Sources of innovative activities and industrial organization in Italy *

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This paper is based on the information gathered through a survey on industrial innovation in 24,000 Italian business units. Two-thirds of the business units surveyed declared they had introduced innovations, although there were significant variations across industries and size. Only 16 percent of the innovating business units monitored declared they had performed R&D: as many as 13,986 business units have introduced innovations without performing R&D.

The paper focuses on the different sources of technical knowledge which support the innovative activities, such as R&D, design, acquisition of capital goods, patents, etc. It considers also the relationship between concentration and innovative intensity at the industry level. It emerges that, at least at the business unit level, there is a weak correlation between the two variables.

On the basis of the measured industrial concentration, the propensity to perform product versus process innovations, and the sources of technological change, a taxonomy of industrial sectors is proposed which elaborates on Pavitt's original approach. This taxonomy, instead of stressing the role of either small firms as in the flexible specialization model or of the Schumpeterian concentration to explain the intensity and nature of the innovative phenomena, indicates that sectoral differences explain more than is generally believed in understanding technological change. Efficient innovation policy should therefore be tailored to match those sectoral characteristics.

1. Preface

In 1985 the National Research Council of Italy (CNR), in collaboration with the Central Statistical Office (ISTAT), carried out a survey on technological innovation in the Italian manufacturing industry. About 24,000 business units with more than 20 employees took part in the survey. Such a very large sample is used here to investigate some of the new research directions appearing in the literature on technological change. The main feature of these new directions is the refusal of any single relationship applicable to all industries between industrial organization and technological change [8,19]. The paper contains a proposal for sectoral taxonomy on the sources of technological change and associated forms of industrial organization based on Pavitt's suggestion of the importance of intersectoral differences as compared to inter-size differences. The proposed taxonomy, although representative of general features of technological change common to many industrialized countries, reflects also the peculiarities of the Italian industrial structure [3].

Some of the theoretical contributions on sources of technological change are discussed in section 2, while section 3 contains an assessment of various contributions to the relationship between innovation and industrial organization. Section 4 contains an assessment of the analytical aspects considered in the previous two sections using the data from the CNR–ISTAT survey. On the basis of theoretical considerations and available empirical data, section 5 proposes a taxonomy of the industrial sectors according to their sources of technological change. This taxonomy owes much to the work carried out by Pavitt in 1984, but differs from it in several ways – in particular in taking the industrial sectors as reference base rather than companies. Section 6 offers some analytical considerations on this approach, while section 7 examines the implications our taxonomy holds for economic policy.

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2. The sources of technological change

Only recently have economists focused their attention on the sources of innovative activity, although no unanimous agreement has been reached by researchers. Simplifying somewhat we may state that economic science traces the sources of technological change back to two factors. On the one hand, technological innovations are ascribed to the *exogenous* progress of science or to the work of individual inventors, while on the other hand the *endogenous* approach stresses learning processes within the firm and marked-induced innovations.

It has not, however, been clarified to what extent the two approaches were complementary or alternative, and in which circumstances one of them was more suitable to explain industrial innovation [17, p. 61].

A third hypothesis on the sources of technological change is offered by the so-called linear model of innovation [12, p. 286]. This model presupposes that the innovations introduced by companies are entirely to be credited to the systematic work of R&D departments and it considers innovative activity as endogenous to the firm, but sets it apart from the other activities carried out therein:

> The process of R&D has often been equated with innovation. If this were true, understanding innovation would be far simpler than it truly is, and the real problems would be far simpler and less interesting than they truly are. Successful innovation requires the coupling of the technical and economic in ways that can be accommodated by the organization while also meeting marked needs, and this implies close coupling and cooperation among many activities in the marketing, R&D, and production functions (Kline and Rosenberg [12, pp. 301–2]).

In fact, there are many cases where the formal R&D activities do not represent the main input for innovative processes. A significant source of innovation for the entire industrial system is represented by design activity in the capital goods sector. Design is part of those activities such as "engineering and other 'lower' forms of knowledge" [24, p. 77] which are among the primary source of industrial innovation. The capital goods industry "communicates" with user sectors through cooperation between companies [14], or through channels such as trade fairs and exhibitions.

Those considerations are particularly valuable in the Italian context, where innovations have very often derived from activities carried out in small or medium-sized companies devoid of formal R&D departments. It has been pointed out how relevant lower forms of knowledge are to a significant part of the innovation process in Italy:

> It is above all in small companies where research is often carried out by entrepreneurs, technicians and foremen.... The history of Italy's industrial districts during the last twenty years is the history of groups of small companies succeeding not only in utilizing but actually producing innovations. One important implication of the mistaken attitude of singling out the big companies as the only example of commitment to research in the entire world of industry, is that it is impossible to measure the country's commitment to innovation with the money spent on research carried out in formalized research laboratories in companies. Thus only formal research is recognized and the non-formalized research is neglected. The resulting tendency is to present a picture where it is only the strategic inventions that count (Brusco and Russo, [6, p. 19]).

One point clearly emerges from these considerations: the variety of sources feeding technological change and its links with company organization. Differences among industries in the sources of innovative activity were also perceived as long ago as the 1960s by researchers on company organization who devised the so-called "contingent theory of organization", which held that organization would change according to the "technological environment" it worked in [7,13,32].

Pavitt [18] attempted to bring some order to the fragmentary notions acquired on the sectoral sources of innovation and industrial organization. He proposed a taxonomy at the company level where the sources of technological know-how are chosen as a decisive criterion for classification. Explicitly placing the emphasis on sectoral analysis, Pavitt focused on various sources of innovation, including design activities and contact with users for "specialized suppliers" companies, the production departments for "production intensive" companies, the R&D departments in "science based" companies, and capital goods suppliers in the case of "supplier dominated" companies. On the basis of the information provided by the Italian innovation survey, we will test and elaborate on Pavitt's taxonomy in section 5.

3. Technological change and industrial organization

3.1. The causality marked structure / innovation

Mention was made in the previous section of the utility of studying the sources of technological change on a sectoral base. We believe that a similar approach should be followed to understand the relationship between technological change and industrial structure.

The approach we will follow, and in favour of which we will present our empirical evidence, differs deeply from the approach often used in the economic theory which tries to trace a causative sequence from market structure to technological change (see Kamien and Schwartz [11]).

This latter approach is implicitly derived from the standard paradigm of industrial economics "structure, conduct, performance" [16]. Its aim is to single out the market structure which optimizes a certain target and, in the field of the economics of technological change, the target is the rate of innovation. Therefore, firms' behaviour and performance, including their innovative activities, are seen as the result of industrial structure and not vice versa.

Thus the quest for the "optimum industrial organization" led economists to ignore the production features peculiar to each branch. Moreover, few attempts were made to account for the origin of the industrial structure taken as the starting point for exploration [1].

3.2. Firm size

Until recently the literature on industrial structure and innovation has tended to attribute a marginal role to small companies. Attention has generally been focused on the innovative capacity of the big companies and the market structures related to them such as the oligopoly. At best, the small companies were seen to play a subordinate role, with the larger companies seen as the primary source of innovation. This view was accurately stressed by Sylos Labini in his classic work *Oligopoly and technical progress*:

> If economic development has led to concentration in many important industries, it has also given rise to a great variety of small companies. However, these small companies cannot be placed on the same level as the larger, to which they very often function as satellites. [30, p. 27].

This view reflects the emphasis that Schumpeter's later work [27] put on big companies equipped with all the technological and financial resources necessary to face the costs and risks of R&D. It is undoubtedly significant that the most convincing empirical analyses favouring the hypothesis of the late Schumpeter (cf. Soete [29]) take R&D expenditure – i.e. an indicator biased in favour of the big companies – as a measure of innovative intensity. The role played by small companies in the initial stages of innovation, driven by the heroic work of the entrepreneur was on the other hand stressed by the early Schumpeter [26]. In the former of these two views the small companies play a secondary role in technological change, while in the latter the role is essentially transitory. It should also be noted that both models failed to take account of sectoral peculiarities in the various industries.

More recent contributions have, on the contrary, argued that, at least in certain specific industries, small and medium-sized companies play a *persistent* role. More particularly, the role played by "technological opportunities" for diversification of company activities and "technological ease of entry" can account for the variable industrial concentrations among the sectors [1,15,19].

Technological ease of entry, i.e. the absence of technical obstacles barring entry into specific industries, may depend on the difficulties companies face in appropriating the results of innovative activities. In the case of capital goods, for example, the technical know-how is often shared by both producers and users of the machinery. Extra profits by machinery manufacturers in virtue of

[1] Significant contributions have pointed to differences between sectors as regards technological opportunities [25], product characteristics [10] or relative ease in imitation [28] as playing an important role in relations between industrial structure and innovation.

technological monopolies would be obstructed by the ease of entry for competitors, as indeed for the users themselves [31]. Moreover, the size of the organization and plants in sectors like machinery represent no real obstacle to entry.

4. The CNR–ISTAT survey on technological diffusion in the Italian manufacturing industry

4.1. Approach and statistical population surveyed

In 1985 the CNR and ISTAT carried out a survey on the diffusion of technological innovation in the Italian manufacturing industry. A short mail questionnaire was sent to about 35,000 manufacturing business units with more than 20 employees. In the majority of cases the business unit corresponded to the firm; in the remaining cases it was a division of a diversified company.

The business units were asked four questions on (a) the type of innovations introduced during the previous five years (product/process/organizational; incremental/major); (b) the sources of the innovative activities; (c) the obstacles to innovate; and (d) the programmes for innovation for the following five years. As many as 24,000 business units answered the questionnaire.

The survey does not allow us to weight the technological and economic relevance of the innovations introduced. In fact the survey does not provide information on their technological level, number and economic impact on the business unit's performance.

The statistical data used in this section do, however, offer indications on various questions referred to in sections 2 and 3, i.e. the features of innovative processes in the various industrial sectors. Sections 4.2, 4.3 and 4.4 contains analyses of the statistical base offered by the survey. In section 5 we attempt an interpretation of the findings on the basis of a taxonomy of the sectors in five groups.

4.2. The nature of the innovations

In the survey, business units have been classified according to two criteria: (i) the main economic activity (industrial sector) and (ii) the number of employees (size).

In order to compare the sectoral intensity of technological change in each industrial sector, we have gauged the percentage of innovating business units in the total answering the questionnaire. Column 2 of table 1 shows the percentage of business units that have introduced innovations, divided up according to size and economic activity. The average of innovating business units is quite high: over two-thirds (69.3%) of Italian business units stated that they had introduced innovations over the period 1980–85. Inter-size and intersectoral variations around the average are assessed by means of the coefficients of variation (standard deviation/average), which are equal to 0.14 for size and 0.15 for economic activity.

In order to bring the intersectoral differences into sharper focus, we applied some selective criteria to the business units. Firstly, we took to be "highly innovating" those business units that satisfied three requirements: (a) indicating at least one *internal* source of knowledge (R&D, design and tooling up, patents registered); (b) with innovations in both products and processes; (c) with at least the introduction of a new product or process (as opposed to improvements in products and processes) (column 3 of table 1). There are, of course, much fewer "highly innovating" than "innovating" business units, amounting to a fifth of all the business units taking part in the survey: inter-size and intersectoral variation coefficients become 0.52 and 0.58 respectively. Thus the differences between business units in terms of size and sector appear much more striking when we consider the business units that have introduced more complex innovations on the basis of internal know-how. The role played by "highly innovating" business units in the economic system is, however, proportionally greater than their mere number suggests: while the highly innovating business units represent only a fifth (20.3%) of the total of business units participating in the survey, they have a much higher share (46.3%) of the total employees of all business units.

The findings of the survey also enable us to distinguish between (1) *product* and *process* innovations, (2) *new* and *improved* products and processes, and (3) sources of knowledge *internal* and *external* to the business unit. Columns 4, 5 and 6 of table 1 report the sectoral results. We have used a simple index in order to stress business units differences according to size and in-

Table 1
Innovating business units, nature and sources of innovations introduced

	Business units participating in survey (no.) [1]	Innovating business units/ business units participating in survey % [2]	Highly innovating business units [b]/ business units participating in survey % [3]	Balance between product vs process innovations [c] [4]	Balance between new vs improved products & processes [c] [5]	Balance between internal vs external sources of knowledge [c] [6]
Classes of employees						
20–199	22,111	67.8	18.4	1.00	0.99	0.97
200–499	1,298	83.4	36.4	1.01	1.07	1.18
500–1,999	569	87.9	45.9	1.00	1.12	1.30
2,000–4,999	87	90.8	64.4	1.04	1.10	1.36
above 5,000	39	100.0	87.2	1.05	1.19	1.42
Total	24,104	69.3	20.3	1.00	1.00	1.00
Coefficient of variation [a]		0.14	0.52	0.02	0.07	0.14
Industrial sectors						
Pharmaceuticals	219	91.3	58.0	1.06	1.14	1.31
Chemicals, petrochemicals, synthetic fibres	775	77.4	31.9	1.08	1.08	1.25
Plastic and rubber	1,195	75.8	28.4	1.00	1.05	1.07
Metallurgical	391	67.3	16.4	0.87	0.84	1.00
Non-metallic mineral processing	1,871	66.8	15.2	0.92	1.00	0.85
Metal products	3,171	69.0	18.8	0.93	0.99	0.99
Machinery/mechanical	2,886	82.5	35.0	1.21	1.06	1.37
Computers and office equipment	21	95.2	66.7	1.20	1.18	1.45
Electrical/Electronics	1,438	78.8	37.3	1.18	1.07	1.35
Automobile components	389	74.6	29.8	1.02	1.06	1.20
Automobiles and engines	14	92.9	64.3	1.06	1.00	1.40
Aircraft	23	91.3	47.8	1.08	1.11	1.37
Other transport equipment	257	61.5	26.1	1.01	1.11	1.17
Scientific instruments	308	83.4	35.4	1.13	1.02	1.23
Food/drinks	1,779	67.0	14.4	0.86	0.95	0.74
Textiles, clothing, and footwear	5,627	58.1	9.2	0.93	0.91	0.65
Wood products and furniture	1,967	66.5	18.2	0.98	1.00	0.92
Paper and printing	1,300	71.8	10.2	0.76	0.95	0.56
Other manufacturing industries	473	66.2	19.0	1.01	1.08	0.95
Total	24,104	69.3	20.3	1.00	1.00	1.00
Coefficient of variation [a]		0.15	0.58	0.12	0.08	0.24

[a] Standard deviation/average.

[b] Highly innovating business units are those which have innovated both in products and in processes and having introduced at least a new product or process using internal sources.

[c] A value bigger than 1 indicates a higher propensity than average of the sector to indicate product innovations (column 4), to introduce new products and processes (column 5), to use internal sources of knowledge (column 6). For details, see methodological appendix.

Source: CNR–ISTAT.

dustrial sector. A value greater (or smaller) than 1 indicates an above (or below) average propensity to perform product (or major or internal sources backed) innovations (for methodological details, see appendix).

Intersectoral differences are more important than inter-dimensional differences in explaining the balance between product and process innovations as indicated by the values of variation coefficients (column 4). The same result was found by Pavitt et al. [19]. The Machinery/mechanical, Computers and office equipment, Electrical/electronics and Scientific instruments industries have an above average propensity towards product innovation. Traditional industries, on the other hand, have a higher propensity towards process innovation.

The same index shows the cross-industries propensity to introduce new (versus improved) products and processes (column 5 of Table 1). Both intersectoral and inter-dimensional variations appear equally significant, although at a quite mod-

Table 2
An analysis of sources of S&T knowledge by classes of employees and industries [a] (indexes)

	Sources of S&T knowledge				
	internal to the business units		external to the business units		
	Design and tooling-up [1]	R&D [2]	acquisition of S&T information [b] [3]	purchase of patents & know-how [4]	acquisition of intermediate and capital goods [5]
Classes of employees					
20–199	0.95	0.82	0.99	0.83	1.00
200–499	1.36	1.95	1.12	1.80	1.03
500–1,999	1.62	2.28	1.11	3.43	0.99
2,000–4,999	1.71	3.81	1.15	5.31	0.99
abore 5,000	1.89	3.93	1.27	4.78	0.89
Average	1.00	1.00	1.00	1.00	1.00
Industrial sectors					
Pharmaceuticals	0.84	4.57	1.16	5.25	0.92
Chemicals, petrochemicals, synthetic fibres	0.85	3.02	0.92	2.27	0.84
Plastic and rubber	1.08	1.04	1.08	1.09	1.00
Metallurgical	0.88	0.94	0.89	1.64	1.07
Non-metallic mineral processing	0.74	0.82	0.87	0.85	1.04
Metal products	1.02	0.61	0.93	0.89	1.04
Machinery/mechanical	1.74	1.20	0.99	1.28	0.81
Computers and office equipment	2.02	2.06	1.14	4.08	1.08
Electrical/Electronics	1.79	1.66	1.04	1.65	0.87
Automobile components	1.46	1.00	0.98	1.45	0.96
Automobiles and engines	2.19	2.27	1.43	2.69	1.22
Aircraft	1.81	3.93	1.18	5.00	1.03
Other transport equipment	1.40	0.97	1.02	1.11	0.95
Scientific instruments	1.48	1.49	1.30	1.36	0.93
Food/drinks	0.52	0.95	0.96	0.64	1.13
Textiles, clothing, and footwear	0.54	0.49	1.05	0.44	1.07
Wood products and furniture	1.00	0.43	1.12	0.56	1.07
Paper and printing	0.41	0.48	0.85	0.70	1.15
Other manufacturing industries	0.92	0.79	1.14	0.63	0.97
Average	1.00	1.00	1.00	1.00	1.00
Total number of business units which reported the source	7,039	2,714	8,062	1,433	11,554

[a] For method, see appendix.
[b] Professional organizations, technical centres, customers, trade fairs and exhibitions.
Source: CNR–ISTAT.

est level. The occurrence of introducing new products and processes slightly increases with business unit size.

Business units acquire technological knowledge either through their internal activities or through various channels outside the company itself. On the basis of the questions put to companies in the CNR–ISTAT survey, we define as *internal sources* of technological knowledge the following factors: R&D, design and tooling-up, patents held. The following are defined as *external sources*: technological-scientific information (the questionnaire referred to "professional organizations, technical centres, clients, trade fairs and exhibitions"), patents and know-how acquired externally, acquisition of intermediate and capital goods. The results for the manufacturing industry as a whole show a preponderance of external (62.6%) over internal sources to the firm (the remaining 37.4%) (see appendix for methodology). However, the ratio between the two sources varies in specific industries. Some sectors (column 6 of table 1) show an above-average ratio for internal sources, particularly those representing the highest shares of innovating or "highly" innovating business units. The coefficient of variation is more significant across industrial sectors than across size. In all the traditional industries external sources are much more important than average. A more detailed analysis of the sources of innovative activity will be carried out in the next section.

4.3. Sources of innovation

Table 2 presents more detailed information about the sources of innovative activity. We have employed an index which singles out the intersectoral differences in the sources of innovation. The index is equal to the share of business units which have indicated certain factors to the share for the total sample. An index above (below) 1 indicates an above (below) average propensity to indicate the factor. The last line of table 2 shows the total number of business units which have indicated the listed factors. First of all, the role of R&D in the overall technological process emerges. On a total of 16,700 innovating business units, only 2,714 have indicated R&D: in Italy there are 13,986 business units which have declared themselves innovative without having performed R&D.

However, the industrial sectors with the higher share of innovating business units are also those with a greater propensity to perform R&D: the linear correlation coefficient is equal to 0.78 (significant at the level of 99.0%) [2]. This indicates that, although R&D represents only the tip of the iceberg of the innovative phenomena, it is not misleading as technological indicator of industrial innovativeness. Patenting activity presents a similar pattern to that of R&D: only 2,500 business units have indicated patenting as a factor linked to the innovations introduced, although at the industry level patenting activity is closely connected to the share of innovating business units (correlation coefficient being equal to 0.62, significant at the level of 99.5%). (For a detailed discussion, see Archibugi et al. [4].)

Among internal sources it is interesting to compare R&D and "design and tooling-up" [3]. It is not easy to make a hard and fast distinction between the two. However, the former could be taken as an indicator of business unit functions specifically aimed at innovation and reflecting the procedures and contents of scientific research. The latter may be taken to refer to stages complementary to R&D in innovative processes, and to sources of know-how differing from R&D, for example in the field of design. Table 2 shows that the importance of both R&D and design/tooling-up increases with business units size, especially in the case of R&D. Among sectors, design and tooling-up is particularly relevant, as compared to R&D, to machinery, automobile components, other transport equipment. R&D plays a dominant role in those industries, such as pharmaceuticals and chemicals, where knowledge of transformation processes and of the materials employed is important. R&D is also important in the aircraft industry, although in this case also design and tooling-up plays a relevant role. In the automobile

[2] At the industry level, R&D intensity monitored by our innovation survey correlates well with R&D expenditure and personnel intensity as measured through the annual survey on R&D (coefficients are equal respectively to 0.81 and 0.87 with levels of significance of 99.9 percent). (Cf. Archibugi et al. [4].)

[3] Patents are excluded from the comparison as they are not in themselves an *activity* on which innovations are based. They are, however, included among the internal sources of know-how, since they undoubtedly point to knowledge produced within companies.

Table 3
Size of business units participating in the survey (average employment)

Industrial sectors	Average size of non-innovating business units [1]	Average size of innovating business units [2]	Average size of highly innovating business units [a] [3]
Pharmaceuticals	78	287	349
Chemicals, petrochemicals, synthetic fibres	89	233	344
Plastic and rubber	54	112	149
Metallurgical	173	587	1,561
Non-metallic mineral processing	63	98	151
Metal products	47	71	101
Machinery/mechanical	49	115	146
Computers and office equipment	14	1,962	2,760
Electrical/Electronics	78	273	393
Automobile components	62	181	307
Automobiles and engines	41	13,143	18,602
Aircraft	101	1,592	2,648
Other transport equipment	87	225	340
Scientific instruments	48	118	180
Food/drinks	62	144	331
Textiles, clothing, and footwear	56	90	149
Wood products and furniture	37	54	69
Paper and printing	72	123	289
Other manufacturing industries	39	64	80
All sectors (average)	58	141	264

[a] Highly innovating business units are those which have innovated both in products and in processes, having introduced at least one new product or process using internal sources.
Source: CNR–ISTAT.

and computer industries both R&D and design and tooling-up are equally relevant. Research on new materials, design of complex products and the large-scale industrialization of these products all play significant roles in the innovative processes in these sectors. R&D and design/tooling-up are also relevant in the scientific instruments and in the electrical/electronics industries.

In the case of external knowledge sources, there is a clear relationship between the size of the business units and the importance of the various channels. Acquisition of patents and know-how plays a more significant role in the larger business units, while capital goods appear to be the major vehicle for the smaller ones. The acquisition of patents and know-how plays a significant role in those sectors where many business units consider their innovations to be related to patents applied for, as in the pharmaceutical, computer, and aircraft sectors.

The importance of the acquisition of intermediate products and capital goods is rather evenly distributed among sectors. However, when compared with the internal sources of technological knowledge, this channel appears quite relevant to sectors such as food/drinks, textiles, paper and printing.

4.4. Business unit size and innovation

The average number of employees in innovating business units is 141, rising to 264 in the "highly" innovating business units, although this number varies from sector to sector (columns 2 and 3 of table 3). The average number of employees exceeds 500 in only four sectors among both innovating and "highly" innovating business units.

Table 4 presents the employment distribution in each industry. The final column contains Lorenz's index of employment concentration of innovating business units broken down into five size categories. The index can vary from 0 in the case of minimum concentration to 1 when employment is concentrated in one single business unit.

Concentration is high in the following industries: metallurgical (0.82), computers and office

Table 4
Employment distribution in innovating business units according to classes of employees (percentage)

Industrial sectors	Classes of employees 20–199 %	200–499 %	500–1,999 %	2,000–4,999 %	above 5,000 %	Lorenz concentration index
Pharmaceuticals	15.9	25.4	35.6	12.6	10.6	0.59
Chemicals, petrochemicals, synthetic fibres	21.6	14.0	31.7	22.4	10.3	0.66
Plastic and rubber	44.5	14.9	13.9	3.0	23.7	0.50
Metallurgical	8.8	5.7	15.3	12.0	58.2	0.82
Non-metallic mineral processing	49.0	17.2	22.8	11.0	0.0	0.44
Metal products	65.8	20.1	14.1	0.0	0.0	0.29
Machinery/mechanical	43.6	15.1	19.0	15.4	6.9	0.50
Computers and office equipment	1.7	3.7	6.2	11.0	77.4	0.81
Electrical/Electronics	17.9	11.6	23.2	16.9	30.4	0.72
Automobile components	31.5	18.4	25.8	24.2	0.0	0.58
Automobiles and engines	0.1	0.5	4.0	1.5	93.9	0.73
Aircraft	1.0	6.6	16.8	38.8	36.8	0.65
Other transport equipment	16.6	19.7	39.2	0.0	24.5	0.68
Scientific instruments	42.1	15.9	26.7	15.3	0.0	0.49
Food-drinks	34.4	16.3	19.8	12.3	17.1	0.58
Textiles, clothing, and footwear	55.6	21.2	15.5	3.9	3.8	0.37
Wood products and furniture	83.0	11.6	5.4	0.0	0.0	0.14
Paper and printing	37.9	16.1	26.1	9.8	10.2	0.55
Other manufacturing industries	69.4	22.3	8.3	0.0	0.0	0.25
Total	34.5	14.3	18.8	10.6	21.8	0.59

Source: CNR–ISTAT.

Table 5
Innovating business units to the total of business units participating to survey, according to classes of employees and industrial sectors (percentage)

Industrial sectors	Classes of employees 20–199 %	200–499 %	500–1,999 %	2,000–4,999 %	above 5,000 %	Total
Pharmaceuticals	87.5	100.0	96.2	100.0	100.0	91.3
Chemicals, petrochemicals, synthetic fibres	74.7	95.2	89.3	90.0	100.0	77.4
Plastic and rubber	75.0	85.2	94.1	100.0	100.0	75.8
Metallurgical	65.3	68.4	75.7	71.4	100.0	67.3
Non-metallic mineral processing	65.8	78.4	83.3	75.0	–	66.8
Metal products	68.3	81.1	90.6	–	–	69.0
Machinery/mechanical	81.5	91.9	96.7	100.0	100.0	82.5
Computers and office equipment	90.0	100.0	100.0	100.0	100.0	95.2
Electrical/Electronics	76.3	88.3	97.4	88.9	100.0	78.8
Automobile components	71.8	93.3	93.3	100.0	–	74.6
Automobiles and engines	66.7	100.0	100.0	100.0	100.0	92.9
Aircraft	66.7	100.0	100.0	100.0	100.0	91.3
Other transport equipment	56.9	80.0	85.0	–	100.0	61.5
Scientific instruments	82.1	94.1	100.0	100.0	–	83.4
Food/drinks	65.3	82.4	82.6	88.9	100.0	67.0
Textiles, clothing, and footwear	57.0	74.9	74.4	100.0	100.0	58.1
Wood products and furniture	66.2	83.3	83.3	–	–	66.5
Paper and printing	70.8	79.2	84.2	100.0	100.0	71.8
Other manufacturing industries	65.2	88.2	100.0	–	–	66.2
Total	67.8	83.5	87.9	90.8	100.0	69.3

Source: CNR–ISTAT

equipment (0.81), automobiles and engines (0.73) and electrical/electronics (0.72). Significantly below average values can be seen in traditional sectors such as textiles (0.37), metal products (0.29), wood products and furniture (0.14). Sectors shown by the survey to be intensively innovative, such as machinery/mechanical and scientific instruments, display below average concentrations (respectively 0.50 and 0.49). The R^2 between the Lorenz concentration index and the share of innovating business units (column 2 of table 1) is equal to 0.24 (significant at the level of 96.7%): thus there is no clear evidence that innovative intensity depends strictly on industrial concentration, at least at the business unit level. Our results are therefore entirely consistent with those of Cohen et al. [9].

Table 5 shows the break-down, according to business unit size categories, of the percentage of innovating business units to the total number of business units taking part in the survey. The table shows that all business units with more than 5,000 employees have introduced innovations. In other words, above a certain size business units in all sectors are innovative, although there remain differences in the type and degree of innovations. Among the smaller business units, on the other hand, considerable differences are to be seen between industries in the case of innovating units. Our data show a even more marked cross-industry difference between the "highly" innovating business units. Although the occurrence of being an innovating business unit increases with size, table 5 shows that small business units belonging to certain industries – e.g. pharmaceuticals, chemicals, plastics and rubber, machinery, computers, electrical/electronics – have only a slightly lower probability to be innovative than their larger counterparts.

This evidence seems to tally with Comanor's conclusion [10] that in industries showing the greatest innovative dynamism both the large and small companies play a leading role in the innovative process. On the other hand, the sectors characterized by a lower share of innovating business units (textiles, clothing and footware, other transport) tend rather to display a structure whereby the probability of being innovative increases with size. Thus, paradoxically, the neo-Schumpeterian hypothesis on the leading role of big companies receives fuller confirmation in the case of the less innovative sectors.

5. Industrial organization and technological change. Towards a taxonomy

The previous sections have shown how industrial sectors differ in the types of innovations they introduce, the sizes of the innovating business units and the activities innovations are based on. These inter-industrial differences emerged quite clearly from the CNR–ISTAT survey, even if information did not extend to the technological significance and intensity of innovative activity but was confined to its presence and origins in the innovating business units.

We shall now attempt a classification of sectors into a few groups, identified according to their technological intensity, the sources of knowledge used in the innovation process and firm size.

The taxonomy we offer is largely derived from Pavitt's model [18], although differing from it in its methodology and results. Firstly, while Pavitt's taxonomy was for companies (pointing to the typical industrial sectors each category of company belonged to), ours is based on business units aggregated into industrial sectors. Since the data yielded by the CNR–ISTAT survey are available by industry (although the survey was carried out at the level of business units), we kept the sectors aggregated as in the statistical source, although they often include business units following essentially different technological trajectories.

Secondly, considerable differences are found in the statistical bases employed. Pavitt referred to 2,000 significant *innovations* introduced in Great Britain between 1945 and 1983, while our data refer to 16,700 innovating Italian *business units* introducing innovations between 1980 and 1985. In other words, our statistical basis referred to the organizations involved in innovative activities, whereas the SPRU referred to the objects, i.e. the innovations themselves (cf. Archibugi [2]). Although we have obtained less information than the SPRU per entry, our statistical base is nevertheless more comprehensive.

We have therefore subdivided the industries into five groups, as outlined in table 6:

(1) *Producers of traditional consumer goods*, i.e. those industries with an above average representation of small business units. Those industries innovate in processes especially by means of sources of technical knowledge outside the industry. The

Table 6
Industrial organization and technological knowledge. A taxonomy

	Percentage of highly innovating business units	Propensity to introduce product innovation [a]	Average size of innovating business units (no. employees)	Lorenz concentration index	Propensity to use internal S&T knowledge [a]	Prominent internal source of S&T knowledge [a]	Prominent external source of S&T knowledge
Producers of traditional consumer goods							
Food/drink							
Textiles, clothing and footwear	low	low	small	low	very low	design & tooling-up	capital goods
Wood products and furniture							
Paper and printing	14.2	0.91	95	0.38	0.76		
Other manufacturing industries							
Suppliers of traditional intermediate goods							
Non-metallic mineral processing							
Metal products	low	low	small (large [b])	low (high [b])	low	design & tooling-up	capital goods
Metallurgical							
	16.8	0.91	84 (587 [b])	0.36 (0.82 [b])	0.95		
Specialized suppliers of intermediate goods and equipment							
Plastic and rubber							
Machinery/mechanical	high	high	medium	medium	high	design & tooling-up	S&T information,
Automobile components						R&D	ext.patents & know-how
Scientific instruments	32.7	1.09	132	0.52	1.22		
Mass-production assemblers							
Computers and office equipment							
Automobiles and engines	very high	high	large	high	very high	R&D	ext.patents & know-how
Other transport equipment						design & tooling-up	
Electrical/electronics	48.6	1.11	3901	0.74	1.34		
R&D based							
Chemicals, petrochemicals,							
synthetic fibres	very high	high	medium-large	medium-high	very high		ext.patents & know-how
Pharmaceuticals						R&D	
Aircraft	45.9	1.07	704	0.63	1.31		
Total							
	20.3	1.00	141	0.59	1.00		

[a] We have used for this taxonomy the same index to show inter-sectoral differences applied in table 1, columns [4], [5], [6]. See methodological appendix for details.
[b] Metallurgical only.
Source: elaborations on tables 1–5.

acquisition of capital equipment is the basic factor which backs up their innovative activities.

(2) *Suppliers of traditional intermediate goods* share with the previous category the same pattern of introducing innovations. However, this second group sells its products to other companies, and receives technological information through the same channel. Unlike the following category of "specialized suppliers of intermediate goods and equipment industries", the "traditional suppliers" play a less dynamic role in the process of selecting the technologies and production systems offered to the user companies they cooperate with.

(3) *Specialized suppliers of intermediate goods and equipment* are those industries in which, although the average size of the business units is small or medium, internal sources of knowledge, both as design and tooling-up and R&D, play a major role. The share of highly innovating business units is double that of the previous two categories. Product innovations are above average in these industries.

(4) *Mass-production assemblers*; industries characterized by highly innovating business units of large size, where there is a greater propensity towards product innovations based on internal sources of knowledge. Both R&D and design and tooling-up play a crucial role.

(5) *R&D based* are those industries with highly innovative medium sized business units, where scientific and technical laboratories provide the fundamental part of their knowledge.

This subdivision appears well suited to our data and tallies with Pavitt's subdivision. The main difference is that the "supplier dominated" group has been divided into "traditional producers of consumer goods" and "traditional suppliers of intermediate goods", in spite of the fact that a supplier dominated category has disappeared in the most recent versions of Pavitt's taxonomy: "we have excluded a 'supplier dominated' trajectory since... it leaves accumulated technological skills and strategic initiatives to the suppliers. Firms intending to move from this position try to adopt either scale intensive strategies (e.g. textile companies), or 'information-intensive' strategies (e.g. certain retailing firms)" (Pavitt et al. [20]). Our experience in Italy leads us, on the contrary, to maintain that many "supplier dominated" companies nevertheless manage to be efficient by virtue of the active procurement policy they pursue in their dealings with the supplier companies, thereby achieving a sort of symbiosis.

The second discrepancy worth mentioning is the different classification of the electrical/electronics industry and the computer industry. Because of the wide range covered by those industries, we decided to exclude them from the R&D based sector despite the fact that many business units undoubtedly merit such classification. The large scale of some business units and the importance attached equally to R&D, design and tooling-up suggested classifying them among the "mass production assemblers".

Our taxonomy does not claim to classify industrial sectors exhaustively, but rather to classify them according to the channels and methods differentiating them in the introduction of technological innovations. This taxonomy has implications for both the theory of industrial organization and for innovation policy, as will be pointed out in the final two sections.

6. Conclusions for analysis

The above analysis suggests that the variety of sources linked to innovative activities varies greatly according to the various industrial sectors. In particular our results indicate that intersectoral differences are more relevant than inter-size differences.

Pavitt's taxonomical approach has been confirmed as a useful tool to organize and interpret the richness of sources of technological change and their relationship with industrial organization. The Italian experience leads also to prefer the first formulation of Pavitt's [18] taxonomy, which included a category of supplier dominated innovating firms, to the subsequent one which excluded it (Pavitt et al. [20]).

Some observers see in today's technological changes the dawn of a new form of industrial organization, with the small and medium-sized companies returning to a leading role in promoting innovation [21]. The experience in various Italian industrial districts [5] has inspired some of the most recent theoretical speculation, and not only in Italy.

Our data do confirm the existence of an innovative potential based on small businesses. But, on the other hand, our evidence indicates that also a simple model which over-emphasizes the innovative potential of small companies in the traditional sector would be misleading.

We certainly do not intend to deny the decisive importance of present-day changes in industrial structure, but the available evidence still suggests the importance of focusing on the inter-industrial differences. Some companies – in many traditional sectors, for example – changed little in average size at the beginning of the century or during the rise of oligopolistic capitalism. It is equally significant that the sources of technological knowledge these companies drew upon – whether for machinery in the Adam Smith era or CAD–CAM systems in the Piore and Sabel period – were mainly located outside the companies. Similarly, we do not believe that the technological advances occurring today can lead to drastic changes in the concentration of mass-production assembling industries. We also expect chemicals and electronics companies to continute to draw on internal know-how sources in the future just as they have in the past.

The previously mentioned capacity of the economic structure to absorb new technologies, pervasive as they may be, can therefore be ascribed to the very nature of technological change: new and pre-existing know-how tend to merge, the latter surviving together with a considerable part of the old industrial structure. Our impression is that researchers have often been dazzled by the effect technological change has had in the new sectors, and this has led them to formulate hypotheses stating that the industrial organization typical of the new sectors must sooner or later extend to the entire economic system. It is our opinion, on the contrary, that a valid description and theory of technological change must take into account both the previously existing and the new technological trajectories, and should also consider the permanence of differential forms of industrial organization and sources of technological know-how.

7. Implications of industrial policy

The taxonomy presented above suggests that the intensity of the various business units to policies in favour of innovation varies according to their size and the branch of economic activity they operate in. It seems clear that failure to distinguish between various sectors or between business units of different sizes within the same sector will lead to great difficulty in pursuing any policy whatsoever.

The analytical and empirical results set out here also demonstrate the futility of treating efficient forms of industrial organization in absolute terms rather than considering the specific features of each sector. This may well be very relevant to the wide-ranging debate on anti-monopoly laws: there is no form of market that can be taken as a model – neither perfect competition nor oligopoly – at least as far as maximizing the rate of technological change is concerned.

Thus, while it is right to be concerned about the relatively small dimensions of Italian companies compared with their foreign competitors, we consider there is a need for a comparative sectoral survey to distinguish in which circumstances the small size negatively affects economic performance. It may well be that in certain sectors Italy actually benefits from an industrial organization based on small companies. Analyses referring to other countries, e.g. Great Britain, argue that the loss of international competitiveness in the nation's industry is due to excessive industrial concentration [22, p. 160; 23, p. 15].

A full understanding of the role played by sectoral peculiarities in the sources of innovative activity can only show how wrong it is to hypothesize diametrical opposition between "technology backed by science" (often identified with R&D) and "small technology" (the gradual acquisition of know-how at the local level). Italy seems to be particularly efficient in introducing innovations through "small technology", but it may well be that, for many companies and sectors, the "flexible specialization" option was in fact dictated by difficulties in developing autonomous technological, productive and financial strategies.

On the other hand, Italy is launching into R&D intensive sectors such as chemical and electronics somewhat belatedly [3]. It would therefore be extremely hazardous to pass from a legitimate analytical recognition of the role played by "small technology" in industrial innovation to prescriptive regulations relegating R&D to a secondary role.

Methodological appendix

This appendix explains the methodology we have used to process the results of the CNR–ISTAT survey.

Product innovations – column 4, table 1. The surveyed business units could indicate if they had introduced product and process innovations although without specifying their number. Business units were allowed to indicate more than one answer. Fifty-seven percent have introduced improved products, and 49 percent new products. Seventy-two percent have introduced improved processes, and 46 percent new processes. We have divided the number of business units indicating product innovations by the total number of answers given by the business units. A "balance" has thus been struck between the share of product and process innovations introduced in each industrial sector. In order to get intersectoral differences, we have divided the balance for each sector by the balance for the overall sample.

New products and processes – column 5, table 1. The surveyed business units could indicate both the introduction of new products and processes and improvements in products and processes although without specifying their number. Business units were allowed to indicate more than one answer (see above for the total number of business units which have indicated improvements and/or new products and processes). We have divided the number of business units indicating new products or processes by the total number of answers given by the units (regarding both the introduction of new and improved products and processes innovations). A "balance" has thus been struck between the share of new versus improved products and processes introduced in each industrial sector. In order to get intersectoral differences, we have divided the balance for each sector by the balance for the overall sample.

Internal sources of technological knowledge – column 6, table 1. The surveyed business units could indicate six factors linked with the innovations introduced, although not specifying their relative importance. Business units were allowed to indicate more than one source. We have defined as "internal sources" the factors R&D, design and tooling-up and patents held; and as "external sources" the factors technological-scientific information, patents and know-how acquired externally, acquisition of intermediate and capital goods. Last row of table 2 reports the total number of business units indicating each source. We have then divided the total number of internal sources reported by the business units by the total number of sources indicated. A "balance" has thus been struck between the share of internal and external sources of innovations used in each sector. In order to get intersectoral differences, we have divided the balance for each sector by the balance for the overall sample.

Sources of technological knowledge – table 2. In order to assess the role played by the various sources we have applied the following index:

$$I_s = Bu_{ij}/Bu_i/\Sigma_i Bu_{ij}/\Sigma_i Bu_i$$

where Bu_{ij} is the number of business units of the sector i which have indicated the factor j and Bu_i are the total number of innovating business units of sector i.

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