role for R&D activity also in a country more oriented to process innovation such as Italy.

Given the difficulties in distinguishing firms by their innovative capabilities, we oriented our exploration on the impact of firm heterogeneity on the innovation economic performance through "groups of innovation strategies" by controlling them in an econometric specification with other firm characteristics.

The feasibility of our work asked for concentrating attention only on firm innovation strategies (as they could be identified through the CIS dataset) without looking at a mix of strategies and in particular to the production value chain of internationalization, which is now a relevant issue for industrial associations, often in connection with innovation strategies.

Another limit of our econometric work, justified by the type of data source, is that it is focused just on one year (2000). It is a cross-section analysis and it doesn't allow us to understand what happens to firms in the medium/long period and towards what economic position the different firm populations converge.

The profitability proxy (firm operating profit before tax and interest payments to firm total sales) is an inter-firms comparable measure and reflects the (exceeding) return once all intermediary goods, labour,

[18] We controlled by a simple robust regression if there is a link between labour cost and number of researchers employed in a firm and we found out a positive and significant relation between these variables.

[19] See, in particular, Mairesse and Mohnen (2002).

organizational and managerial work and risk financial capital have been remunerated. The accountability measure of profits takes into consideration only monetary current expenses (included the yearly fixed capital amortization expenses and the yearly R&D expenditures). Profit margins can derive from different combination of firm and market conditions, and this is a largely studied field in the Schumpeterian tradition.

Many interesting results came out of our work. First of all, looking at the distribution of the firm's average profit margin over three year (2001-2003) we built a rank between firm populations in terms of OPM mean, coefficient of variation and skeweness. Then, through the standardization of results, we plotted different combinations of these indicators by firm population on coordinates axes. Our benchmarking is the pooled sample, combining innovators and non-innovators. In this way we found out a very different positioning of innovators and non-innovators, but also that:

- the strategy characterised as intra-muros R&D based innovation seems to be weak, since both OPM mean value and the coefficient of variation are respectively low and high (compared to the benchmarking term). The persistent intra-muros R&D based strategy, even if better positioned as OPM mean, has a high coefficient of variation (the firms within the group face a risk similar to that of the pooled sample). Totally different is the case of a small group of firms (6% of the sample) with a complex R&D strategy characterised by a combination of intra and extra-muros research activity and by the persistence of this behaviour: they are the best performing and the best protected from risk, only after the persisting patenting firms. We conclude, therefore, that an R&D strategy asks for being articulated on search and combination of competences intra and extra-firm for being really successful;
- patenting strategy (once or in a persistent way) is well positioned both in terms of OPM mean and coefficient of variation. When looking for a specification of innovation, the use of patents allows really well the identification of the better performing firms even if it is worth do not extend these results to all the innovator populations;
- the persistence of the innovation strategy is another relevant aspect: it identifies a good performing strategy in terms of combination of OPM mean and risk (coefficient of variation). It represents a sort of protection or a basis for the firms self selection. At the same time it doesn't give the same result when applied to different strategies: so, persistent intra-muros R&D based innovators (38% of our sample) do not present a significant better protection (coefficient of variation) than that of the sample population, while being a persistent innovator (44% of our sample) gives better results. We cannot control for the effect on a long term of being an innovator, but other works (Cefis and Ceccarelli, 2005) show that the effect on economic return lasts for an average period of three/four years. This is a comprehensible result for patenting firms, which are the unit of observation in Cefis and Cecarelli (2005), while persistence of result is less sure for a simple innovator group of firms. In general from our work we derive that the ability to compete and gain is not reached once for all, the process of learning have to be "maintained" during the time and, finally, even if being a "persistent" innovator improves the performance, the effect of persistency depends on the innovation strategy.
- process innovation strategy (identified as separated from mix product and product innovation) obtains an OPM mean higher than the benchmarking term, but the risk is the same faced by the pooled sample of firms (innovators and non-innovators).
- imitative and first to market innovation strategy have not been extensively commented since CIS data, based on subjective distinctions, are not enough trustable on this aspect.

Before looking at the econometric model, it is worth to consider the result coming from the application to our database of a simple correlation between OPM and innovation output (innovation sales per employee) or OPM and innovation input (R&D expenditure per employee). For all the firm populations the first correlation is statistically non significant, while the second one is significant and positive. The innovation output proxy (innovation turnover per employee) reflects both private returns appropriated by firms that introduce a new (to firm or to market) innovation product and consumer surplus due to the presence of imitators/competitors. Even if we didn't use the ratio "firm innovation sales to total sales", where innovation process is not counted in the innovation sales while it contributes to the firm total sales value, we think that this innovation output indicator does not represent the different product quality and it is not a good proxy for studying the relation with economic result.

The econometric model had the aim of looking in depth to what factors contribute to the probability that a firm in each different population is a best performer, defined as "being above the OPM sample mean value". The model specification has been presented above so that here we want to underline just some results:

- firm total R&D expenditure (intra and extra-muros) has a statistical significant impact on the probability of being a good performer (except for innovator population, where the model is not well specified), but its elasticity is different according to different strategy populations. It also seems to be very relevant for innovative firms operating in high tech sectors, more than for the patenting population;

- the sectoral R&D expenditure is statistically relevant, but in one case it has a negative sign (innovators in high tech sector), where it seems to assume the meaning of "risk of higher competition" with negative effect on firms OPM positioning. In the case of "complex and persistent R&D" population it is a fundamental aspect of the strategy and we find that if the sectoral R&D expenditure doubles then the average firm in the group can get a probability of 80% of being a best performer;
- efficiency and quality aspects related to the production process are specifically worth in less complex strategies, such as persistent innovators, where their elasticity is higher than that of the total R&D expenditure;
- size is not significant or even significant and negative, since almost all firm populations we considered start from a high average size;
- the firm market share is worth only for two (the more complex) strategies, persistent patenting and persistent and combined R&D strategy and, in this second case, it plays a higher role on the probability of being a best performer. This, again, has to be taken into consideration when econometric model are specified for aggregated pools of firms;
- finally the ex-ante market structure (CONC) is redundant, since it is associated with the sectoral dummy for all the cases, except in the IV probit regressions, where it is not significant or even it has a negative sign (persistent patenting group).

In conclusion, this work gives two general messages: when studying the impact of R&D activity (both on firm productivity or competitiveness) it is worth to distinguish between different kinds of innovation strategy. It seems that competition awards more complex innovation strategies, the only case in which firms playing the business game have both higher returns and a lower risk of being looser.

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APPENDIX A

CONDITIONAL MAXIMUM LIKELIHOOD ESTIMATION (CMLE) FOR THE IV-PROBIT MODEL

In this appendix we provide a brief formal description of the conditional maximum likelihood estimation (CMLE) for the instrumental variable probit model (IV-Probit) proposed in the paper (see Newey, 1987). Our point of departure is the following population structural equation:

$$[\text{A.1}] \quad \begin{aligned} y^* &= \mathbf{x'\delta} + \alpha x_1 + u \\ y &= 1[y^* > 0] \end{aligned}$$

where y^* is the latent variable and $1[y^* > 0]$ is an index function that values 1 if $y^* > 0$ and 0 otherwise. Suppose that the variable x_1 is endogenous having the following reduced form:

$$[\text{A.2}] \quad x_1 = \mathbf{x'\gamma}_1 + \mathbf{z'\gamma_2} + v = \mathbf{w'\gamma} + v$$

where **z** is a vector of instrumental variables for x_1. To apply CMLE we bear on the following assumptions:

1. u and v follow a bivariate normal distribution of this kind: $(u,v) \approx N_2(0,\sigma^2{}_u;0,\sigma^2{}_v;\rho)$ where ρ is the correlation between u and v (that is, $\rho = \sigma_{uv} / \sigma_u \sigma_v$)
2. u and v are independent of **w**;
3. $\sigma^2{}_u = 1$.

These assumptions suggest that the only possible cause producing endogeneity of x_1 is a ρ different from zero, that is, the existence of some correlation between u and v. In order to estimate the parameters we have to remember that, in the case of normal bivariate distribution (u, v), we have that:

$$f(u \mid v) = N(\alpha + \beta v; \sigma_y{}^2(1-\rho^2))$$

where $\alpha = \mu_v - \beta\mu_u$, and $\beta = \dfrac{\sigma_{uv}}{\sigma^2{}_v}$. We can write u as:

$$u = E(u \mid v) + [u - E(u \mid v)] = \alpha + \beta v + e$$

where e is by construction independent of **w** and v and, as a consequence, of x_1. Since $\mu_v = \mu_u = 0$ we obtain from the preceding equation that:

$$[\text{A.3}] \quad u = \beta v + e .$$

From the joint normality of (u,v) we have that also e is normally distributed with:

$E(e) = 0$

$Var(e) = Var(u - \beta v) = Var(u) + Var(-\beta v) + 2Cov(u;-\beta v) = 1 + \dfrac{\sigma^2{}_{uv}}{\sigma^4{}_v}\sigma^2{}_v - 2\dfrac{\sigma^2{}_{uv}}{\sigma^2{}_v} = 1 - \rho^2$ (since $\sigma^2{}_u = 1$).

Now, we can substitute [A.3] into [A.1] obtaining:

$$\begin{aligned} y^* &= \mathbf{x'\delta} + \alpha x_1 + \beta v + e \\ y &= 1[y^* > 0], \end{aligned}$$

that represents a "latent variable model" for which the probability of succeeding takes the following form:

[A.4]

$$\Pr(y = 1 \mid \mathbf{w}, x_1, v) = \Pr(y^* > 0 \mid w, x_1, v) = \Pr(e > -(\mathbf{x'\delta} + \alpha x_1 + \beta v)) = 1 - \Phi(-(\frac{\mathbf{x'\delta} + \alpha x_1 + \beta v}{\sqrt{1-\rho^2}})) = \Phi(\frac{\mathbf{x'\delta} + \alpha x_1 + \beta v}{\sqrt{1-\rho^2}})$$

where $\Phi(\cdot)$ is the normal standard cumulative distribution function of e.

Given these premises we can consider the maximum likelihood estimation for the parameters of the model identified by equations [A.1] and [A.2]. The procedure focuses on the join distribution of (y,x_1), the two endogenous variables. In fact, by considering the law of conditional probability, this join distribution conditional to **w** can be written as:

$$[\text{A.5}] \quad \Pr(y, x_1 \mid \mathbf{w}) = \Pr(y \mid x_1, \mathbf{w}) \cdot \Pr(x_1 \mid \mathbf{w}) .$$

Let us focus first on $\Pr(y \mid x_1, \mathbf{w})$. Tacking equation [A.4] and substituting v with $v = (x_1 - \mathbf{w'\gamma})$ from equation [A.2] we get that:

$$\Pr(y = 1 \mid \mathbf{w}, x_1) = \Phi\left(\frac{\mathbf{x'\delta} + \alpha x_1 + \beta(x_1 - \mathbf{w'\gamma})}{\sqrt{1-\rho^2}}\right) = \Phi\left(\frac{\mathbf{x'\delta} + \alpha x_1 + (\rho/\sigma_v)(x_1 - \mathbf{w'\gamma})}{\sqrt{1-\rho^2}}\right),$$

so that, by posing $\lambda = [\mathbf{x'\delta} + \alpha x_1 + \beta(x_1 - \mathbf{w'\gamma})]/\sqrt{1-\rho^2}$, we can calculate the probability distribution of $(y \mid \mathbf{w}, x_1)$ as:

$$[\text{A.6}] \quad \Pr(y \mid \mathbf{w}, x_1) = [\Phi(\lambda)]^y \cdot [1 - \Phi(\lambda)]^{1-y}$$

As regards the $\Pr(x_1 \mid \mathbf{w})$ it is particularly simple to write down it, since from [A.2] and previous assumptions $(x_1|\mathbf{w}) \approx N(\mathbf{w'\gamma};\sigma^2{}_v)$. Therefore we have that:

$$[\text{A.7}] \quad \Pr(y, x_1 \mid \mathbf{w}) = [\Phi(\lambda)]^y \cdot [1 - \Phi(\lambda)]^{1-y} \cdot (1/\sigma_v)\phi\left[\frac{x_1 - \mathbf{w'\gamma}}{\sigma_v}\right],$$

where $\phi(\cdot)$ represents the density function of the standard normal distribution. By tacking log of [A.7] for the observation i and getting rid of the terms non containing parameters we have that:

$$[\text{A.8}] \quad \log \Pr(y_i, x_{1i} \mid \mathbf{w}_i) = y_i \cdot \log \Phi(\lambda_i) + (1 - y_i)\log[1 - \Phi(\lambda_i)] - \frac{1}{2}\log(\sigma^2{}_v) - \frac{1}{2}\frac{(x_{1i} - \mathbf{w}_i\mathbf{'\gamma})^2}{\sigma^2{}_v} .$$

Now, summing this expression on i and maximizing with respect to parameters $\gamma, \alpha, \rho, \sigma_v$ we obtain their maximum likelihood estimation. These estimations are calculated using an iterative procedure. Finally, we can test the exogeneity of x_1 either using an asymptotic t-test or a likelihood ratio test for the null H_0: $\rho = 0$. In our application we use a likelihood ratio test with 1 degree of freedom since we suppose just one endogenous regressor. This procedure, nevertheless, can be easily extended to the case of multiple endogenous regressors.

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