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Concentration, firm size and innovation: evidence from innovation costs

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Abstract

By means of a new technological indicator, i.e. original data on firms' innovation costs (survey CNR–ISTAT), the neo-Schumpeterian hypothesis on the positive association between innovative intensity, concentration and firm-size has been tested at the aggregate and at the sectoral level for the Italian manufacturing industry. The advantage of the evidence presented here lies mainly in the comprehensive nature of the indicator used. The data on innovation costs include, in addition to R&D, other relevant innovative sources such as those related to production investment, marketing, design and engineering. The empirical results based on this new indicator confirm the existence of a positive association between firm-size and innovative intensity in sectors with high technological opportunities, and also at the aggregate level. A significant concentration of innovative activities in a restricted group of large Italian firms has also been found.

1. Introduction

In *Capitalism, Socialism and Democracy* [1], Schumpeter emphasized the increasing importance in modern industrialized economies of large firms (or units of control) in promoting technological change. Since then, a whole generation of economists has been discussing the two so-called 'neo-Schumpeterian hypotheses', i.e. the existence of a positive correlation between (i) innovative intensity and firm size, and (ii) innovative intensity and market concentration.

The various surveys of the literature on the

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subject have examined hundreds of works (see [2–5]) to reach the verdict that the results furnished have so far been partial, contrasting, and hence to some degree inconclusive. This is due to a variety of factors, which include the difficulty of (a) finding adequate measures of innovation, and (b) identifying a causal link between technological and economic variables.

With reference to point (a), criticism has concentrated on the partial nature of the traditional technological indicators and the distortion involved in their use: innovation is one of the most heterogeneous of economic activities, and it is not easy to gather comparative data for it. For point (b), attention has been drawn to the one-way view of the functional relationships between structural variables and technology [5], and the omission of important firm- and sector-specific technological determinants of innovative activities [6–9]. If these factors are taken into account, the Schumpeterian hypotheses might become 'obsolete' since each industry will present its specific behaviour [5].

In this paper we present fresh empirical evidence on the Schumpeterian hypotheses for the Italian manufacturing industry. This has been made possible by the availability of a new and more comprehensive technological indicator, and a particularly broad and significant database available for the Italian economy.

2. Measuring innovation and its problems

Strongly influenced by the availability of data regarding innovative activities, the problem of the choice of a technological indicator to test empirically the neo-Schumpeterian hypotheses has permeated much of the literature produced so far. The resources (financial and human) devoted to R&D have been by far the most used proxy, and the one providing most empirical backing for the hypothesis that innovative activities increase more than proportionately with firm size [10]. Such studies, however, have been criticized on the grounds that indicators based on R&D constitute a reliable proxy of innovative activity only for large-sized firms and fail to reflect a whole series of (often unformalized) technological activities prevalent in medium and small firms [8, 11].

In the wake of the pioneering work of Jacob Schmookler [12] and Mike Scherer [13], patents have thus been employed as an alternative indicator. Although generally regarded as less 'biased' in favour of the large firms [14, 15], this indicator is not free of distortion stemming from the varying degrees of propensity to patent in the different technological fields, from the fact that not all the patented inventions are commercialized and result in innovations, and from the marked heterogeneity of their economic and technological impact.

In view of the problems connected with the employment of these two indicators, the neo-Schumpeterian hypothesis has also been tested taking into account the number of innovations introduced into the economic system (see [16] for a review of innovation surveys; a special issue devoted to innovation surveys has appeared in the *Science Technology Industry Review*, No. 11, 1992). The most important database, developed at the Science Policy Research Unit of the University of Sussex, includes a sample of significant innovations introduced in Great Britain between 1945 and 1983 [8]. Studies carried out on this databank have not refuted the neo-Schumpeterian hypothesis, although they have lessened its standing considerably. On the one hand, there has been significant reappraisal of the innovative capacity of small firms; on the other, attention has been drawn to sectoral differences in the nature and intensity of innovative activities.

Empirical studies have also been carried out on another databank (set up by the US Small Business Administration) concerned with the innovations commercialized and publicized in the technical literature. Studies based on this data source have revealed a negative correlation between market concentration and innovative output, and borne out the neo-Schumpeterian hypothesis of a positive correlation between firm size and innovative intensity only for concentrated sectors where conditions of imperfect competition prevail. Conversely,

greater innovative intensity has been shown in small and medium-sized firms in low-concentrated sectors [9]. Despite the relevance of these findings, indicators of innovation output add up heterogeneous items in terms of technological and economic impact.

It is clear that the technological indicators used to measure the innovative intensity of small and large firms play a crucial role in the debate on the neo-Schumpeterian hypotheses. The originality of this paper is in the use of a new indicator, innovation costs, which has significant advantages over other available measures.

3. A new indicator of innovation

The empirical evidence presented is based on an indicator that is more comprehensive than those used hitherto. Its availability is the result of a broad survey on the diffusion of technological innovation in the Italian manufacturing industry carried out jointly by Italy's National Research Council and the National Statistical Institute (CNR–ISTAT) [17, 18].

The sample examined is composed of 6839 manufacturing firms that introduced innovations in Italy in the 1981–1985 period. Selection was not carried out at random, but was itself based on a preliminary postal survey involving over 24 000 firms. This initial phase made it possible to eliminate roughly 65% of the firms as 'non-innovating', or 'less-innovating', and to concentrate on the remaining 8220 firms, which constitute the core of Italian innovative firms. The follow-up involved an interview during which a further questionnaire was completed. The results obtained for each firm were then compared with those of the national survey on gross product (carried out by ISTAT). Combining the two surveys led to the exclusion of over 1000 more firms, leaving a sample of 6839; these firms account for over 50% of the sample involved in the survey on gross product in terms of employees and sales. For these firms economic data were obtained for items such as sales, value added, employment and investment, as well as specific data on innovative activities made available by the CNR–ISTAT survey.

The indicator furnished by the CNR–ISTAT survey is represented by the *total costs sustained by the firms for innovative activity as a whole*. The significant advantage of this indicator is the fact that it reflects in homogeneous quantitative terms the efforts made by the firms in carrying out a particularly broad spectrum of innovative activities. New innovative sources thus come to be included, as well as forms of innovative activity omitted from previous analyses and empirical testing owing to the lack of relevant data. At the empirical level, this means a considerable reduction of the biases connected with the use of the traditional technological indicators.

Innovation costs is one of the innovative indicators recommended by the new Manual of Innovation Statistics of the OECD [19]. A major survey on innovation in Europe and elsewhere (EC innovation survey) is now underway, and it will shortly produce internationally comparable data on innovation costs. Current empirical research using innovation costs includes refs. [20 and 21].

4. The empirical results

4.1 The nature of innovation costs

Table 1 presents the total of the innovating firms, the percentage of these carrying out R&D

TABLE 1 Innovating firms and R&D by firm size

Firm size (sales in billions of lire)	1 No of innovating firms	2 % carrying out R&D	3 Innovation costs (billions of lire)	4 % spent on R&D
< 100	6515	29 8	9394	12 2
100–500	268	73 1	5795	18 5
> 500	56	91 1	11537	20 6
Total	6839	32 0	26726	17 2

Source: Elaborations on CNR–ISTAT database

activities, the total innovation costs, and the percentage of these for R&D alone broken down by firm size.

In comparison with the annual R&D survey (the 'Indagine sulla ricerca scientifica' carried out by ISTAT), the CNR–ISTAT survey has identified a greater number of firms performing R&D activities, especially among small firms. In other words, the CNR–ISTAT survey has shown that the amount of R&D activities carried out in Italian industry is larger than according to the standard OECD definition (see the OECD *Frascati Manual*). This result is consistent with studies carried out in other countries which have also shown that national statistical surveys underestimate the total amount of R&D performed in the business sector [11]. Nevertheless, the CNR–ISTAT data show that the costs of performing R&D are relatively small in comparison to the total amount of innovation costs. Only 17.2% of total innovation costs are related to R&D activities, and only 32% of all firms considered have undertaken R&D activities. R&D can be considered the 'head' of innovative activities, but in order to provide economic benefits it needs a substantially heavier 'body'.

Table 2 presents data broken down by firm size, in terms of employee numbers, regarding the division of innovation costs into four categories (R&D; design and engineering; production investment; marketing) for the whole sample involved in the CNR–ISTAT survey (8220 firms). R&D expenditure accounts for 21.4% for the largest size group and barely 7.4% for the smallest, providing confirmation of how much this indicator underestimates the innovative efforts of the smaller firms. Conversely, the item 'production investment' predominates for the whole sample (51.5%), its relative weight displaying an inverse relation with firm size: 73.1% for the smallest size group and 43.5% for the largest.

TABLE 2 Breakdown of innovation costs by firm size

Firm size (no. of employees)	R&D	Design and engineering	Production investment	Marketing	Total
20–49	7.4	15.1	73.1	4.4	100.0
50–99	9.6	17.5	68.2	4.7	100.0
100–199	10 6	18.3	66.2	4.9	100.0
200–499	14.3	16.1	64.2	5.4	100.0
500 and over	21 4	29.5	43.5	5.6	100.0
Total	17.9	25.2	51.5	5.4	100.0

Source: CNR–ISTAT; sample of 8220 firms.

The above data thus bear out our views of the 'comprehensive' nature of the indicator represented by total innovation costs. In particular, it appears to overcome one of the greatest limitations attributed to the indicator constituted by resources devoted to R&D, i.e. its inability to reflect the innovative efforts of the smaller firms, which largely consist of non-formalized activities and the acquisition of technology embodied in plants and machinery [22, 23]. The inclusion under innovation costs of spending on design and engineering, and above all on production investment connected with the introduction and diffusion of innovation processes, serves to make our indicator far more comprehensive than those previously used.

Table 3 reports evidence on innovation costs broken down at the industry level. The data indicate how sources of innovation differ across industries, as suggested by a large body of literature [24–26], some of which refers to the Italian case [27, 28]. Even at this relatively low level of disaggregation, the sectors reporting a larger expenditure on innovation are those generally associated with higher technological opportunities. The six sectors reporting the highest innovative intensity are office machinery and computers, other transports and aircraft, rubber and plastic, motor vehicles, precision instruments, and electrical and electronics (from now on referred to as 'innovation-intensive' sectors). Together these sectors cover 55% of the total innovation costs and 67% of the R&D activities.

In all the industries considered, production investment absorbs a substantially higher share of innovation costs than R&D. Only in three industries, namely office machinery and computers, electrical and electronics, and rubber and plastics,

TABLE 3 Innovation costs by industry (sectoral average values)

Industrial sectors	No. of firms	Innovative activities (sectoral percentages)		Innovative intensity (innovation costs per employee in millions of lire)				
		Innovation costs (%)	R&D expenditure (%)	R&D expenditure	Design and engineering	Production investment	Marketing	Total innovation costs
Petrochemicals	17	0.91	0.75	2 6	2 3	13.1	0 3	18 3
Metals	137	4.83	1.85	0 8	5 4	5.9	0 5	12.6
Non-metals, minerals	495	4 94	1.38	0 9	1 7	16.4	0 5	19.6
Chemicals	409	7 74	13 49	4 5	2 4	6 9	1.3	15 1
Synthetic fibres	9	0 46	0 31	1 3	1 1	8.5	0 2	11 1
Metal products	864	3.37	1.29	0.7	1 7	7 6	0 4	10 4
Mechanical machinery	1166	9.37	8.78	2 2	4 6	6 4	0 6	13 9
Office machines, computers	11	10 11	20.41	25 0	19 3	17 8	10 0	72 0
Electrical, electronics	526	13 99	19 69	5.1	7 1	8 2	0 8	21 2
Motor vehicles	155	16 09	14 31	4 2	6 5	16 3	0 5	27 5
Other transport	88	7.69	1 74	1 1	13 7	13.9	0 2	29.0
Precision instruments	110	1.37	1.65	5 3	7 0	11.3	2 1	25 7
Food	268	2.38	0.50	0 5	0 8	11 7	0 6	13 7
Sugar, drinks	177	2.10	1 34	1 0	1 2	6.6	0 3	9 1
Textiles	610	2.99	1 11	0 7	0 7	8 6	0 3	10 3
Leather	97	0.20	0.05	0.3	0 8	6 4	0 3	7 7
Footwear, clothing	343	0 64	0.20	0.2	0 6	2 4	0 2	3 5
Wood, furniture	469	1.11	0 50	0 8	1 2	7 5	0.6	10 1
Paper, printing	369	3.86	0.99	0 6	0 6	12.6	0 7	14.5
Rubber, plastic	389	5.51	9.16	8.1	7 0	10 0	3 1	28 2
Other manufacturing	130	0.32	0 24	1 3	1 6	6 9	0 4	10 2
Coefficient of variation				1 69	1 16	0 41	1 90	0 78
Total	6839	100.00	100.00	3 2	4 6	9 6	0 9	18 3

Source: Indagine CNR–ISTAT and Indagine sul Prodotto lordo (1985).

is R&D nearly as important as production investment. This shows that even in industrial sectors characterized by high technological opportunities, the innovative activities connected to the introduction and adaptation of innovation at the 'shop floor' level represents the largest part of the firms' total financial innovative effort.

The variability of innovation costs across industries is much lower than that of R&D costs. Among the different components of innovation costs, production investment is by far the most uniformly distributed across industries, with a coefficient of variation equal to 0.41. This confirms that innovative activities related to production investments represent a common and necessary basis of the innovative activities in all the sectors. Conversely, R&D expenditure, and to a lesser degree design and engineering, are much more skewly distributed across industries, with coefficients of variation equal to 1.69 and 1.16, respectively.

4.2. Innovation costs and firm size

Now that the general characteristics and attributes of the data at our disposal have been specified, it remains for us to employ them in empirically testing the relationship between firm size and innovative intensity.

Figure 1 shows, for each size group, the average

innovation cost per employee, identified by us as an 'index of innovative intensity', thus providing immediate visual evidence that firm size and innovative intensity are indeed positively correlated. From the data presented, it emerges that the largest group, comprising the 56 largest Italian firms, sustains innovation costs per employee which are nearly twice as high as those in the smallest group (25.3 million lire as against 13.7 million). At the aggregate level, the neo-Schumpeterian hypothesis is strongly confirmed by data on innovation costs.

However, the literature has for a long time questioned the significance of such a relationship at the aggregate level, since firms belonging to heterogeneous industries, as far as technological opportunities and structural characteristics are concerned, are merged together. The crucial role played by sectoral differences in terms of technological regimes is, according to the most recent reports [5, 26], at the very basis of the obsolescence of the Schumpeterian suggestions. It makes little sense, for example, to compare small firms belonging to the textile industry with large, highly innovative firms belonging to the office and computing machines sectors.

Table 4 reports the same evidence broken down by 21 industrial sectors. At the sectoral level, the results are much more complex. However, a clear confirmation of the neo-Schumpeterian relationship holds for six sectors. Not surprisingly, these are ones where innovation costs per employee are higher. It might appear tautological, but the first neo-Schumpeterian hypothesis holds in the 'Schumpeterian' industries only, i.e. the industries which spend more on innovation and where higher technological opportunities are expected to be found (Fig. 2). In the traditional industries such as metal products, food, sugar and drinks, textiles, leather, footwear and clothing, firms of small or medium size spend more on innovation than large firms, even when large firms spend proportionally more on R&D.

Several authors have also questioned the consistency of the neo-Schumpeterian hypotheses with the original Schumpeterian perspective. It has been suggested that Schumpeter [1] did not claim that innovative intensity should increase with firm

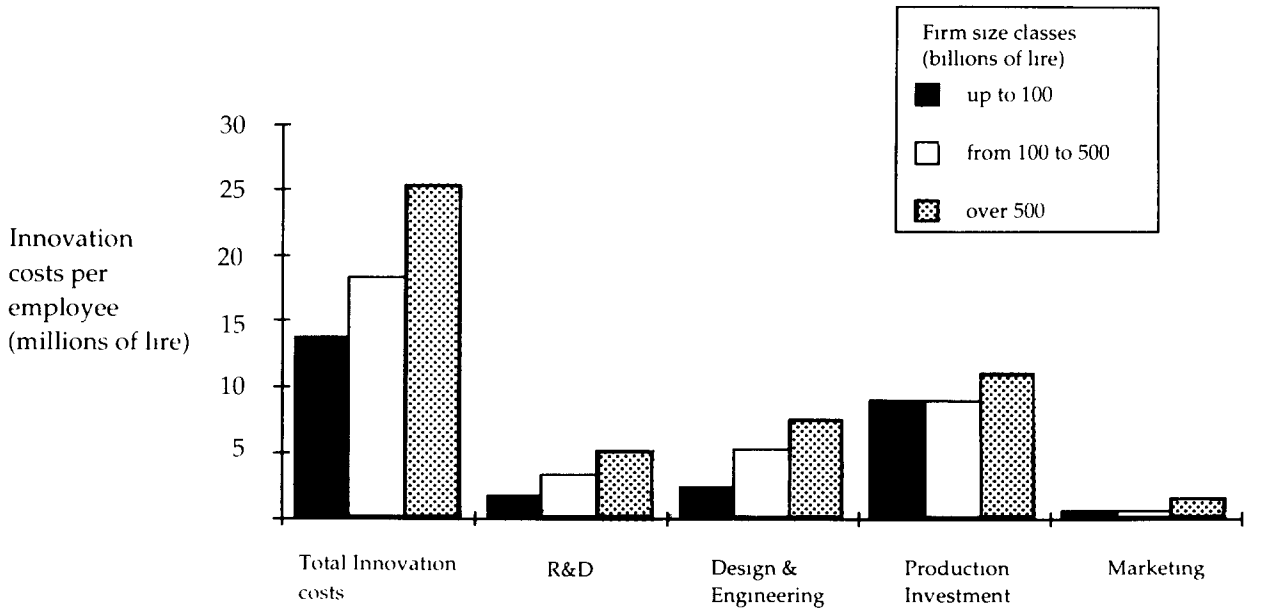

Fig. 1. Innovation costs per employee and firm size (all samples).

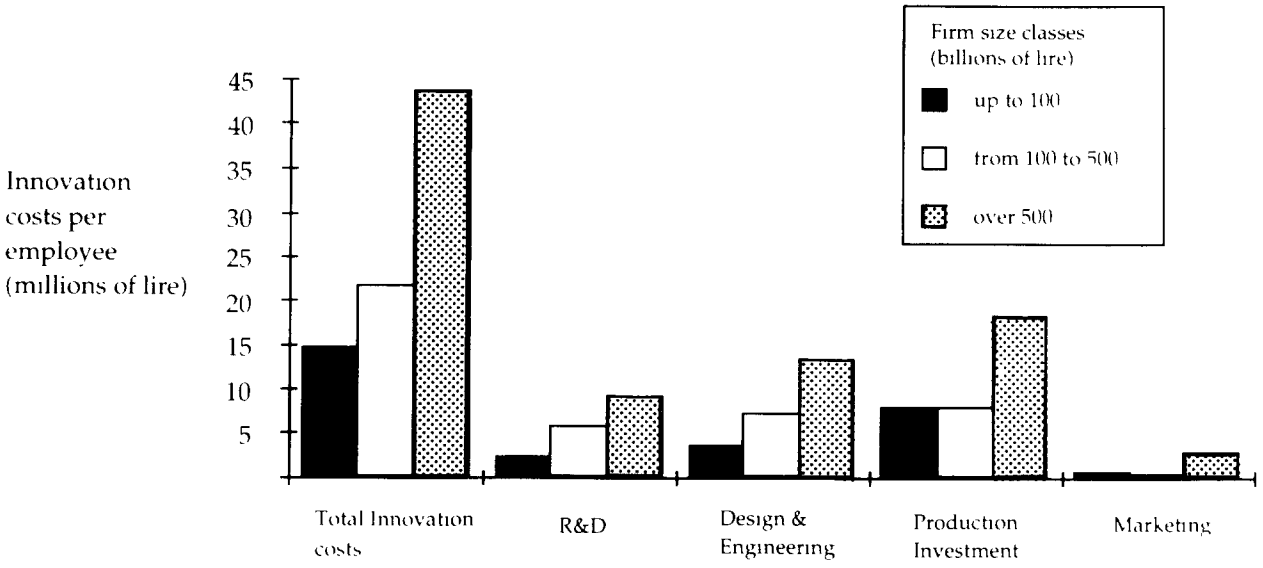

Fig 2 Innovation costs per employee and firm size — innovation-intensive industries

size. Rather, he pointed out what he saw as a straightforward feature of modern industrialized economies, i.e. the growing importance of large firms (or units of control) as a major innovative source [2, 5]. Our data set does not allow us to check for changes of the share of innovative activities performed by large firms over time (however they are defined). However, Table 5, reporting the combined evidence for the six most innovation-intensive industries, confirms the presence of a high concentration of technological activities within a very restricted number of large firms. Of the 56 largest Italian firms, only 16 belong to the innovation-intensive industries. These 16 firms account for 37.4% of the innovation costs of the 6839 firms in our sample, and for an even larger share of R&D expenditure (45.6%). The same 16 firms account for 68.3% of the innovation costs of the 56 largest Italian firms. In other words, they represent the core of the Italian technological capabilities.

5. Final remarks

The CNR–ISTAT database on innovation in the Italian manufacturing industry has provided information on a new and valuable indicator of technological change, i.e. innovation costs. This has allowed data on R&D to be related to other expenditures incurred by firms in introducing innovations. Innovation costs consist of a material part, generally embodied in investment, machinery and equipment, and an immaterial part, i.e. R&D and design and engineering. We have shown how the sources of innovations vary across firms of different sizes and from different industries.

The empirical results, based on innovation costs, confirm the existence of a positive association between firm size and innovative intensity for a handful of key highly innovative sectors, and also at the aggregate level. A significant concentration of Italian innovative activities in a restricted group of large firms has also been found. These results appear even more significant when the following factors are borne in mind: (i) the characteristics

TABLE 4 Innovation costs and firm size by industry

Industrial sectors	Firm size (sales in billions of lire)	No. of firms	No. of employees	Innovation cost per employee (millions of lire)	R&D expenditure per employee (millions of lire)
Petrochemicals	< 10	3	92	18.6	0.0
	10–100	3	834	18.6	0.0
	> 100	11	12 310	18.3	2.8
Metals	< 10	32	1 297	10.7	0.5
	10–100	76	11 651	16.0	0.5
	> 100	29	89 464	12.2	0.9
Non-metals, minerals	< 10	344	16 358	18.3	0.3
	10–100	140	35 392	20.2	1.1
	> 100	65	17 059	19.0	1.4
Chemicals	< 10	128	5 088	16.6	4.5
	10–100	214	39 795	21.5	7.5
	> 100	67	92 079	12.2	3.2
Synthetic fibres	< 100	5	693	13.2	0.1
	> 100	4	10 433	11.0	1.4
Metal products	< 10	629	29 105	12.4	0.6
	10–100	229	47 907	9.4	0.7
	> 100	6	9 688	9.2	0.8
Mechanical machinery	< 10	769	35 254	13.5	1.4
	10–100	364	74 927	13.4	2.1
	> 100	33	70 054	14.6	2.8
Office machinery, computing	< 10	3	116	19.8	2.1
	10–100	5	1 706	61.1	35 4
	> 100	3	35 720	72 7	24.6
Electrical, electronics	< 10	272	13 862	12.5	1.5
	10–100	215	57 204	14.9	2.4
	> 100	39	105 579	25.7	7.1
Motor vehicles	< 10	70	3 874	13.1	0 9
	10–100	72	21 551	12.1	1 4
	> 100	13	120 499	33.1	5 2
Other transport	< 10	36	1 791	10.4	0.9
	10–100	41	17 474	11.0	2.2
	> 100	11	51 678	35.7	0 8
Precision instruments	< 10	76	3 672	13.9	2.7
	> 10	34	10 629	29.7	6.2
Food	< 10	97	3 562	16.5	0.7
	10–100	147	18 091	19.1	0.5
	> 100	24	24 877	9.3	0.5
Sugar, drinks	< 10	57	2 147	17.2	0.1
	10–100	91	12 477	16.0	0.5
	> 100	29	46 801	6.9	1.2
Textiles	< 10	383	19 994	12.2	0.4
	10–100	219	44 267	11.2	0.6
	> 100	8	13 726	4 5	1 3
Leather	< 10	58	2 566	5.7	0.4
	10–100	39	4 471	8.9	0 2
	> 100	7	7 037	2.9	0.1
Footwear, clothing	< 10	241	14 817	4.3	0.2
	10–100	95	24 105	3.2	0.2
	> 100	7	10 593	2 9	0 1

TABLE 4 Continued

Industrial sectors	Firm size (sales in billions of lire)	No. of firms	No of employees	Innovation cost per employee (millions of lire)	R&D expenditure per employee (millions of lire)
Wood, furniture	< 10	389	16 856	9 1	0 3
	10–100	80	12 438	11 4	1 4
Paper, printing	< 10	222	9 851	13.6	0 2
	10–100	124	22 692	14 0	0 1
	> 100	23	38 450	15.1	1 1
Rubber, plastic	< 10	236	11 113	14 1	1 3
	10–100	150	29 240	13.8	1 6
	> 100	3	11 882	76.6	30 4
Other	< 10	99	4 659	8.2	0 7
	> 10	31	3 828	12.6	2 1

Source: Elaborations on CNR–ISTAT database.

TABLE 5 Innovation costs and R&D expenditure of innovation-intensive industries* by firm size

Firm size (billions of lire)	No of firms	Total innovation costs (%)			R&D expenditure (%)		
		On total innovation-intensive sectors	On total sample (6839 firms)	On total firms of the same size-class	On total innovation-intensive sectors	On total sample (6839 firms)	On total firms of the same size-class
< 100	1208	17.2	9 4	26 7	13 5	9 1	36 4
100–500	55	14.6	8 0	36.8	18 5	12 4	53 3
> 500	16	68.3	37 4	86 6	68 0	45 6	88 1
Total innovation-intensive firms	1279	100.0	54.8	54 8	100.0	67 1	67.1

Source: Elaborations on CNR–ISTAT database

*These include: office machinery and computing; electrical and electronic appliances and components, motor vehicles, other transport, precision instruments; rubber and plastics

of the technological indicator employed; (ii) the size of the sample examined; (iii) the country this sample is drawn from.

(i) As pointed out above, our indicator is more comprehensive than indicators such as R&D or patents. While some distortions are present in our analysis, this would appear to work to the advantage of the smaller firms. In fact, while the data at our disposal concentrate exclusively upon innovative firms, it was shown elsewhere [17, 18, 27] that the number of 'non-innovating' or 'less-innovating' firms is significantly greater among small firms than large firms.

(ii) Although our sample is particularly large, we have focussed on innovating firms only. While virtually all the firms above a certain threshold have innovated, innovation is more skewly, and to a certain extent randomly, distributed among firms of smaller size. However, our data show that in some traditional industries small firms

which have actually introduced innovations can be as vital as, and often more vital than, large firms.

(iii) Finally, our empirical evidence is particularly significant in that it refers to Italy, a country generally taken as an example of small-firm efficiency and innovative capacity [29, 30]. In the light of the above, there thus appears to be no reason to assume that the use of our indicator in other national contexts should lead to different results.

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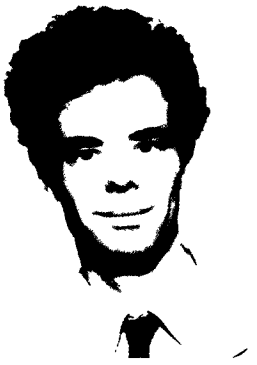
APPENDIX: Information on the statistical sources

Table 1: The data in columns 1 and 3 refer to the sample of 6839 firms resulting from the operation of combining the 8220 innovating firms that answered the second questionnaire of the CNR–ISTAT survey and the 30450 firms involved in the gross product survey of 1985. The data in columns 2 and 4 refer to a sample of 2191 firms resulting from the operation of combining the 2557 firms registered by the CNR–ISTAT as carrying out R&D with the sample of firms involved in the gross product survey.

Table 2: The data refer to the total sample of 8220 firms that answered the second questionnaire of the CNR–ISTAT survey.

Tables 3, 4 and 5: The data refer to the sample of 6839 firms broken down by 21 industrial sectors. Results are also available, on request, at a higher level of sectoral disaggregation.

For the data contained in all tables, cf. ISTAT, *Indagine statistica sull'innovazione tecnologica nell'industria italiana*, Collana di informazione, 1990, n. 14. The methodology employed in the survey is illustrated in [17]. The data of the CNR–ISTAT survey refer to the innovative activities carried out over the 5-year period 1981–1985 by the firms interviewed.



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