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Nature and impact of innovation in manufacturing industry: some evidence from the Italian innovation survey

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Abstract

Using data on more then 22,000 manufacturing firms participating to the second Italian Innovation Survey, fresh evidence is presented on the number of firms involved in innovation, the total expenditures devoted to innovation and the quantity and quality of innovating output. The most important innovation expenditures are investment in new machinery and R & D. The existence of major cross-industry differences are however confirmed. Within the group of innovating firms, the small ones do not emerge less innovative than the large ones. However, data clearly show that small firms introducing innovations are a minority and that they account for only a small share of total innovation expenditure of the Italian manufacturing industry. The paper also quantifies the share of new products and processes on total sales showing that a substantial part of sales in the manufacturing industry (62%) is made of unchanged products and processes and only 1.2% of total sales is made of entirely new products. It is also shown that only to a limited extent the innovation patterns highlighted in this article reflect the peculiar characteristics of Italian industrial structure. Most of them are common to most of the European countries which have taken part to the Community Innovation Survey (CIS). © 1997 Elsevier Science B.V.

Keywords: Community Innovation Survey (CIS); Manufacturing industry; R & D

1. Introduction

Although technological change is one of the main determinants of long-term economic development, our knowledge of some of its most crucial aspects is still incomplete, and an exhaustive quantification of all key dimensions of innovation activities is still lacking. The following issues are some of those which have not yet been fully answered.

1.1. How many firms do innovate?

We can assume that, in a competitive economic system, all firms are forced to innovate or to perish in the long run. However, it has not yet been quantified what is the share of firms introducing innovations in each time period and how this share changes over time. Some firms might be persistent innovators, especially in industries characterised by high technological opportunities, while in other industries the frequency of innovation might be much lower (see Malerba and Orsenigo, 1995; Geroski et al., 1996).

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1.2. What is the amount of resources devoted to innovation?

It is now widely acknowledged that firms innovate through a variety of sources and that innovation patterns are industry-specific (Pavitt, 1984; von Hippel, 1988; Archibugi et al., 1991; Evangelista, 1996). However, a quantification of the different inputs devoted by firms to nurture their innovative projects is still needed.

1.3. What is the amount and significance of the innovated production?

Not even the most innovating companies will entirely replace their old products and processes with new ones. It is therefore necessary to quantify the share of new products and processes and to assess their degree of novelty.

Since the earliest Schumpeter's suggestive analyses (Schumpeter, 1934, 1942), these issues have been addressed in a great deal of research. The debate is, nonetheless, still open due to the lack of suitable measuring instruments. The empirical evidence we present in this paper is a contribution to the debate on the widespread of innovation, on the resources which absorbs and on its economic significance. It is based on a new data source, namely a survey carried out in 1993 by the Italian National Statistical Institute in collaboration with the Institute for Studies on Research and Scientific Documentation of CNR (hereunder referred to as the Italian Survey) and promoted and coordinated by the European Commission and Eurostat under the Community Innovation Survey (CIS) venture. Few comparisons between Italian data and those drawn form the European sample (CIS) will be also carried out.

The paper is organised as follows: Section 2 examines the methodological aspects concerning the measurement of innovative activity. Section 3 analyses the spread of innovation phenomenon in the Italian manufacturing sector and in Europe looking at percentage of innovating firms across main industries and firm size classes. Section 4 quantifies the importance of the different sources of innovation again both in the Italian manufacturing industry and across main European countries. The innovative contribution of small and large firms is analysed in Section 5, while Section 6 analyses the output of innovation by looking at the quantity and quality of new and improved products. The main findings of this work and some policy implications are drawn in Section 7.

2. Measuring innovative activities

Satisfactory analyses are only possible with the help of appropriate methodologies and measuring instruments. Compared to other economic variables (such as, for example, production, value added, investment, exports, and employment), innovation variables are much harder to be measured. The difficulties have to do first of all with the very nature of the phenomenon of innovation, characterised by a high heterogeneity. In particular, four aspects hamper the measurement of technology and innovative activities:

(i) Technological knowledge may be formal or tacit. While only a portion of such knowledge may be written down in books, manuals, patents and designs, another part remains tacit.

(ii) Sources of innovative activity may be internal or external to firms. In the majority of cases, the innovations introduced by firms are based upon both types of sources.

(iii) While some innovative activities may be easily identifiable in economic terms, through prices and costs, other technological activities occur outside the sphere of market transactions.

(iv) Technological change consists both of identifiable tangible activities—for example, new machinery and equipment—and intangible activities, which include the generation of new ideas, inventions and innovations.

In addressing these problems, economists, sociologists and statisticians have tried to produce indicators capable of describing and predicting reality, but none of them is totally satisfactory. Nonetheless, if they are used properly, they may provide helpful indications both for analysis and for economic policy choices.

The intellectual framework of the new measurement tools developed over the last decade is defined by the notion that "the linear model of innovation is dead" (Rosenberg, 1994, p. 139). The onus is now placed on the fact that innovative activity is an interactive process in which the different phases and sources of technological change are interdependent and not hierarchically structured. Thus, whereas in the past a great deal of attention was attached to R&D activities, regarded as the main source of innovations, recently the focus has shifted to the role played by other complementary sources. Hence the development of surveys to measure innovative activity directly. Public research centres, statistical offices, international organisations—including the OECD and the European Commission—and numerous university centres have thus attempted to supplement the statistical information already available with a new indicator based on direct surveys of 'the innovative phenomenon'. Albeit performed with different methodologies, surveys have followed two main approaches (see Archibugi, 1988; Hansen, 1992):

- collecting information on the innovations introduced, hence concentrating on the *objects* of innovative activity;
- questioning firms about input, output and the nature of the innovative process, hence focusing analysis on the *subjects* of innovative activity.

The first group comprises surveys conducted by Spru in Great Britain on a set of innovations (Townsend et al., 1981; Pavitt, 1984; Pavitt et al., 1987), by the Small Business Administration in the United States (Acs and Audretsch, 1990), and those on new products advertised on specialised magazines and publications (Kleinknecht and Bain, 1993; Santarelli and Piergiovanni, 1996; Coombs et al., 1996). The second group encompasses the surveys carried out by Ifo in Germany (Scholz, 1992), certain Dutch surveys (Kleinknecht and Reijnen, 1991) and the Istat/Isrds-Cnr surveys (Archibugi et al., 1991; Cesaratto et al., 1991).

The diversity of the various surveys has enhanced our knowledge on the advantages and limits of the various approaches. Furthermore, it has still not been possible, however, to obtain comparative statistical data over time and across countries.

In recent years, great efforts have been made to harmonise surveys on innovation at international level. The OECD, for example, supplemented its family of manuals on technological indicators [2] with the Oslo Manual (OECD, 1992a; OECD-EUROSTAT, 1997) on the methodologies and contents of direct surveys on the innovative activity of firms. In 1992, the European Commission launched the 'Community Innovation Survey'. This was the first ever survey on innovation to be carried out simultaneously in so many countries on the basis of a harmonised questionnaire. Data on almost 41,000 European firms have been collected. Unfortunately, the results for each country are only in part comparable as a result of modifications to the text of the questionnaire introduced by some of the national contracting parties and the inadequate harmonisation of the statistical methodologies adopted (cf. Archibugi et al., 1995a; Evangelista et al., 1996). It is nonetheless encouraging to take stock that various countries outside the European Union—including the United States, Canada, Australia, Hungary and China—have also undertaken similar surveys. [3]

The following sections of this paper will assess some of the results emerging from the survey on innovation in the Italian manufacturing industry conducted within the framework of the Community Innovation Survey. The Italian Survey has involved a number of firms larger than in any other European country and accounts for as many as 40% of the total returned questionnaires of the Community Innovation Survey (cf. Archibugi et al., 1995a; Evangelista et al., 1996). Despite data presented in this paper necessarily reflect the specificity of Italian industrial structure, we will show that they also highlight some

[2] The OECD has already compiled manuals for collecting data on R&D expenditure, patents, human resources for science and technology, the technology balance of payments and surveys on innovation.

[3] The OECD and the European Commission have hosted international conferences where the methodology, results, policy implications and perspectives of these new innovation indicators have been explored. Among these, we would like to recall the Conferences 'Innovation, Patents and Firms' Technological Strategies,' Paris, OECD, 8–9 December 1994; and 'Innovation Measurement and Policies', Luxembourg, European Commission-Eurostat, 20–21 May 1996.

Table 1
Innovating and non-innovating firms by firm size (Italian Survey)

	Total firms on total firms	% Innovating firms on total firm	% Employees of innovating firms on total firms	% Sales of innovating firms on total firms
Classes of employees				
20–49	15,109	25.9	27.5	29.1
50–99	4142	40.8	41.6	43.0
100–199	2012	48.0	48.7	47.8
200–499	1041	58.5	59.8	67.3
500–999	292	74.0	74.5	79.1
1000 and over	191	84.3	91.5	95.9
Total	22,787	33.3	61.5	70.7

Source: Istat (1995).

basic characteristics of innovation patterns in industry which are shared by most European countries.

3. The spread of innovation in the manufacturing industry

One of the first aims of innovation surveys is to establish how widespread the innovative phenomenon is within the industrial structure. With the exception of very few craft-based firms, in a dynamic and long-term perspective all firms are bound to innovate. Although it is reasonable to expect all firms to innovate, it is still necessary to establish how frequently firms innovate and what is the fraction of the industrial fabric which is affected by the introduction of new products and processes.

Table 1 shows for the manufacturing sector as a whole and for the main firm size classes the number of firms participating to the survey, the percentages of these firms that have introduced innovation in the period 1990–1992, and the percentage of sales and employees accounted for by innovating firms in 1992. The Table shows that only one third of the firms involved in the survey have introduced innovation during the three years period considered. The innovative phenomenon has involved however a much larger portion of the Italian industrial structure, 61.5% of employees and 70.7% of turnover of the manufacturing industry covered by the survey being concentrated in innovating firms. The Table shows that there are significant differences in the percentage of innovating firms across different size classes. Only one fourth of the firms with less than 50 employees have innovated during the period 1990–1992, while 84.3% of firms with over 1000 employees have introduced innovations. This pattern holds also at the level of all European countries participating to CIS taken as a whole. Fig. 1 also shows that at the European level, a clear positive relationship between firm size and the percentage of innovating firms is found. It should also be noted that the percentage of European firms which have introduced innovations in the period 1990–92 rises up to 53%. These figures, however, are likely to be somewhat overestimated. This is due to very low response rates obtained in many countries, which are likely to be associated to samples biased towards innovating firms (cf. Evangelista et al., 1996). [4]

Significant differences in the percentage of innovating firms also emerge across industries as shown in Table 2, referring to the Italian industry. Industrial sectors showing the highest percentages of innovating firms are Aerospace (67.7%), Office machinery (64.6%), Radio, TV and Telecommunications (59.8%). Also at industry level a more effective indicator of actual economic relevance of the innovation phenomenon is given by the percentage of sales and employees of innovating firms. In sectors such as Aerospace, Office machinery and Radio, TV and Telecommunications innovating firms concentrate more than 90% of the employees and sales of these industries, while in most of the industries producing

[4] An analysis of the CIS dataset has shown a clear negative correlation between response rates and percentage of innovating firms across countries (cf. STEP-ISRDS, 1996).

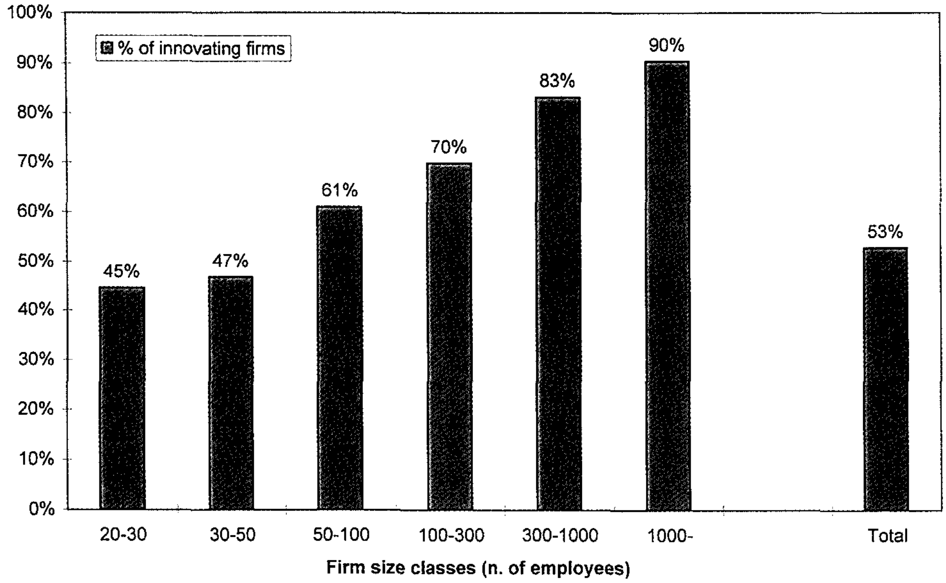

Fig. 1. Percentage of innovating firms across firm size classes in Europe (values reported to the population of European firms) *.

Table 2
Innovating and non-innovating firms by industry (Italian Survey)

	Total firms on total firms	% Innovating firms firms on total firms	% Employees of innovating firms on total firms	% Sales of innovating firms on total firms
Industrial sectors				
Aerospace	31	67.7 (1)	99.0 (1)	99.5 (1)
Office machinery	48	64.6 (2)	94.4 (2)	97.6 (2)
Radio, TV, telecom.	249	59.8 (3)	91.9 (3)	93.4 (4)
Pharmaceuticals	198	56.1 (4)	78.6 (8)	80.6 (8)
Precision instruments	435	50.3 (5)	65.8 (12)	67.7 (12)
Mechanical machinery	2713	48.9 (6)	70.5 (10)	75.4 (10)
Chemicals (excl. pharmac.)	561	45.6 (7)	78.8 (7)	80.9 (6)
Motor vehicles	445	44.7 (8)	91.5 (4)	92.0 (5)
Synthetic fibres	31	41.9 (9)	82.9 (5)	80.7 (7)
Rubber and plastic	866	41.8 (10)	63.6 (13)	65.1 (14)
Oil	89	39.3 (11)	81.2 (6)	97.5 (3)
Electrical machinery	989	38.7 (12)	67.7 (11)	72.5 (11)
Printing and publishing	732	38.3 (13)	54.7 (16)	53.7 (16)
Paper	496	38.3 (14)	58.5 (15)	63.5 (15)
Metals	643	37.9 (15)	60.8 (14)	65.2 (13)
Metal products	2874	33.4 (16)	42.4 (19)	45.6 (19)
Other transport	272	32.7 (17)	75.1 (9)	75.5 (9)
Food, drink, tobacco	1501	31.2 (18)	53.0 (17)	51.5 (17)
Mineral and non mineral pr.	1486	29.7 (19)	47.1 (18)	49.1 (18)
Wood	622	28.8 (20)	36.6 (22)	26.1 (23)
Textile	2008	28.1 (21)	38.0 (20)	41.9 (20)
Other manufacturing	1679	26.0 (22)	36.7 (21)	40.2 (21)
Leather and footwear	1486	18.8 (23)	24.6 (23)	27.9 (22)
Clothing	1991	11.3 (24)	17.8 (24)	18.0 (24)

Source: Istat, 1995.
Ranking in brackets.

traditional consumer goods the percentages of employees and sales accounted for by innovating firms remain quite low. Comparing the ranking of industrial sectors according to the percentages of innovating firms and the percentages of sales and employees it is possible to identify few industries where despite it is a relatively small fraction of firms which introduces innovations the actual percentage of sales affected by innovation activities are much larger. This is the case of Oil products and Motor Vehicles where

Table 3
Probability of carrying out innovative activities and R&D (Italian Survey) (logit estimates)

Dependent variables	Eq. 1, presence of innovative activities	Eq. 2, presence of R&D activities
Number of observations	22,787	22,787
Concordant	70.0%	77.5%
Discordant	29.7%	22.1%
−2Log L	2774	3725
Score	2641	3837
Intercept	−3.972	−6.114
Belonging to an industrial group	0.166	0.327
Not belonging to an industrial group	reference	reference
Log of employees	0.578	0.742
North–West	0.771	1.361
North–East	0.454	1.496
Centre	0.208	1.127
South	0.067[a]	0.612
Islands	reference	reference
Office machinery	1.486 (1)	1.927 (1)
Aerospace	1.276 (2)	1.544 (3)
Radio, TV, telecom.	1.212 (3)	1.578 (2)
Precision instruments	0.962 (4)	1.415 (4)
Mechanical machinery	0.875 (5)	1.219 (5)
Pharmaceuticals	0.71 (6)	1.097 (6)
Rubber and plastic	0.648 (7)	0.637 (10)
Chemicals (excl. pharmac.)	0.584 (8)	0.894 (7)
Autovehicles	0.579 (9)	0.800 (8)
Printing	0.558 (10)	−0.700 (18)
Paper	0.467 (11)	−0.221[a] (21)
Electrical machinery	0.435 (12)	0.776 (9)
Metal products	0.411 (13)	0.262 (13)
Oil	0.324[b] (14)	0.572 (12)
Metals	0.296 (15)	0.021[b] (16)
Wood	0.203[a] (16)	−0.130[b] (22)
Other transport	0.17[b] (17)	0.254 (14)
Food, drink, tobacco	0.16[a] (18)	−0.129[b] (23)
Mineral and non mineral prods.	0.116[b] (19)	0.086[b] (15)
Clothing	−0.913 (20)	−1.287 (19)
Leather and footwear	−0.319 (21)	−0.225 (11)
Synthetic fibres	−0.06[b] (22)	0.599[a] (20)
Textile	−0.015[b] (23)	−0.279 (17)
Other manufacturing	reference	reference

Source: Elaboration on the Istat database.
[a]Significant at the level of 90%.
[b]Not significant.
Ranking in brackets.

few innovating firms account for an overwhelming share of employees and sales in these industries.

Overall, the evidence presented so far confirms that industrial sectors and firm size prove to be important factors for determining the presence of innovation activities within firms. This kind of evidence however, does not allow us to test whether large firms are more likely to be innovative independently from the industry in which they operate. [5]

To check whether any sectoral and size 'composition effects' exist we have estimated two logit equations in which the mere presence–absence of the innovative phenomenon (Eq. 1) and R&D activities (Eq. 2), are considered as the independent variables (see Table 3). In both equation as regressors, we used firm size (measured by the logarithm of the number of employees) and the industrial sector firms belonged to (expressed by 24 sectoral dummies variables). Another two variables were included as controlling factors, namely the geographical location of the firm (identified by five regional dummies) and the fact the firm belongs to an industrial group. In the two logit equations estimated, the dependent variables are either equal to 1, if the firm has introduced innovation in the period 1990–1992 (Eq. 1) or performed R&D (Eq. 2), or 0 if it has not. In both equations, the total sample included in the survey has been taken into account.

The coefficients of the different variables allow to estimate (through a logistic transformation) the probability of a firm with given characteristics (size, sector, geographical area, membership of a group) to be innovative or perform R&D. In the case of the dummies variables the coefficient can be interpreted as a gross index of the relative importance of the characteristic of the firm taken into account by the dummies. As the dummy coefficients increase, so the probability of the firm's introducing innovations or performing R&D increases. The value of the intercept refers to the firm with the reference characteristics: namely, non-membership of a group, location in the islands, belonging to the 'Other manufacturing industries' sector.

For both equations, tests confirm that the regressions have an acceptable capacity to interpret the phenomenon. Firms behaviour is predicted by the model in 70% of the cases in Eq. 1 and 77.5% of cases in Eq. 2. [6] The probability of firm's being both innovative and performing R&D increases monotonically with firm size and increases considerably for industrial sectors with are usually labelled as those characterised by high technological opportunities, namely Aerospace, Radio, TV and Telecommunications, Precision instruments, Mechanical machinery and Pharmaceuticals. These results confirm therefore that the industry in which firms are located and firm size are important factors for explaining the presence of innovating activities, irrespective one from another. Table 3 also shows that the probability of a firm's being innovative and perform R&D increases if the firm is a member of an industrial group and it is much higher among firms in the North–West and lower in other areas, with a minimum level in the South and Islands. The positive effect of firm size on the probability to introduce innovation should not come as a surprise if one considers large firms are multiple of small production units. [7] However, this is less true in the case of performing R&D and this because R&D activities are much more permanent and systematic in their very nature.

4. Sources of innovation

The multiform nature of innovative activities and their sectoral specificity have been underlined in a vast amount of literature (Pavitt, 1984; Kline and Rosenberg, 1986; von Hippel, 1988; Archibugi et al., 1991), which has shown the existence of a multiplicity of interdependent sources of innovation. Besides activities generating new technological knowledge, special attention has also been attached to processes

[5] The most recent literature has argued that precisely because of the presence of marked sectoral specificities in levels of technological opportunity and appropriability, the relationship between firm size and innovation studied at the level of the entire manufacturing industry may furnish spurious indications of the actual importance of the size factor (cf. Cohen, 1995).

[6] The value of the Concordant test is similar to that of R^2 in a standard regression.

[7] We thank an anonymous referee for urging us to stress this point.

of technology adoption and diffusion (both embodied and disembodied), an acknowledged sine qua non for technology to express its economic effects to the full (OECD, 1992b, 1996b; Evangelista, 1996).

The relative importance of the various sources should however also be measured using a common yardstick. The Community Innovation Survey attempted to do it according to an input measure such as innovation expenditure, i.e., the breakdown of innovation-related expenditures by items. Table 4 shows the breakdown of expenditure incurred to introduce innovations by firm size. The picture which emerges form the Table is very clear-cut. Industrial innovative processes consist, first and foremost, of the purchase and use of 'embodied' technologies (innovative machinery and plants), which accounts for 47% of total expenditure on innovation, and, secondly, of efforts to generate and develop new knowledge inside firms, as measured by the percentage of innovative spending for R&D activities (35.8%). The other components play a relatively minor role: expenses incurred for design and trial production each account for 7% of total expenditure on innovation, while just 2% and 1.5% of the latter are allocated, respectively, to the purchase of patents and licences and to marketing activities related to the introduction of technological innovations.

The distribution of innovation expenditure shown in Table 4 not only reflects the distinctive profile of the Italian manufacturing industry—with its accentuated specialisation in medium and low technology sectors (Archibugi and Pianta, 1992). It highlights a more generalised pattern of innovation activities which holds across all European countries. This is clearly shown in Fig. 2 which shows the break-down of innovation costs across the main European countries. The data shown in the Figure confirm the following:

(i) R&D activities are confirmed to be a central component of the technological activities of firms and as the most important 'intangible' innovation expenditure. Nonetheless, in all countries they account for no more than one third of total expenditure of European innovating firms;

(ii) The largest part of firms' innovation financial efforts is confirmed to be linked to the adoption and diffusion of technologies embodied in capital goods, across all European countries;

(iii) Expenditure-wise, the acquisition of 'disembodied' technology through patents and licences emerges as a secondary innovation component when compared to the other technological sources;

(iv) Other innovative activities, such as design expenses, play a secondary role with respect to the total expenditures sustained by manufacturing firms for introducing technological innovations.

The importance of the different sources of innovation in business strategies is, however, strongly influenced by firm size, especially as far as R&D expenditure and investment are concerned. Small firms have a high propensity to innovate by acquiring machinery and plants against the greater propensity of large firms to internally generate new technologies. Table 5, referring to the Italian Survey, shows that for firms with fewer than 50 employees, R&D activities account for 15% of total innovation expen-

Table 4
Innovation expenditure by firm size (% values) (Italian Survey)

Classes of employees	R&D	Patents and licenses	Design	Tooling-up and trial production	Marketing	Innovative investment
20–42	14.9	1.5	9.4	7.7	1.9	64.6
50–99	16.3	1.3	8.4	8.5	1.7	63.8
100–199	19.8	1.7	12.8	9.0	2.2	54.5
200–499	27.6	2.2	9.1	9.6	2.2	49.3
500–999	26.0	1.6	13.4	8.1	1.3	49.6
1000 and over	46.7	0.8	4.8	5.7	1.2	40.8
Total	35.8	1.2	7.4	6.9	1.5	47.2

Source: See Table 1.
Rows add up to 100%.

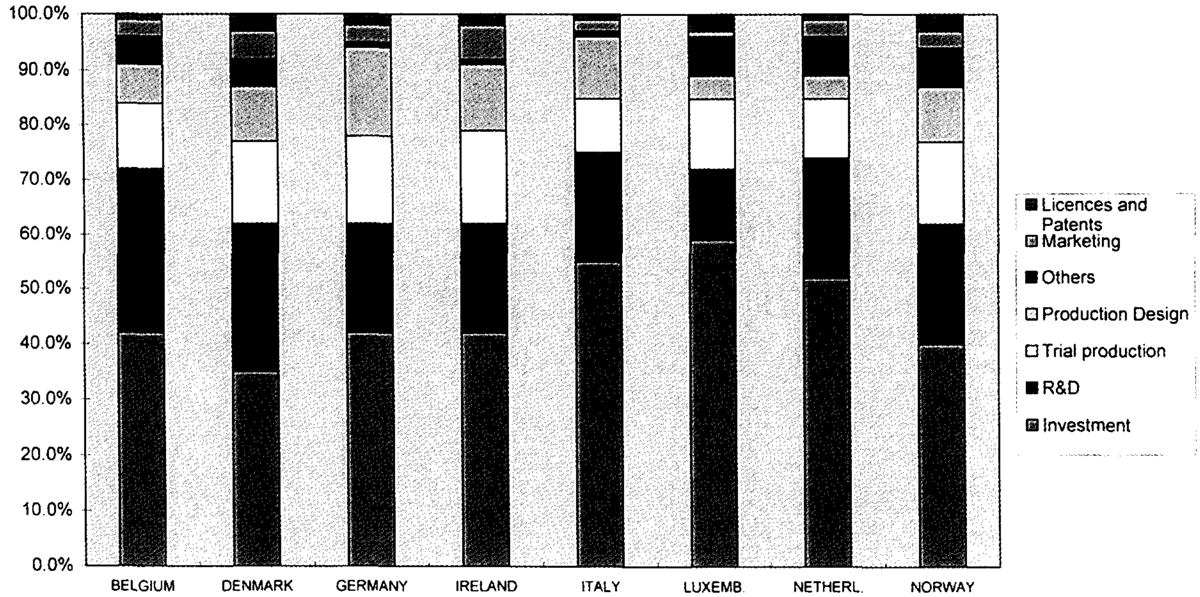

Fig. 2. Break-down of innovation costs across European countries (average values on 8729 innovating firms)*.

diture against a percentage close to 47% in the case of firms with more than 1000 employees. Data on investment show an opposite pattern. Innovative investments of firms with less than 200 employees account for more than 50% or more of total innovation expenditures. The other components of innovation also do not appear systematically correlated to firm size. All that emerges is the greater importance of design activities in intermediate size categories, with percentages over 10% of total innovation expenditures in firms with 100–200 and 500–1000 employees. This again is a pattern which holds across most European countries (Evangelista et al., 1996).

Table 5 allows to look in detail at the importance of the different sources of innovation across industries. The Table allows us to identify industries traditionally defined as science-based in which activities aimed at generating new technological knowledge play a fundamental role. Among the industries which allocate over 50% of total innovation expenditure to R&D, Office machinery and computers (64.8%), Radio, TV and Telecommunications (66.1%), Pharmaceuticals (66.7%) and Precision instruments (54%) are found. Compared to other science-based sectors, Aerospace shows a conspicuously lower percentage of R & D expenditure (39.3%), although it does allocate sizeable portions of its total innovation expenditure to Trial production (22%) and Design (12%). The importance of design is much higher than the manufacturing average not only in the Aerospace, but also in the sectors which produce specialised machinery, such as Electrical and Mechanical machinery and Precision instruments. A noteworthy portion of innovation expenditure is allocated to design in Clothing.

The acquisition of new machinery and plants is by far the prevalent source of technology for most traditional consumer good sectors, such as Wood (78.1%), Textiles (67.7%), Leather and footwear (63.4%), Food (66.7%), Metal products (67.5%) and capital-intensive sectors such as Printing and publishing (77.2%), Paper (81.7%), Metals (79.9%), Rubber and plastic (57.3%) and Motor vehicles (57.8%).

The last two columns of Table 5 show two indicators of innovation intensity, namely total innovation costs and the R&D expenditures sustained by innovating firms in each industry divided by the total number of employees in each sector. Sectors are ranked according to the total innovation costs per employee. The top industries in terms of total resources devoted to innovation are Office machinery,

Table 5
Innovation expenditure and innovative intensity by industry (Italian Survey)

Industrial sectors	Breakdown of innovation expenditure (% values)[a]						Innovation intensity	
	R&D	Patents and licenses	Design	Tooling-up and trial prod.	Marketing	Investment	Innovation expend. per employee[b]	R&D expend. per employee[b]
Office machinery	64.8	0.1	4.5	17.2	1.0	12.4	34.7 (1)	22.5 (1)
Motor vehicles	36.7	0.2	1.9	3.2	0.2	57.8	27.6 (2)	10.1 (4)
Radio, TV, telecom.	66.1	0.8	12.9	5.3	1.2	13.7	25.7 (3)	17.0 (2)
Oil	6.8	1.0	8.5	4.3	0.2	79.2	24.7 (4)	1.7 (12)
Aerospace	39.3	5.0	12.1	22.7	0.7	20.2	23.7 (5)	9.3 (5)
Pharmaceuticals	66.7	4.5	4.3	4.4	2.1	18.0	22.7 (5)	15.1 (3)
Metals	8.1	0.4	6.7	4.6	0.3	79.9	16.7 (7)	1.4 (13)
Chemicals (excl. pharmac.)	42.9	1.1	3.6	3.9	4.5	43.9	11.3 (8)	4.9 (7)
Precision instruments	54.0	1.4	12.4	8.9	2.0	21.3	9.5 (9)	5.1 (6)
Other transport	21.8	0.4	20.7	7.3	5.7	44.2	7.7 (10)	1.7 (11)
Synthetic fibres	30.6	2.4	2.0	7.1	2.3	55.6	7.7 (11)	2.4 (9)
Electrical machinery	30.4	1.1	14.6	8.8	2.1	43.0	7.2 (12)	2.2 (10)
Paper	7.2	0.4	4.7	4.6	1.4	81.7	7.2 (13)	0.5 (18)
Mechanical machinery	36.0	1.9	15.0	11.8	2.2	33.1	7.0 (14)	2.5 (8)
Printing and publishing	7.9	3.7	6.2	4.0	1.0	77.2	6.3 (15)	0.5 (20)
Rubber and plastic	19.8	1.4	9.4	10.1	2.0	57.3	5.6 (16)	1.1 (14)
Non mineral products	12.8	1.4	8.0	8.6	1.9	67.3	5.4 (17)	0.7 (17)
Food, drink, tobacco	17.5	0.8	6.4	5.8	2.8	66.7	4.6 (18)	0.8 (15)
Metal products	12.3	1.4	8.8	8.1	1.9	67.5	4.2 (19)	0.5 (19)
Wood	9.7	0.7	3.7	6.5	1.3	78.1	3.7 (20)	0.4 (23)
Other manufacturing	20.8	0.9	6.5	7.9	2.8	61.1	3.6 (21)	0.8 (16)
Textile	12.2	0.5	8.9	8.8	1.9	67.7	3.5 (22)	0.4 (21)
Leather and footwear	15.5	1.3	8.4	8.6	2.8	63.4	2.5 (23)	0.4 (22)
Clothing	16.5	1.3	25.1	11.1	18.9	27.1	1.4 (24)	0.2 (24)
Total	35.8	1.2	7.4	6.9	1.5	47.2	9.9	3.5

Source: See Table 1.
[a] Rows add up to 100%.
[b] 1992 millions of Italian lire (see Appendix A). Total innovation costs have been divided by the total number of employees in each sector, including both innovating and non-innovating firms.
Ranking in brackets.

Oil products, Motor vehicles, Pharmaceuticals, Radio, TV and Telecommunications, Metals and Aerospace. Specialised sectors in machinery and electronic components reveal an average innovative intensity. The industries which devote fewest resources per employee to innovative activities are: Clothing, Food, Drink, Tobacco and Rubber and plastic. What should be highlighted here is that with the exception of few capital intensive sectors—which heavily invest in the acquisition of new machinery and equipment—the ranking of industries does not change if it is measured through a traditional indicator based on R&D expenditure or using a more comprehensive innovation indicator such as total innovation expenditure per employee. In other words, all Science-based industries remain the leading actors of technological change, irrespective of the indicator used.

5. The role of small and large firms in innovation

The relationship between innovation and firm size has been dealt with over the last two decades by a vast amount of empirical literature. Two models of industrial and technological development have often been contrasted: on the one hand, the model based on large firms, characterised by radical innovative processes centred on R&D activities; on the other, the model of industrial organisation based on small

Table 6
Intensity and concentration of innovative activities by firm size (Italian Survey)

Classes of employees	Innovating firms	Total firms	Concentration of technological activities and sales (innovating firms, % values)				
	Innovation expend. per employee	R&D expend. per employee	Innovation expend. per employee[a]	R&D expend. per employee[a]	Innovation expend.	R&D expend	Sales
20–49	14.7	2.2	4.0	0.6	8.1	3.4	15.0
50–99	12.3	2.0	5.1	0.8	6.8	3.1	9.6
100–199	11.7	2.3	5.7	1.1	7.3	4.0	10.3
200–499	11.8	3.3	7.1	1.9	10.2	7.9	12.9
500–999	16.4	4.3	12.2	3.2	11.2	8.1	8.2
1000 and over	18.3	8.5	16.7	7.8	56.4	73.6	43.9
Total	15.7	5.6	9.7	3.5	100.0	100.0	100.0

Source: See Table 1.
Data are expressed in 1992 millions of Italian lire (see Appendix A).
[a]The index considers the employees of both innovating firms and non-innovating firms to the denominator, whereas the innovation expenditure of innovating firms alone is obviously shown to the numerator.

firms, characterised by informal innovative activities but technologically 'creative' nonetheless (for an overview, cf. Cohen, 1995).

(i) by comparing the innovation intensity of large and small firms, considering innovating firms only;
(ii) by considering the relative contribution of large and small firms to the overall innovation performances of a given economic system;
(iii) by considering the innovation intensity of large and small firms, including both innovating and non-innovating firms.

The data provided by the Italian Survey allow us to analyse the relationship between innovation and firm size on the basis of all the three methodologies recalled above. The results are shown in Table 6. The first two columns show data on firms' expenditure per employee, taking into account total innovation and R&D expenditure respectively for the sample of innovating firms only. Column 2 confirms that large firms are much more R&D-intensive than small ones (see, for example, Soete, 1979); this is hardly surprising since R&D is an innovative source which requires a minimum threshold and it does not 'capture' the innovative effort typical of small firms. But when a much more comprehensive indicator such as total innovation expenditure is considered (column 1 of Table 6), it emerges that innovative small firms are not substantially disadvantaged compared to their larger competitors. In fact, the data show an u-shaped curve: the innovation intensity of firms with fewer than 100 employees is higher than that of firms in the intermediate size groups, despite the fact that it is still lower than that of firms with more than 1000 employees. [8] This result is totally consistent with the analyses of Pavitt et al. (1987) and Acs and Audretsch (1990), which have taken into account the universe of innovating firms without considering firms which do not introduce innovations.

However, the indicators shown in the first two columns of Table 6 fail to take into account that the number of innovating firms considerably differs between small and large firms. This aspect is crucial when the role in innovation of large and small firms wants to be assessed. As already shown in Table 1, 84% of larger Italian firms are innovative whereas such percentage drops to 26% for smaller firms. This is a pattern which is found also across all other European countries (Evangelista et al., 1996).

Columns 3 and 4 of Table 6 report respectively the average values per employee of innovation ex-

[8] In considering average values per size class, we obviously neglect the albeit significant specificities of sectors. For an analysis of the relationship between innovation intensity and firm size at the level of the main industrial sectors, see Archibugi et al. (1995b).

Table 7
Distribution of total sales according to the type of innovation introduced (% values)[a] (Italian Survey)

Industrial sectors	Percentage of sales				
	Not innovated	Innovated by process innovations	Innovated by incremental product innovations	Innovated by significantly new products	Total sales
Office machinery	19.1	7.9	16.4	56.6	100
Electrical machinery	50.9	13.6	20.3	15.2	100
Radio, TV, telecom.	43.2	20.4	23.0	13.4	100
Aerospace	37.7	24.7	12.6	25.0	100
Chemicals (excl. pharmac.)	69.2	12.9	11.4	6.5	100
Pharmaceuticals	70.1	8.5	8.7	12.7	100
Synthetic fibres	58.3	13.5	19.4	8.9	100
Mechanical machinery	56.7	11.9	19.0	12.4	100
Precision instruments	57.9	9.4	18.6	14.1	100
Motor vehicles	53.4	7.4	24.6	14.6	100
Other transport	41.3	19.5	23.2	16.1	100
Rubber and plastic	64.1	15.0	13.2	7.7	100
Metals	53.3	37.9	6.0	2.8	100
Printing and publishing	63.1	28.2	3.6	5.1	100
Paper	69.7	15.2	9.7	5.4	100
Food, drink, tobacco	78.3	13.0	5.8	2.9	100
Textile	74.9	13.2	6.7	5.3	100
Clothing	86.5	8.7	2.6	2.3	100
Leather and footwear	82.1	7.1	4.8	6.0	100
Wood	84.4	9.2	3.0	3.4	100
Metal products	73.0	14.6	6.9	5.5	100
Mineral and non mineral pr.	77.2	11.5	7.0	4.3	100
Other manufacturing	73.9	11.7	8.0	6.4	100
Oil	63.4	18.3	10.2	8.0	100
Total	62.5	18.2	10.7	8.6	100

Source: See Table 1.
[a]Including the sales of non-innovating as well innovating firms.

penditure and the R&D expenditure for all Italian firms participating in the survey. [9] The positive relationship between innovation intensity (in a broad sense) and firm size strongly re-emerges. The average innovation expenditure per employee with over 1000 employees is 16.7 million lire, while for firms with 20–50 employees it is only 4 million lire. This difference has to do with the fact that, although small innovating firms are not less innovative than large firms, they are not representative of the overall productive universe of small firms.

Finally, the last three columns of Table 6 allow us to assess the effective economic and technological weight of large and small enterprises in the Italian manufacturing industry. The picture which emerges is one of a high level of concentration of technological activities. The 161 firms with over 1000 employees cover 56% of total innovation expenditure and over 74% of R&D expenditure. The role of the 5602 innovating firms with fewer than 100 employees appears rather limited. These firms account for only 15% of total innovation expenditure and just 6.5% of R&D expenditure. The technological weight of small firms is thus much lower than their economic weight in terms of turnover (25%).

[9] Since it is our intention here to measure the total innovation intensity of each group of firms (by size or industrial sector), the index considers the employees of both innovating firms and non-innovating firms to the denominator, whereas the innovation expenditure of innovating firms alone is obviously shown to the numerator.

6. The output generated by innovation

We have so far considered the inputs devoted by firms to innovation. This is only one way to measure technological change in industry (the consistency of a variety of innovation indicators is explored in Hollenstein, 1996 and in Calvert et al., 1996, using CIS data). But the intensity of innovation can also be measured according to output indicators. The Community Innovation Survey offers a significative indicator of innovation output, namely the part of firm total sales due to innovation. This does not measure the economic impact of innovation (such as the productivity-based indices reviewed in Griliches, 1995), but rather it provides direct information on how a firm, an industry or even an economic system as a whole have changed their production output in relation to innovation.

Table 7 shows the distribution of sales according the nature of the innovations introduced broken down by industries. Looking at the Italian manufacturing sector as a whole as much as 62.5% of the sales have not been affected at all by innovation. If we exclude the Office machinery sector, where non innovated turnover account for 19.1% only, even in high-tech industries there is a remarkable share of non-innovating sales. The most remarkable result is represented by Chemicals and Pharmaceuticals, with a share of non-innovating sales which reach 70%.

The data also allow to decompose innovative sales between process innovations, incremental product innovations and significantly new products. Also, these data (shown in Table 7) highlight, first and foremost, the gradual and incremental nature of firms' innovative activities. 18.2% of turnover was innovated by introducing process innovations and 10.7% through the introduction of incremental improvements of pre-existing products. Only the remaining 8.6% of turnover of the Italian manufacturing sector referred to totally new products.

Table 8
Sales according to the degree of novelty of the product innovations introduced (% values)[a] (Italian Survey)

Industrial sectors	New for the firm	New for the Italian market	New in absolute terms
Office machinery	17.2	24.0	15.5
Electrical machinery	5.5	8.5	1.2
Radio, TV, telecom.	8.7	2.8	1.9
Aerospace	2.3	15.7	7.0
Chemicals (excl. pharmac.)	4.1	2.3	0.2
Pharmaceuticals	4.9	5.1	2.7
Synthetic fibres	5.0	3.6	0.2
Mechanical machinery	6.2	2.9	3.3
Precision instruments	8.6	3.0	2.5
Motor vehicles	1.5	9.3	3.8
Other transport	6.1	7.6	2.4
Rubber and plastic	3.7	2.2	1.8
Metals	1.0	1.6	0.2
Printing and publishing	2.9	1.8	0.5
Paper	4.2	1.0	0.2
Food, drink, tobacco	1.6	1.2	0.1
Textile	2.6	1.4	1.3
Clothing	1.3	0.5	0.5
Leather and footwear	2.3	1.4	2.3
Wood	1.8	1.4	0.2
Metal products	3.1	1.4	1.0
Mineral and non mineral pr.	2.6	0.9	0.7
Other manufacturing	3.8	1.7	1.0
Oil	4.1	3.1	0.7
Total	3.6	3.8	1.2

Source: See Table 1.
[a]Including the sales of non-innovating as well innovating firms.

A further qualification of the quality of innovations can be assessed by taking into account the degree of novelty of the products introduced. The results are reported in Table 8 which shows the percentages of the total sales of the Italian industry related to the introduction of products which are (i) new for the firm, (ii) new for the Italian market, and (iii) new in absolute terms. Again, the figures in the Table show that it is a very small fraction of economic output which is affected by technological activities. For the Italian manufacturing sector as a whole sales linked to introduction of products new in absolute terms represent only 1.2% of total manufacturing sales in 1992, while products new for the Italian market, or new only for the firm, represent 3.8% and 3.6% of total manufacturing turnover of Italian turnover. The incremental nature of technological change seems a feature which characterise not only traditional industries but also some of the most typical science based sectors such as Radio, TV and Telecommunications and Chemicals. Equally, rather low shares are found in specialised industries such as Mechanical machinery and Precision instruments. The little impact that innovation has on firms' output might reflect the relatively backwardness of the Italian productive system also in industrial sectors characterised by high technological opportunities. [10] However, we believe that first and foremost such results suggest that the pace of technological change in an economic system is probably slower than generally believed. [11]

7. Conclusions

The analysis of the results of the Italian Survey has allowed to empirically address three main issues of industrial innovation: the spread of innovation in the manufacturing industry, the nature of firms' technological activities and the outcome of innovation. In some cases, the evidence presented has allowed to confirm known findings though on the basis of a more robust empirical data; in others, it has allowed to quantify phenomena which were not so far measured, and on other occasions to rectify some generally hold views. All in all, the evidence presented shows that the measurement of innovation by firm-based surveys provides relevant information both for researchers and policy-makers. Much more information can be squeezed out by the Community Innovation Survey. Due to a only partial international comparability of CIS data we have chosen to present data on the other European countries only to highlight some broad regularities in innovation patterns which hold across most European countries.

The major findings of this article can be summarised as follows.

Firms rely on a variegated range of innovation sources. Although R&D represents a crucial source for the generation of innovations and it is the single most important intangible source of innovation, it absorbs just above one third of total innovation expenditures. The largest part of firms' innovation financial efforts is linked to the adoption and diffusion of technologies embodied in capital goods. The evidence presented also confirms that innovation patterns vary significantly across industries and firm size. This finding suggests that sector and firm-specific policy measures are highly advisable.

Only a fraction of small firms innovate. We have shown that innovating small firms are just a minority and that this is true irrespective of (albeit important) sectoral specificities and the geographical location of the firms. Small firms which introduce innovations are however not substantially less innovative than their larger competitors. The evidence presented suggest therefore that, to foster the economic performance of small firms, it is more important to *broaden* rather than *intensify* the innovating industrial base.

The leading sectors in innovation remain the same irrespective of the technological indicator used. In order to measure the innovative intensity of industries, in this article we have used a very comprehensive technological indicator such as total innovation expenditure. While the Italian Survey has confirmed that there is much ground to enlarge the understanding and measurement of technological change from a narrow R&D concept to a wider innovation concept, it has also shown that the *ranking* of industries

[10] This is also confirmed by Calvert et al. (1996), which using the CIS dataset have analysed the impact of innovation on output in the different European countries.

[11] For a comparison at the industry level of inputs and outputs from innovation, see Sterlacchini (1996).

according their innovativeness only to a limited extent depends upon the indicator used.

Technological change is very cumulative in nature. Data on innovation output confirm the very cumulative nature of technical progress. Over a three-year period, the percentages of sales linked to the introduction of new products represent only a small portion of total turnover both at the level of all manufacturing industry and also in many industries characterised by high technological opportunities.

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Appendix A

The Italian Survey and CIS cover innovative activities undertaken in manufacturing industry in the period 1990–1992. Firms were asked whether they had introduced innovations during such a three years period. With reference to the same period, firms were asked another set of qualitative questions on objectives and obstacles of innovation, and sources of information used. Some more quantitative data on firms' innovation inputs and outputs have been collected on a one year basis. In particular, firms where asked to provide data on their innovation expenditures and innovative sales for the year 1992 only. Accordingly, the figures on innovation expenditures reported in Tables 4–6 (for Italy) and Fig. 2 (for the other European countries) refer to 1992 only. The data on firms' innovated sales reported in Tables 7 and 8 also refer to 1992 although the definition of innovative sales includes product and process innovations introduced during the period 1990–1992.

In Figs. 1 and 2, 'micro aggregations' of the original data carried out by EUROSTAT have been used. This in order to protect confidentiality. The results represent however a very accurate estimation of the 'true' values which will be later produced by EUROSTAT.

Estimations on the percentage of innovating firms in Europe shown in Fig. 1 have been computed using the raising factors (weights) provided by EUROSTAT in order to re-proportionate the national sample to the populations from which the samples have been drawn. The above procedure has not be used for the analysis of the data on innovation costs shown in Fig. 2 because of the large number of missing values in the relevant questionnaire section. The reproportioning to the statistical population would have yielded highly distorted estimates. The average values reported in Fig. 2 are therefore calculated summing up the percentages of the manufacturing firms that in each country have filled out the innovation cost section of the questionnaire. This implies that all firms have been attributed the same weight.

A more detailed analysis of the Community Innovation Survey and data on innovation costs is contained in Evangelista et al. (1996) and in a earlier EIMS-CIS report: STEP-ISRDS 'Patterns of innovation input, innovation costs, non-research and intangible inputs—Analysis of the data from the Community Innovation Survey'.

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