Are small firms less innovative than large ones? A statistical overview on an European context and the peculiarities of Italy

by

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Abstract

In this paper the authors want to verify, in a sample of seven European countries, if there is a relationship between firm size and the ability to obtain product, process and organisational innovation. If such relationship exists, they try to understand if this may be attributed to a different allocation of key resources or to some "intrinsic" differences. Besides the analysis of the overall sample, the authors look specifically at Italy, making a comparison with the international context.

The authors find that small firms (from 10 to 15 employees) have a disadvantage respect to medium and large firms in the innovative capacity; with partial exception of process innovation, this can be explained by a different allocation of key resources, like R&D, human capital and professional management.

The international comparison let conclude that the above results substantially hold for Italy too; there are anyway some peculiarities medium (from 16 to 50 employees) Italian firms have an higher capacity in process innovation respect to the average of the sample, while all dimensional classes suffer in organisational innovation; in the end, in all kinds of innovation the distance between small and medium/large firms in Italy is not significantly different than the average of the sample.

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1. Introduction

Because of its importance for competitiveness and for well-being, many scholars studied characteristics and determinants of innovation.

A tradition of well-established studies, dating back to the founder of the modern economics of innovation, Josef Schumpeter, investigated the relationship between firm size and innovation. Other largely investigated sources of variety in innovation performances have been identified in the countries where firms operate and in their technological sectors, generating the concepts of national system of innovation and technological system of innovation and giving birth. This focus on the country and sector peculiarities gave birth to a lot of studies which investigated, mainly in a comparative perspective, the characteristics and the innovative performance of specific countries and sectors.

This study aims to give a contribution to the study of the relationship between firm size and innovation, with a particular focus on Italy, compared with a European context and controlling for the sectorial variety.

This paper presents in fact a statistic framework about the product, process and organisational innovation in the small firms, compared with the same kinds of innovation in medium and large firms. We compare the reality of seven European countries (Germany, Austria, United Kingdom, France, Spain, Italy and Hungary), with a peculiar attention for Italy.

More precisely, we want to understand if there are systematic differences between firms of different dimensions in the ability to obtain product, process and organisational innovation. If such difference exists, we try to understand if this may be attributed to a different resource allocation or to intrinsic abilities due to the dimension itself.

After investigating this issue over the whole sample, we focus specifically on Italy. First, we pose for the Italian firms the same research question as above, trying to verify if and why in Italy small firms are less innovative than larger ones. Then, we try to understand if the distance between small and medium/large firms in innovation ability in Italy is larger or smaller than in the other countries.

The interest of this study lies in the width of the database used, which lets an international comparison, and in the use of econometric techniques, which allow a closer and more detailed look at issues otherwise treated in many descriptive reports. This study is anyway conceived as a quantitative overview, preliminary to more in-depth theoretical analysis.

The paper is so structured: the following section reports summarizes some findings of the previous literature; the third section describes the data used and reports some descriptive statistics; the fourth section reports the results of the multivariate analysis about the relationship between firm size and innovation; the fifth section presents the results of some econometric insights about the Italian situation. A synthesis of results and conclusions close the paper.

2. Literature review

As mentioned in the Introduction, The importance of innovation has been largely emphasized by economists: it is a key factor for competitiveness and productivity of firms (Galia and Legros 2004; Tourigny and Le 2004; Storey 2000) and a main key to long-term well being as a mean to address future societal challenges through the introduction of new products, services, business and social processes (Economic Commission, 2010).

Because of its universally acknowledged importance, scholars investigated in depth its characteristics and determinants.

First of all, the distinction between the various type of innovation is fundamental. The term innovation includes technological innovation and innovation in organizational methods (AECA, 1995). According to Freeman (1974) technological innovation refers to innovation in products (changes in products or commercialization of new products) and innovation in production processes (changes in manufacturing processes or acquisition of new equipment). Organizational innovation is based on changes introduced in the organizational structure of the company and the administrative process, aspects that are more related to management than with the company's main activities.

The issue of the relationship between firm size and innovative capacity is largely debated in the economic literature. The milestone is represented by the two classical contributions by Schumpeter: in Schumpeter Mark I (Schumpeter, 1912) the engine of innovation is placed in dynamic, highly

competitive small firms; this view is based on his theory of *creative destruction*: small, entrepreneurial firms, coming from outside the existing circle, with their innovations challenge the incumbent firms; in Schumpeter Mark II (1942) large firms, with great financial resources and R&D laboratories, are seen as the drivers of innovation, creating entry barriers for potential rivals, protecting their monopoly power: this is the view of *creative accumulation*.

On the basis of both models, many later economists identified three different theories of innovation patterns (Keklik, 2002).

The first one is the theory of industry life cycle. According to this theory, the relationship between innovation and firm size is a function of the state the industry is in. Rothwell and Dodgson (1994) suggest that the role of small firms is more relevant where entry cost are lower and a niche market exists; then, along an S-shaped cycle, the relationship evolves toward a mature situation where a higher concentration is found in both innovation and markets.

The second theory considers the relationship between firm size and innovation as dependent from the market structure: according to Acs and Audretsch (1988) large firms are more innovative in monopolistic markets and concentrated industries with high barriers to entry, whereas small firms perform better in competitive markets.

The third theory is really a group of theories referred to as new evolutionary theories: they underline the importance of technological regimes for different industries in explaining innovative activities.

It is not among the goals of this paper to retrace such debate; we just desire to recall some key points, identified by the theory and confirmed by the empirical analysis. On one side, it has been underlined the dynamism of small firms, particularly in industrial districts or in some innovative sectors like spin-off deriving from the world of the research, which lets them avoid excessive bureucratization or lets them better exploit some "informal" sources of knowledge, like learning process; on the other side, some characteristics of the main source of innovation, R&D, favour large firms: increasing returns to R&D imply higher efficiency associated to larger projects; the risky and uncertain nature of innovation favours a diversified R&D portfolio, which is more easily accessible to large firms

Consistently with these theoretical premises, empirical analyses generally show that large firms spend more in R&D than small ones, but often large firms show a lower productivity of R&D itself (Evangelista and Mastrostefano, 2006). Notwithstanding their relatively low R&D productivity, the higher amount of R&D expenditure and of other crucial

factors imply that, on aggregate, large firms introduce innovations more frequently than small ones. As an example of such analyses, we cite the paper by Bugamelli et al. (2012), which reports that, according to data of CIS 2008, in all major European countries, the ratio of innovative firms is higher among larger firms.

Indeed, this is just an aggregate results: many studies underlined the sector-specific nature of technological activity, so that some scholars talk about sectoral systems of innovation (Malerba, 2002). In this view, the relationship between firm size and innovation is different in different technological sectors.

Another source of variety in innovation performance has been identified in the economic, social and institutional framework in which firms operate, because it affects the ways in which knowledge is generated, shared and diffused within the economy (Archibugi et al. 1988). Even though some significant differences, in such institutional framework, may exist between cities, region, etc., the relevance of national dimension justifies the concept of National System of Innovation (Nelson and Rosenberg, 1993). According to this concept, the characteristics and the relationship between the institutions which are crucial for innovation (firms, education system, government, etc.) affect the long term technological performance of countries. Explicitly belonging to this stream of literature, or inspired far away from it, many studies analysed the innovative characteristics and performance of single countries, often in a comparative perspectives. As regards Italy and the issue of firm size, Bugamelli et al. (2002), focused on the Italian situation, concludes that the average small dimension of Italian firms is an element of weakness for innovation. Many other contributions (see, for instance, Onida, 2004 and Giunta and Rossi, 2017) underlines the limit represented for Italy by the firm size in the current economic environment, notwithstanding the persisting dynamism of many small firms.

From this synthetic review of the literature, it is possible to conclude that the relationship between firm size and innovation is remarkably complex; it implies considerations about endowments of factors and efficiency in exploiting them; it depends on the life stage of the firms, on the market structure where firms operates; it varies across sectors and countries. This complexity and the still unanswered question justify a study like this, which analyses many of these questions, considering a set of countries belonging to a rather homogeneous economic context, controlling

for the sector variety and focusing on a specific country, Italy, comparing it with the rest of the set.

3. Source of data and descriptive statistics

For our analysis, we used data from the EFIGE survey. EFIGE (European Firms in a Global Economy) is an international research project under the auspices of the European Commission. A large survey with six sections was submitted to a sample of 14,911 firms in seven European countries: 3,019 in Italy, 2,975 in France, 2,973 in Germany, 2,832 in Spain, 2,142 in the United Kingdom, 488 in Hungary, and 482 in Austria. The stratification of the sample was done according to the size and business sector, taking into account the main geographical areas of each country. The questions are related to the 2007-2009 period.

In the survey firms with less than 10 employees are not considered. Therefore, our analysis will not concern the micro-firms. This category of firms is by far the largest everywhere and it is particularly prominent in Italy: Onida (2004) reports that 95.4% of Italian firms are micro firms (from 1 to 9 employee); the percentage of micro firms is 94.5% in United Kingdom, 87.9% in Germany, 93.1% in France, 94.8% in Spain, 86.2% in Austria.

To have a more easily understandable comparison between firms of different dimensions, we group firms in three categories, according to the number of their employees: we have small firms from 10 to 15 employees; medium firms from 16 to 50 employees and large firms with more than 50 employees. The threshold of 15 employees is particularly significant for Italy, as some important laws regarding dismissals hold for firms with more than 15 employees.

It has to be underlined that our definition does not match the international definitions (small firms are usually identified as firms between 10 and 50 employees, and often some other characteristics are needed about property and turnover).

As our analysis is focused on firm size, as a first step we calculate the average and medium number of employees per firm.[3] Table 1 reports such

[3] The firms were asked to declare the total number of employees in their home country in 2008. They had to refer to the firm and not to the Group (if the firm belongs to one) and had to include all the employers, temporary staff, excluding free lancers and occasional workers.

values for each of the seven countries, then, in the last row, the values for the whole sample.

Tab. 1 - Average and median number of employees per country

Country	*Average*	*Median*
Italy	52.5	26
Germany	85.4	35
United Kingdom	61.5	29
France	67.0	27
Spain	53.3	25
Austria	81.1	30
Hungary	78.7	31
All countries	65.1	28

We observe significant differences across countries: the average number of employees goes from 85.4 in Germany to 52.5 in Italy; the median from 35 employees in Germany to 25 in Spain. Italy is clearly characterized by an average small size of firms, only comparable to Spain, which has a lower average and an higher median.

Now we consider our tripartition of firms by size and report their distribution in each country.

Tab. 2 - Percentage of firms, by size and country

Country	*Small firms (10-15 employees)*	*Medium firms (16-50 employees)*	*Large firms (51+ employees)*
Italy	20.29%	62.10%	17.61%
Germany	16.22%	48.42%	35.37%
United Kingdom	22.16%	50.51%	27.33%
France	20.22%	53.18%	26.62%
Spain	22.49%	58.90%	18.61%
Austria	20.32%	50.11%	29.57%
Hungary	20.49%	49.80%	29.71%
All countries	20.16%	54.57%	25.27%

From such values, it results that the average small number of employees of Italian firms mainly depend on the small percentage of large firms (17.61% of Italian firms are large, while this figure is 25.27% for all the sample), more than by a high percentage of small firms (20.29%, very close to the global average).

The proper object of our analysis is innovation and its relationship with firm size. We identify three kinds of innovation; product, process and organizational innovation. The firms were asked if they had introduced, in last three years (2007-2009) such innovations. The exact content of these innovations is defined in the interview:

-product innovation is the introduction of a good which is either new or significantly improved with respect to its fundamental characteristics; the innovation should be new to your firm, not necessarily to the market;

- process innovation is the adoption of a production technology which is either new or significantly improved; the innovation should be new to your firm; the firm has not necessarily to be the first to introduce this process;

- organizational innovation is not exactly defined, but the firms were asked if the product and/or process innovation also prompted any organizational innovation. Therefore, it is important to remember that is observed only the organizational innovation which follows another (product or process) innovation.

It has to be underlined that, through such kind of questions, it is detected a less formalized, and probably less radical innovation than that observed through patents or publications (Istituto Guglielmo Tagliacarne-Focus PMI, 204). This may be a reason, together with the absence in our sample of micro-firms, of the global good performance of Italy, which is on the contrary defined as a little innovative country (see e.g. Bugamelli et al., 2012).

Table 3 shows, for each country and for each size category, the percentage of firms which introduced a product innovation.

Tab. 3 - Percentage of firms which introduced at last one product innovation, by size and country

Country	*Small firms (10-15 employees)*	*Medium firms (16-50 employees)*	*Large firms (51+ employees)*	*All firms*
Italy	40.78%	48.11%	62.78%	49.21%
Germany	37.39%	47.08%	59,73%	49.98%
U.K.	48.47%	56.61%	70.09%	58.49%
France	33.78%	43.45%	53.86%	44.27%
Spain	36.73%	44.90%	58.44%	45.59%
Austria	51.11%	52.25%	76.34%	59.14%
Hungary	33.00%	45.27%	48.97%	43.85%
All countries	39.19%	47.48%	60.47%	49.09%

It is clear that, when the firm size increases, the percentage of firms which realize a product innovation increases. 49.09% of the firms introduced at least one product innovation; this percentage is 39.19% among small firms, 47.48% among medium firms, 60.47% among large firms. This correlation between firm size and innovation holds both considering the whole sample and in every single country.

Let us consider a dichotomous variable, called *innoprod*, which assumes value 1 if the firm has introduced at least one product innovation, 0 if it does not introduce any product innovation. The Pearson correlation between *innoprod* and the number of employees is 0.13, significant at 1% level of significance. This correlation in each country is positive, higher than 0.12 and significant at 1%

From this data, Italy does not result as a little innovative country: the percentage of innovative firms, considering all the firms, whatever their dimension, in Italy is 49.21%, exceeding, albeit slightly, the percentage for all the countries (49.09%); the percentage of innovative firms in Italy is higher than France, Spain and Hungary and lower than Germany, United Kingdom and Austria.

Even considering each dimensional category, the percentage of innovative firms in Italy is a bit higher than the percentage considering the whole sample.

Let us now turn to process innovation. Table 4 shows, for each country and for each of three size categories, the percentage of firms which introduced a process innovation.

Tab. 4 - Percentage of firms which introduced at least one process innovation, by size and country

Country	*Small firms (10-15 employees)*	*Medium firms (16-50 employees)*	*Large firms (51+ employees)*	*All firms*
Italy	33.61%	45.17%	56.39%	44.80%
Germany	29.83%	38.35%	47.50%	40.20%
U.K.	35.39%	43.68%	60.88%	46.59%
France	30.12%	35.80%	46.90%	37.61%
Spain	42.70%	51.02%	63.38%	51.45%
Austria	38.89%	54.05%	78.63%	58.24%
Hungary	24.00%	31.28%	44.14%	33.61%
All countries	34.39%	42.97%	53.88%	44.00%

Like in the product innovation, it is clear that, when the firm size increases, the percentage of firms which realize a process innovation increases. 44% of the firms introduced at least one process innovation; this percentage is 34.39% among small firms, 42.97% among medium firms, 53.88% among large firms. This holds considering the whole sample and it happens in every single country.

Like in the previous case, let us consider a dichotomous variable, called *innoproc*, which assumes value 1 if the firm has introduced at least one process innovation, 0 if it does not introduce any process innovation. The Pearson correlation between *innoproc* and the number of employees is 0.12, significant at 1%. The correlation is positive and significant at 1% in each country (with a higher variability than for *innoprod*, where the values are more similar across countries).

Even regarding process innovation, Italy does not result as a little innovative country: the percentage of innovative firms, considering all the firms, whatever their dimension, in Italy is 44.80%, slightly exceeding the percentage for all the countries (44%); the percentage of innovative firms in Italy is higher than Germany, France and Hungary and lower than United

Kingdom, Spain and Austria. It is remarkable the high percentage of firms realising process innovation in Spain (51.45%, more than seven points above the overall average), while the percentage of Spanish firms realising product innovation is below the average.

Let us now consider the third kind of innovation: the organisational innovation, realised in consequence of a product or a process innovation. In the following statistics, we consider therefore only the firms which realised at least one of these two innovation (9,508 firms over 14,911). Table 5shows, for each country and for each of three size categories, the percentage of firms which introduced an organisational innovation.

Tab. 5 - Percentage of firms which introduced at last one organisational innovation, by size and country

Country	*Small firms (10-15 employees)*	*Medium firms (16-50 employees)*	*Large firms (51+ employees)*	*All firms*
Italy	37.61%	43.68%	50.47%	44.06%
Germany	65.97%	66.78%	69.09%	67.62%
U.K.	30.80%	34.96%	42.26%	36.52%
France	46.10%	49.15%	45.89%	47.64%
Spain	42.64%	46.90%	49.65%	46.65%
Austria	61.11%	68.99%	70.59%	68.28%
Hungary	10.64%	32.06%	51.06%	34.93%
All countries	43.45%	48.55%	54.17%	49.34%

As for the other two kinds of innovation, there is a positive relationship between size and organizational innovation. 49.34% of the firms which had introduced at least one product and/or process innovation introduced an organizational innovation too. This percentage is 43.45% among small firms, 48.55% among medium firms, 54.17% among large firms. The relationship between organizational innovation and firm size holds for the whole sample and for each country, with the exception of France, where large firms are less innovative than small and medium. It has also to be observed the little difference by size categories in Germany and Spain and the great differences in Hungary, where only 10.64% of small firms realize an organizational innovation, 32.06% of medium firms and 51.06% of large firms realize it.

Like in the previous cases, let us consider a dichotomous variable, called *innorg*, which assumes value 1 if the firm introduced at least one organizational innovation, 0 if it did not introduce any organizational innovation. The Pearson correlation between *innorg* and the number of employees is 0.08, significant at 1% level of significance. Considering the single countries, the correlation is positive and significant at 1% in Italy, United Kingdom and Hungary, positive and significant at 5% in Spain, at 10% in Germany, positive but not significant at 10% in Austria, negative but not significant in France (with an higher variability than for *innoprod*, where the value were more similar across countries).

In organisational innovation, Italy results less innovative than the average (44.06% of the firms against 49.34%); the percentage of innovative firms in Italy is higher than in United Kingdom and Hungary and lower than in Spain, France, Germany and Austria. It is remarkable the low percentage of firms realising organizational innovation in United Kingdom (36.52%, more than thirteen points under the overall average), while that country has a high percentage of firm realising product and process innovation.

4. Multivariate analysis: the relation between firm size and the innovative performance

In order to better understand the effect of firm size on the ability of the firms to innovate and to distinguish it from the country effect, we conduct a multivariate analysis, having *innoprod, innoproc* and *innorg* as dependent variables and the categorical variables for firm size and for countries as independent variables. Being the *innoprod, innoproc* and *innorg* dichotomous variables, *probit* model seems the more appropriate technique to adopt (we estimated the *probit* model with robust standard errors); the results should therefore be interpreted in terms of probability (the coefficients of independent variables indicates how that variable increases or decreases the probability for a firm to realize a product/process/organizational innovation). Having three firm size categories, we included two of them (*Medium* and *Large*) in the *probit*: their coefficient must be interpreted in comparison with the excluded category (small firms); similarly, having seven countries, we included six of them, excluding Italy: the results of the other countries must be interpreted in comparison with Italy.

As it is well known, the intensity of innovation may differ a lot across sectors; as the distribution of firms by size may also vary across sectors and different countries may have different distribution of firms across sectors, in order to have an effect of size and countries independent on the industrial structures, we have to "control" for sectors. In the database EFIGE, firms are classified in 12 sectors; as usual, we include all these categories minus one (therefore eleven) in the analysis. To save space, we do not report such coefficient in the table below. Table 6 reports the results of the three *probit* analysis.

Tab. 6 - Probit model: determinants of product, process and organisational innovation – with robust standard errors

Dependent variables→	*Innoprod*	*Innoproc*	*Innorg*
Independent variables↓			
Firm size			
Ref: Small firms			
Medium	0.217***	0.229***	0.120***
Large	0.512***	0.533***	0.221***
Country			
Ref: Italy			
Germany	-0.066**	-0.182***	0.599***
U.K.	0.195***	0.018	-0.199***
France	-0.101***	-0.221***	0.080*
Spain	-0.091***	0.174***	0.068*
Austria	0.265***	0.325***	0.603***
Hungary	-0.179***	-0.339***	-0.243***
Dummy variables for sectors	Yes	Yes	Yes
Number of obs.:	14758	14758	9508
Pseudo R^2:	0.0461	0.0266	0.039
Log pseudolikelihood	-9755.522	-9853.983	-6332.178
Wald chi2(d.f.)	(18)905.95	(18)528.18	(18)500.14
Prob>chi2:	0.000	0.000	0.0000

***Significant at 1%; **Significant at 5%; *Significant at 1%

In all three *probit* regressions, the variables expressing firm size are positive and significant at 1%: this means that, being constant the

distribution of firms across sectors and the national peculiarities in innovation abilities, the probability that a small firm realizes a product, a process, an organization innovation is less than the probability of a medium and large firm to realize it. The coefficient for large firms is higher than for medium: this indicates that a large firm has a higher probability to realize an innovation than a medium one. Therefore, it is confirmed the proportionality between firm size and innovativeness.

The signs of the dummy variables for countries indicate if those countries have a larger or smaller propensity to innovate than the reference country, regardless of its industrial structures (in terms of sectoral and dimensional distribution). The comparison is established with Italy, the excluded variable.

With regard to product innovation, considering only results significant at 10%, United Kingdom and Austria have a higher propensity than Italy to innovate, while Italy has a higher propensity than France, Spain, Hungary and Germany. In process innovation, Italy results less innovative, in a significant way, than Spain and Austria, more innovative than Germany, France and Hungary. In organisational innovation Italy is significantly more innovative than United Kingdom and Hungary, less innovative than Germany, Austria, France and Spain.

Established that small firms are less innovative than medium and large ones, a crucial question is whether this is due to a different endowment of crucial resources or to "intrinsic" characteristics which change with size, like economies of scales or personnel organization, etc. In the first hypothesis, larger firms have an higher quantity of factors determinant for innovation and this different endowment explains the different capacity to innovate: "controlling" for such factors, firm size should not be able anymore to explain differences in innovativeness; in the second hypothesis the different endowment does not completely explains the differences in innovativeness by size, which remains even "controlling" for such factors. This distinction, rather clear on a theoretical point of view, is quite difficult to verify empirically, as it requires the identification of the determinants (at least the main ones) of the different types of innovation.

The abundant existing literature on the determinants of innovation lets us identify the amount of expenditures in R&D, the human capital of the workforce, the nature of management as basic determinant of innovativeness (see D'Amore, Iorio and Lubrano Lavadera, 2015, and the

reference included in this paper). The EFIGE database allows us to have some information about such variables.

Regarding expenditure in R&D, firms are asked to declare which percentage of the total turnover they invested in R&D on average in the last three years (2007-2009); through information on turnover, we calculated the absolute amount of R&D expenditure; it must be warned that the turnover is registered in classes, therefore the value of R&D expenditure is approximate[4]. We call this variable *R&D*. In the following analyses we adopt the natural logarithm of this variable, as it is usual in such kind of analysis: with its smoothed shape, it implies a better fit of the regressions. We called this logarithmic transformation *ln_R&D*

Regarding the human capital of workforce, the firms are asked the number and percentage of university graduates in the workforce and the percentage of employees who have participated to formal training programs. As we want to verify if the firm size has an effect on innovation whatever the amount of resources, we take into account the absolute values of graduates (we call this variable *Graduated*) and of trained workers (we call this variable *Trained*). For the same reasons as for R&D, in the regressions we adopted the natural logarithm of these variables (we call them respectively *ln_grad* and *ln_train*)

Regarding the nature of management, firms were asked wheter the chief executive officer (CEO)/ Company Head of the firm is: a) a member of the family that owns /controls it or b) a manager appointed within the firm or c) a manager recruited from outside the firm. We codified these three possible answers as dummy variables and, as usual, we included two of them: we call *Manag_int* the answer b) and *Manag_est* the answer c): the coefficient of such variables must be interpreted in comparison with the "familiar manager" (answer a)).

We suppose that such variables are fundamental for innovation, but we also suppose that they significantly change with the firm dimension. This second hypothesis is easily verified by some statistical tests:

[4] We used the central value of the classes, then we multiply it for the percentage of turnover declared by firms. The last class is "more than 250 million euro": we considered the value 300 million euro (results do not substantially change using other values, like 250, 350, etc.

-the logarithm of the amount of R&D expenditures (*ln_R&D*) is positively (0.42) and significantly (at 1%) correlated with the number of employees; the correlation also holds if we consider not the number of employees but the size categories of firms (small, medium and large);

- the logarithm of the number of university graduated in the workforce (*ln_grad*) \is positively (0.55) and significantly (at 1%) correlated with the number of employees; like in the previous case, the correlation also holds if we consider the size categories of firms (small, medium and large);

-the logarithm of the number of employees who participated to a formal training program (*ln_train*) is positively (0.60) and significantly (at 1%) correlated with the number of employees; like in the previous case, the correlation also holds if we consider the size categories of firms (small, medium and large);

- the composition of management changes when firm size changes: in small firms the CEO is a member of the family in 93.85% of the cases, he is a manager appointed within the firm in 4.23% of the cases and in 1.91% of the cases he is recruited outside the firm; in medium firms these percentage are respectively: 92.39%, 4.29%, 3.32%; in large firms they are: 79.52%, 9.83%, 10.65%. Therefore the percentage of familiar managers decreases when the firm size increases; the opposite for the other two kinds of managers. These results are all statistically significant (at 1%), except for the difference in the percentage of internal but not familiar managers between small and medium firms.

Now we can run the regressions having the different kinds of innovation (*innoprod*, *innoproc*, *innorg*) as dependent variables and, as independent variables, we add to the variables considered before (firm size, countries, sectors) the variables now analysed: *ln_R&D*, *ln_grad*, *ln_train*, *Manag_int, Manag_est*. The estimated coefficients are reported in Table 7 (to save space we do not report the coefficients for country dummies).

Tab. 7 - Probit model: determinants of product, process and organisational innovation: effect of key determinants – with robust standard errors

Dependent variables→	*Innoprod*	*Innoproc*	*Innorg*
Independent variables↓			
Firm size			
Ref: Small firms			
Medium	0.030	0.099***	0.029
Large	-0.173***	0.035	-0.117
ln_R&D	0.288***	0.175***	0.108***
ln_grad	0.099***	0.005	0.044
ln_train	0.038**	0.138***	0.191***
Management			
Ref: familiar manag.			
Manag_int	-0.060	-0.206***	-0.373
Manag_est	-0.084	0.196**	-0.153
Dummy variables for coutries	Yes	Yes	Yes
Dummy variables for sectors	Yes	Yes	Yes
Number of obs.	7881	7881	1391
Pseudo R^2	0.147	0.084	0.062
Log pseudolikelihood	-4652.149	-4941.000	-896.630
Wald chi2 (d.f)	(23)1233.85	(23)804.70	(17)196.35
Prob>chi2	0.000	0.000	0.000

***Significant at 1%; **Significant at 5%; *Significant at 1%

We can observe that the logarithm of the expenditures in R&D is a significant determinant for every kind of innovation; the logarithm of the number of graduated employees is a significant determinant of product innovation; the logarithm of the number of workers who participated to training program results a significant determinant of product, process and organisational innovation; a manager recruited outside the firm

significantly increases the probability to obtain a process innovation compared with a manager belonging to the family which owns or control the firm; as regards process innovation, a manager recruited inside the firm is significantly less efficient than a familiar manager.

The remarkable result is that the firm size generally lose its significance; only for process innovation medium firms show a significantly higher propensity than small ones. It is notable the negative sign for large firms, even significant in product innovation, which means that, controlling for the amount of the crucial resources, large firms lose their advantage in innovation. These results mean that, with the partial exception of process innovation, the disadvantage that small firms register in matter of innovation is not due to an "intrinsic" weakness, to a worse organization of resources or men, but to a lower amount of those resources, like R&D and human capital, which are crucial for innovation.

5. Econometric insights on Italy

In the previous section we found that small firms have a disadvantage, respect to medium and large firm, in innovative capacity *ceteris paribus*; now we try to verify if this disadvantage is also true for Italy.

We replicate the first regression in the section above (Table 6), having *innoprod*, *innoproc* and *innorg* as dependent variables, the dummy variables for firm size (*Medium* and *Large*, whose results must be read in comparison with small firms) and the dummy variables for sectors; of course, being an analysis concerning only Italy, the dummy variables for countries are not included. Results are reported in Table 8.

Tab. 8 - Probit model: determinants of product, process and organisational innovation in Italy– with robust standard errors

Dependent variables→	*Innoprod*	*Innoproc*	*Innorg*
Independent variables↓			
Firm size			
Ref: Small firms			
Medium	0.188***	0.303***	0.162**
Large	0.533***	0.587***	0.356***
Dummy variables for sectors	Yes	Yes	Yes
Number of obs.:	3020	3020	2038
Pseudo R^2:	0.034	0.020	0.010
Log pseudolikelihood	-2021.533	-2036.415	-1384.479
Wald chi2 (d.f.)	(12)137.47	(12)79.47	(12)27.41
Prob>chi2:	0.000	0.000	0.000

***Significant at 1%; **Significant at 5%; *Significant at 10%

The positive sign for all the reported coefficients means that medium and large firms have a greater probability than small firms to realise a product, process and organisational innovation. All these results are significant at 1%, with the exception of the advantage of medium firms over small ones in organisational innovation, which is significant at 5%.

As a further step of the analysis, we verify if even in Italy the disadvantage of small firms in innovation persists even controlling for the distribution of some key resources.

First of all, we compare the endowment of such resources in Italy, in the three size categories, with the endowment in the whole sample. Table 9 reports the average value, for Italy and the whole sample, in the tree size category, of the R&D expenditure and of its natural logarithm[5] , the number and percentage of graduate workers, the number and percentage of workers who attended a training program, the percentage of managers coming from inside and outside the firms.

[5]The logarithm is calculated on R&D plus one, to allow the logarithm to have value zero when R&D expenditure is zero. The same holds for the number of graduated workers and of workers who attended training programs.

Tab. 9 - Average values of the key endowments for innovation, by firm size, in Italy and for all countries

Size category/country→	*Small firms*	*Medium firms*	*Large firms*	*Small firms*	*Medium firms*	*Large firms*
Variables↓		*Italy*			*All countries*	
R&D	11.05[6]	31.25	298.07	9.83	21.42	229.06
ln_R&D	1.096	1.800	3.697	0.852	1.459	3.047
Graduated	0.84	2.18	18.30	1.23	2.32	14.88
ln_grad	0.433	0.702	1.949	0.568	0.867	1.887
Percentage of graduated	6.39%	6.06%	10.48%	9.78%	8.73%	10.76%
Trained	1.26	3.58	39.96	2.58	6.21	54.11
ln_train	0.422	0.818	2.393	0.833	1.332	3.044
Percentage of trained	9.35%	12.14%	17.53%	20.06%	21.18%	27.03%
manag_int	2.06%[7]	1.49%	6.73%	4.23%	4.29%	9.83%
manag_est	1.86%	1.78%	3.67%	1.91%	3.32%	10.65%

It is possible to observe that, a bit surprisingly, Italian firms spend in R&D more than the average of the seven countries together[8], while the endowment in human capital (percentage and number of graduated and trained people) and in non-familiar management in Italy is lower than the average of seven countries in each dimensional category. Such endowments generally increase when size increases, with the exception of the percentage of graduates between small and medium firms (but we consider in the following regressions the absolute number of graduates) and of the non-familiar managers, whose percentage is higher in small than in medium firms, contrary to what happens in the whole sample. In the end, in the

[6] In million euro.

[7] 2.06% of the Italian small firms have a manager coming from inside the firm. The other figures for Manag_int and Manag_ext must be interpreted analogously.

[8] The private expenditure in R&D in Italy is notoriously low respect to other countries. But we have to consider that in this sample there are not the micro firms, which usually spend nothing or little in R&D and which are abundant in Italy, pushing down its relative position in R&D expenditure.

Italian firms it is particularly remarkable, among the large firms, the small percentage of managers coming from outside the firm.

Verified the endowment of the key resources for innovation, we run the *probit* regressions including such variables (in logarithm) among the determinants of the three kinds of innovation, besides the dummy variables for firm size and for sectors. Results, not reported here, concerning the size categories of firms and the "key variables" for innovation are very similar, for sign and significance, to those obtained in the whole sample. The only remarkable differences are: in product innovation the non significance of the number of trained personnel; in process innovation the positive and significant coefficient for large firms and the non significant coefficient for external manager. This means that in Italy, as in the overall sample, the disadvantage of small firms in innovative capacity may be explained with the endowment of crucial resources, not with some their "intrinsic" weakness.

It is remarkable the not significant effect of trained employees for product innovation and of the external management for process innovation: it is likely that their scarce amount in Italian firms limit their effectiveness.

After verifying that for Italy holds what happens in the whole sample, namely that small firms are less innovative than medium and large ones, even controlling for the sectoral structure, the opportunity to have an international dataset lets us enlarge the comparative perspective. We want to compare the distance, in innovative capacity, between small and medium/large firms in Italy with the same distance in the whole sample.

The first stage of this analysis consists in comparing, in each dimensional class, the innovative performances of Italian firms .with the performance of the firms in the whole sample: small Italian firms compared with the small firms of the seven countries, medium Italian firms with medium firms of the whole sample, large Italian firms with large firms of the whole sample. The aim is to have an idea of the "relative" position of each group of Italian firms respect to the homologous group in the whole sample.

This comparison may be done with a very simple method: to obtain the relative position of small Italian firms respect to all the small firms, we select the small firms only; then, having the usual dependent variables for the three kinds of innovation, as independent variables we have the dummy variables for sectors and the dummy variable for Italy; the coefficient of this last variable indicates how much the probability for an Italian small

firm to obtain an innovation exceeds the average probability of the small firms in the sample to obtain the same innovation, being constant the sectoral structure. The same holds for medium firms and for large firms. The results of such estimation for small firms is reported in Table 11; the results for medium firms is reported in Table 12, the result for large firms are reported in Table 13.

Tab. 11 - Probit model: determinants of product, process and organisational innovation among small firms; Italy vs. the whole sample – with robust standard errors

Dependent variables→	*Innoprod*	*Innoproc*	*Innorg*
Independent variables↓			
Italy	0.032	-0.029	-0.195**
Dummy variables for sectors	Yes	Yes	Yes
Number of obs.:	2972	2975	1587
Pseudo R^2:	0.028	0.006	0.008
Log pseudolikelihood	-1934.852	-1903.440	-1078.321
Wald chi2 (d.f.)	(10)109.19	(11)22.34	(10)16.35
Prob>chi2:	0.000	0.006	0.090

***Significant at 1%; **Significant at 5%; *Significant at 1%

Tab. 12 - Probit model: determinants of product, process and organisational innovation among medium firms; Italy vs. the whole sample – with robust standard errors

Dependent variables→	*Innoprod*	*Innoproc*	*Innorg*
Independent variables↓			
Italy	0.010	0.077**	-0.167***
Dummy variables for sectors	Yes	Yes	Yes
Number of obs.:	8054	8054	5149
Pseudo R^2:	0.030	0.032	0.008
Log pseudolikelihood	-5402.9811	-5484.952	-1078.321
Wald chi2 (d.f.)	(11)333.13	(11)35.26	(10)16.35
Prob>chi2:	0.030	0.003	0.090

***Significant at 1%; **Significant at 5%; *Significant at 1%

Tab. 13 - Probit model: determinants of product, process and organisational innovation among large firms; Italy vs. the whole sample – with robust standard errors

Dependent variables→	*Innoprod*	*Innoproc*	*Innorg*
Independent variables↓			
Italy	0.074	0.077	-0.117*
Dummy variables for sectors	Yes	Yes	Yes
Number of obs.:	3729	3729	2771
Pseudo R^2:	0.020	0.004	0.004
Log pseudolikelihood	-2452.351	-2563.649	-1903.988
Wald chi2 (d.f.)	(11)99.39	(11)19.55	(11)13.97
Prob>chi2:	0.020	0.052	0.234

***Significant at 1%; **Significant at 5%; *Significant at 1%

As concerns product innovation, no coefficient is significant, therefore we can conclude that for no size class there is systematic difference between innovative capacity in Italy and in the whole sample.

For process innovation, the coefficient of medium firms is significantly (at 5%) positive: this means that medium Italian firms are significantly more innovative than the average of medium firms in the sample.

For organisation innovation the coefficient is negative and significant in all three size groups: this means that small, medium and large Italian firms have less capacity to obtain organisation innovation than their homologues in the whole sample.

These results are *per se* interesting, indicating a propensity of Italian firms, at least medium ones, for process innovation and a generalised difficulty in organisational innovation. As a previous regression (see Table 7) demonstrated that training is a key determinants of organisation innovation, we may conclude that the shortage of this factors in Italian firms may be the main reason for the poor performance in such kind of innovation.

Besides, these results suggest that there may be a high distance in the capacity to introduce process innovation between small firms, which are not beyond the average of the sample, and the medium firms, which have a performance above the average.

The analysis above gives interesting results but it is an indirect measure of what we are looking for: comparing the distance in the innovative capacity between small and medium/large firms in Italy with the same distance in the whole sample. A more direct method is the following: in the *probit* regression whose results are reported in Table 8 the coefficient of *Medum* and *Large* gives respectively, for Italian firms, the distance in the probability to obtain an innovation between medium and small firms and between large and small firms; if we run the same regression for each country, we obtain the same distance for each country; then we may compare the coefficients, that is what we are looking for: a comparison of distances between the innovative capacity of different dimensional classes of firms.

In Table 12 we report the coefficients and the significance of the dummy variable *Medium*, which express the distance, in innovative capacity, between small and medium firms. To favour the comparison, in the last line we report the coefficients obtained running the same *probit* regression for the whole sample.

Tab. 12 - Coefficients for the dummy variable "medium firm" if compared with small firm in different countries – probit model with robust standard errors

Dependent variable→ / *Countries↓*	*Innoprod*	*Innoproc*	*Innorg*
Italy	0.188***	0.303***	0.162***
Germany	0.257***	0.218***	-0.002
United Kingdom	0.179**	0.194***	0.133
France	0.268***	0.149**	0.079
Spain	0.204***	0.218***	0.101
Austria	0.030	0.367**	0.271
Hungary	0.276*	0.229	0.807***
All countries	0.211***	0.225***	0.129***

We comment only the comparison between Italy and the sample as a whole: for product innovation the coefficient is smaller for Italy than for all countries: this means that the disadvantage in innovative capabilities of small firms respect to medium firms is lower in Italy than in the average of the sample. The opposite happens for process and organisation innovation: the distance between small and medium firms is larger in Italy than in the sample as a whole.

Anyway, this is just a comparison between punctual estimations, without any information about the significance of such differences. For a more rigorous analysis it is needed to compare the confidence intervals of the coefficients, or estimating a model including, among the independent variables, besides the dummy variables for firm size, countries and sectors, interaction effects between size categories and countries, which allows for different slopes for different countries, which in turn means that different countries have different relationships between firm size and innovation. We carried out such more rigorous comparisons and we can conclude that almost none of the differences emerging from the difference between the coefficients above may be considered significant at 10%.

Neglecting the differences between Italy and the single countries and focusing on the comparisons between Italy and the whole sample, the suggestion coming from the previous analysis, that in Italy the distance between medium and small firm in process innovation could be greater than in the whole sample, could be accepted only if the threshold were 15%, indeed beyond the usually accepted thresholds. In product and organisation innovation the distance existing in Italy between small and medium/large firms must be considered not significantly different from the distance in the whole sample.

6. Synthesis of results and conclusions

Studying a sample of seven European countries, including the five largest economies of the continent, the firm size appears as a determinant of firm's capacity to innovate, in terms of product, process and organizational innovation. This correlation between firm size and propensity to innovate holds even controlling for the different distributions of firm size across

countries and across productive sectors. Some other factors appear as key determinants of innovation, like the expenditure in R&D, the "human capital" of the workforce (formal instruction and training programs), the professionalism of the management (if external to the family that owns or controls the firm). Such factors are disproportionally distributed across firm size (when the dimension increases, the quantity of such factors increases), and it is essentially this different amount of key resources for innovation to explain the lower innovative performance of small firms, not some "intrinsic" or "black box" motivations linked to the limited size. Only in process innovation small firms seem to have a disadvantage respect to medium firms not explained by such factors.

As concerns Italy, we must premise that this study does not consider the micro firms, from 1 to 9 employees, which are particularly abundant in Italy (Onida, 2004); therefore the relative position in innovative performance emerging from this study is likely a bit shifted to a more favourable position respect to a framework which considers all the kinds of firms. Besides, innovation is measured through a survey, not with measures like patents or publications, which generally indicate a more radical innovation and where Italy is notoriously weak (Istituto Guglielmo Tagliacarne-Focus PMI, 204). Therefore, when positive signals emerge about Italian innovative performances, they should be taken *cum grano salis*.

The descriptive statistics indicate for Italy, if compared with the other countries, a large presence of medium firms and a shortage of large firms. The innovative performance, measured as the percentage of firms who introduced in a three-year period at least one product, process and organisational innovation, is in line with the average of the sample in product and process innovation and below such average in organisational innovation.

The international framework appears quite articulated: the multivariate analysis allows to do a "ranking" of the innovative performance of the countries, even excluding the effect of different distributions of productive sectors and of firm size; such ranking results different in different types of innovation; in the tree types of innovation, Italy occupies intermediate places. Comparing Italy with the whole sample, the statistically significant results are that medium Italian firms have an higher propensity to process innovation than the medium firms of the whole sample, while all firm sizes have a disadvantage in organisation innovation.

Even in Italy, small firms have a disadvantage respect to medium and large firms in all three types of innovation. The amount of this disadvantage does not seem significantly different in Italy respect to the other countries.

Trying to verify if the disadvantage of small firms in the innovative capacity is due to a different allocation of crucial resources, we discovered that there is a shortage, if compared with the other countries, of human capital (graduated workers and workers who participate to training programs) and of non-familiar management. This is probably the reason why in many cases the human capital and the management do not appear in Italy as key determinant of innovation.

A more educated and trained workforce, a more professional management seem therefore the way for Italy to close the innovative gaps or to reinforce its strengths.

This results goes together with another policy conclusion of our study: we unequivocally find an advantage given by a larger firm size in every kind of innovation; being the Italian industrial characterised by an average small dimension of firms, this suggests to implement policies aiming at increasing the firm size.

Actually, looking closely, these two conclusions go together: the size of a firm increases if it is successful; but, a firm's workforce becomes more trained, its management more professional, it certainly becomes more innovative, therefore more successful; in this way the firm grows. Becoming larger, it has more resources to undertake innovative projects, to hire more qualified personnel and management; the public intervention should operate to trigger such virtuous circle

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