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PATTERNS OF INNOVATION IN ITALIAN INDUSTRY

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Executive summary

This report investigates the relationships between industrial structure and patterns of innovation, on the basis of an empirical study of Italian industry.

An expanded set of links between structural and technological variables has been analysed, considering in particular the role played by investment as a form of innovative activity and as a determinant of industrial structure. The inclusion of investment makes it possible to focus on an aspect which is only marginally treated in the literature, that is the complementary or subsidiary (trade-off) relationship between the different forms of innovative activities; in particular the links between embodied and disembodied technological change is investigated. In order to understand why and how firms innovate and grow, we argue that it is not enough to look for explanatory technological factors in the "technological appropriability conditions" as most of current literature does. Rather, it is important to fully acknowledge and investigate the role played by investment and its relationship with innovation and economic performance.

The empirical work refers to the case of Italy. A variety of technological and economic data on 6,839 firms provided by the Cnr-Istat (National Research Council of Italy - Italian National Statistical Institute) survey on innovation are used. The data refer to the 1981-85 period. Innovation surveys allow to move beyond the exclusive reliance on few variables such as R&D expenditures or patenting as indicators of innovative activities and to consider also new and more specific variables such as expenditure for Design and Engineering (D&E) and investment in machinery as a form of acquisition, adaptation and use of innovation (embodied technical change).

The analysis focuses on three key questions:

1) to what extent are in-house R&D and D&E activities substitutive or complementary to innovative investment? This question highlights the relationship between disembodied and embodied innovative activities.

2) do larger firms perform (relatively) more R&D and D&E activities than smaller firms? This question remains one of the most controversial subject in the economics of technological change, that is the relationship between firm size and innovative activities.

3) are larger firms more capital intensive than smaller firms? This question points out how important are scale factors in explaining high levels of investment.

In the first part paper an analysis is carried out on 30 manufacturing sectors (using average values for each class). This has made it possible to develop a sectoral taxonomy based on the nature of innovative patterns and on structural characteristics. Three broad aggregations of sectors have been identified:

a) *Technology users and traditional sectors*, characterized by a low innovative intensity and a prevalence of small firms.

b) *In-house innovators*, characterized by an internal technological capability based on R&D or D&E activities (or on both of them) and with an average firm size largely depending on the importance of scale factors and relevance of investment.

c) *Investment intensive sectors* characterized by a high capital intensity and modest R&D efforts. Most of these sectors are also characterized by large scale and high investment necessary to acquire and use process technologies.

On the basis of this analytical framework, the second part of the paper has addressed the behaviour of individual firms. A key original investigation of this study has been the use of data referring to each individual enterprises (6,839) (and not consolidated industrial groups) in order to test the relationships between nature innovative activities, industrial structure and economic performance. The analysis has been carried out both within the three aggregations of sectors and at the level of 3-digit industrial class.

The main findings are the following:

(i) No significant relationships between firm size and all other technological and economic variables has been found at the level of the three major sectoral aggregations. Only one industry, Rubber, has shown a strong relationship between *firm size* and *innovative intensity*. In other words larger firms show neither higher innovative efforts nor better economic performance than smaller firms.

(ii) A positive and significant association between total innovation cost and investment has emerged for all three major aggregations of sectors. At the level of industrial classes, less innovative *technology users sectors* and the Metal products industry have shown a correlation between total innovation cost and investment in machinery higher than other *technology users* and *investment intensive* sectors..

(iii) The association between fixed investment in machinery and innovative investment is higher in the case of *Technology users* and *Investment intensive* *sectors* as the reliance on outside sources of embodied technological change is greater.

(iv) For *In-house innovators* the complementary relationship between disembodied and embodied forms of technological change is much stronger than in other sectors. Such a complementarity is particularly evident in the Electronic components sector where also a positive link between *investment intensity, innovative intensity and productivity* is found.

(v) Finally, productivity is weakly positively associated to total innovative activities and investment in fixed capital in the three major aggregations. Innovative efforts do not seem therefore to play a key role in explaining differences across firms in economic performances.

These results are remarkably different from much received wisdom on innovation, industrial structure and performance. They point out the need to expand the interpretative models of innovation beyond the disembodied dimension of technological change (R&D activities or patenting), and to consider both the more specific activities of D&E carried out in firms and the more general investment activity which in fact incorporate a large part of innovative efforts. Such data however can normally be provided by specific innovation surveys only, which appear to be of great importance as the basis for future research. In this context, a large variety of different behaviours and the scope for alternative strategies of firms has emerged even within particular sectors.

These results have also to be related to the characteristics of Italian industry. Small and medium firms are particularly important and even in the '80 have shown dynamic performances which have not been matched by similar innovative and economic success of larger firms (both private and state-owned). In particular, the relatively weak association emerged between R&D or D&E intensity and performance should be seen in the context of the large role of State owned large firms in many High technology fields. These firms have shown in the last decade a lower than average productivity performance.

In conclusion, our work suggests that a new perspective on industrial innovation should consider more carefully the characteristics of the industrial structure and the role of investment in the analysis of technological change and its impact at the firm and sectoral level.

List of Tables and Figures

Introduction

Innovation is a complex phenomenon receiving increasing attention from recent research. The existence of strong relationships between technological change and many aspects of economic and social life is largely accepted, even if the nature of these relationships, mostly dynamic in their nature, is far from having been fully investigated and understood. Technological change is seen as an essential ingredient of economic growth and performance (both at firm and country level) but a general agreement and theoretical framework on the economic determinants and effects of technological change has not yet been developed.

The relationships between industrial structure, innovative activities and economic performances, examined in this study, are key elements in the economics of technological change. The strong interdependence between innovative performances and industrial structure is widely acknowledged, but much is left to be explored both in conceptual understanding and in empirical description.

In this field, scholars have been recently following two main directions of research, characterized by different methodologies and research objectives.

On the one hand, the relationship between industrial structure and innovative activities has been analysed from an evolutionary perspective, that is, trying to understand the way innovative activities interact with the industrial structure, mainly at the sectoral level, assuming that the relationships run both ways, in a dynamic context.

On the other hand, a second stream of work has made an empirical effort focussing, in a static context, on the firm and sector-specific innovative patterns. This approach has usually stressed the absence of any general relationship between structural characteristics such as firm size or market structure on the one hand and the nature and intensity of innovative activities on the other.

From a methodological point of view, this work is closer to the second stream of research. Our empirical analysis is essentially static in nature and aims at highlighting the structural and technological differences among firms and sectors.

However, while most studies of the second approach have mainly emphasised the technological differences, our work tries to identify also the key relationships between technological and structural variables looking at the case of Italy.

Furthermore, unlike both the approaches mentioned above, we look at the technological activities from a broader perspective, including not only R&D activities but also the Design and Engineering work and investment activities.

The inclusion of the investment variable makes it possible to enlarge the conceptual framework of the analysis. Usually a "disembodied" concept of innovative activities has been used, and the role played by investment activities either as a form of acquisition of innovations, or as a possible technological determinant of firm size and market structure, has not been taken into account.

On the empirical ground, this integration is made possible thanks to the availability of the Cnr-Istat survey on innovation in Italian industry, which covers 6,839 Italian manufacturing firms. The data refer to a wide and diversified range of innovative activities, investment in machinery and plants and other economic variables. Such body of data makes sectoral and inter-firm comparisons possible in terms of structural, technological and economic performance variables.

Chapter 1

Technological change and industrial structure: the theoretical background

The relationship between technological change and industrial structure is a central issue in industrial economics and in the economics of technological change.

A key question addressed by a large literature in this field is the following: Do large firms or concentrated market structures lead to a higher innovative intensity? Such a question follows the structure-conduct-performance debate, and has lead to various attempts to verify the so-called Neo-Schumpeterian hypotheses.

Such work has been justified with the attempt to answer questions on how firms and markets should be organized in order to produce the best innovative performance and the higher pace of technological change and economic growth. The existence of marked sectoral technological and structural differences stemming from historical cumulative processes, especially at sectoral level, has been often neglected.[1]

The debate has also been characterized by a particular conceptualization of technology and innovative activities. The latter have been seen in a disembodied perspective, i.e. as activities of production of new knowledge and innovations, measured by technological indicators such as R&D expenditure and personnel, number of patents or innovations. Embodied technological change, that is the acquisition and use of this new knowledge and innovations through investments has not been considered.[2] Also other innovative activities, such as Design and Engineering, and their complementary or alternative role in relation to both R&D and investment have been only marginally studied.

More recent analyses have tried to overcome some of these shortcomings, leading to a more complex (and adequate) framework.

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[1]In this respect much of the debate on the Neo-Schumpeterian hypotheses misses the historical perspective of Schumpeter's analysis (especially that of Capitalism, Socialism and Democracy, 1942). In Schumpeter's writings there is no claim of the existence of a correlation between industrial structure and intensity of innovative activities. His emphasis was on the increasing importance of large firms (or "units of control") in promoting technical change and, as a result, productivity (Schumpeter, 1942, chapter 5 - 8).

[2] Schumpeter pointed out the "progressive role of the large-scale establishment or unit of control" due to its "levels of productive and organizational efficiency", which appear as a precondition to develop and adopt innovation on an industrial scale. The embodied aspects of technological change is in this perspective equally important than the higher capability of large firms to "produce new technologies" or "knowledge" (i.e. disembodied technological change) (Schumpeter, 1942, chapter 5 - 8).

Three principal elements, making the relationship between industrial structure and technological change a complex one, have been pointed out:

a) the existence of strong sector and firm-specific characteristics of innovative activities mainly in terms of the sources of innovation (Pavitt, 1984);

b) the presence of marked inter-sectoral and inter-firm differences in the levels of technological opportunity and appropriability. As a result, the levels of innovative activities have been considered, alongside firm size, market structure, and the outcome of other fundamental determinant factors (Pavitt, 1984; Pavitt et al. 1987; Levin et al., 1985);

c) other studies have pointed out that the relationship between technological change and industrial structure runs both ways within differentiated "technological regimes". Technological opportunity and appropriability conditions have feed-back effects on the industrial structure in a dynamic context (Nelson and Winter, 1982; Dosi, 1984, Dosi and Orsenigo, 1989; Pavitt, 1984).

The existence of strong sectoral specificities in the technological patterns makes testing the existence of a relationship between firm size or market structure and innovative performance meaningless. Industrial sectors differ widely in terms of the sources and nature of the innovative activities undertaken and in the levels of technological opportunity, the latter representing a fundamental explanatory factor for the inter-sectoral differences in the innovative intensity (at least measured by R&D and patenting indicators). Because of the existence of these differences it makes little sense to compare for instance the innovative intensity of the (large) firms in the chemical sector with the innovative intensity of the (small) ones of the textile industry. A series of studies have therefore analysed the effect of firm size or the market structure on innovative intensity taking into account single industrial sectors separately (Mansfield, 1968; Scherer, 1984) or adding dummy variables classifying the industry's technological characteristics (Scherer, 1967; Levin et al., 1985).

The consideration that the relationship between technological activities and industrial structure runs both ways represents another important step ahead in this analysis. In this regard several authors have argued that the differences in the technological regimes, first of all in terms of technological appropriability and opportunity conditions, nature of the knowledge base, can explain the differences in the market structure (Dasgupta and Stiglitz, 1980, Nelson and Winter, 1982; Levin et al. 1985, Malerba and Orsenigo, 1990)

Figure 1 summarizes the main relationships analysed by the Neo-Schumpeterian literature. Most of the empirical work has tested the one-way effect of market structure and firm size on the innovative performance (link a). They have usually adopted a disembodied conceptualization of innovative activities. The more recent contributions have integrated this approach by introducing the sector- and firm-specific characteristics of innovative patterns. The differences in the levels of technological opportunity and appropriability have been seen as fundamental factors influencing: i) the nature and levels of innovative activities (link b); and ii) the characteristics of the industrial structure (link c).

The inclusion of embodied technological change

The conceptual framework shown above can be enlarged by introducing the role played by investment. However, this integration requires a wider conceptualization of the nature and forms of technological change.

The debate considered so far seems to underestimate the importance of fundamental structural factors affecting innovative activities. Basic structural differences between firms and sectors, related to complementary aspects such as the capital intensity of the production processes, the relevance of economies of scale, the importance of innovative activities undertaken through investment in fixed capital are not explicitly related to technological change.[3] These aspects are left to the field of industrial economics, where firm (or plant) size and type of market structure are related (alongside to other organizational factors) to sector-specific or firm-specific structural characteristics, i.e. characteristics connected to production and cost functions, to the presence of economies of scales, to technical barriers to entry, to the capital intensity of production processes.

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3 Pavitt's taxonomy has represented an important breakthrough in the present debate. The delineation of sectoral innovative patterns is based on differences in the sources and nature of the innovative activities as well as on structural characteristics of firms and industrial sectors (Pavitt, 1984).

Production and *use* of technology

Differences in the perspectives adopted by economists and scholars of technological change stem from (implicit or explicit) differences in the conceptualization of the nature of innovative activities. In this respect a crucial distinction is made between innovative activities conceived as *production of general or specific technological knowledge* (disembodied technological change) and innovative activities conceived mainly as the *use and application of this new knowledge and innovations via investment activities,* mainly in fixed capital (embodied technological change) (Rosenberg, 1967).

These differences in the perspectives adopted can also be seen in terms of indicators used to measure innovative activities. In the former case expenditure in R&D activities, number of patents or innovations are generally considered, while in the latter, investment in fixed capital and levels of capital intensity are (also) used.

The debate on the relationship between industrial structure and technological change shows similar patterns. As already pointed out, most of the literature has exclusively adopted a disembodied view of technological change. Such a choice, however, has been surely influenced by problems of measurement of innovative activities, and by the availability of data on R&D, patenting and other traditional indicators only.

Even the more recent contributions have not changed this perspective. Concepts like technological opportunity and appropriability are still part of a disembodied conceptualization of technological change. The most common terms and concepts associated to the sources of innovative activities are "knowledge", "information", several forms of "learning", "search processes". Investment related to innovative activities, both in the forms of direct purchasing of equipment and machinery, and the development of internal resources for the application of new technologies on industrial scale (both purchased from external sources or internally produced) are not considered as being a central part of the innovative activities.

In order to overcome this separation, a shift is needed from an exclusive concept of technological change in disembodied terms (without investment) (Figure 2) to an integrated framework where production and use of technology, in embodied and disembodied forms of innovative activities, are both considered (Figure 3).

Fig. 4 shows this expanded set of links where (together with the relationships reported in the Figure 3) the *missing links* in the Neo-Schumpeterian literature have been drawn. The role played by investment as a form of innovative activity and as a determinant of industrial structure is pointed out.

The inclusion of investment activities makes it possible to focus on an aspect which is only marginally treated in the literature, that is the complementary or subsidiary (trade-off) relationship between embodied and disembodied forms of technological change. In other words, the specific alternatives (and complementarities) between in-house production of innovations and their acquisition from outside, need to be explored. Sectoral and firm specific differences as well as structural and behavioural differences may be relevant in this regard.

FIGURE 1

TECHNOLOGICAL CHANGE AND INDUSTRIAL STRUCTURE: THE NEO-SCHUMPETERIAN LINKS

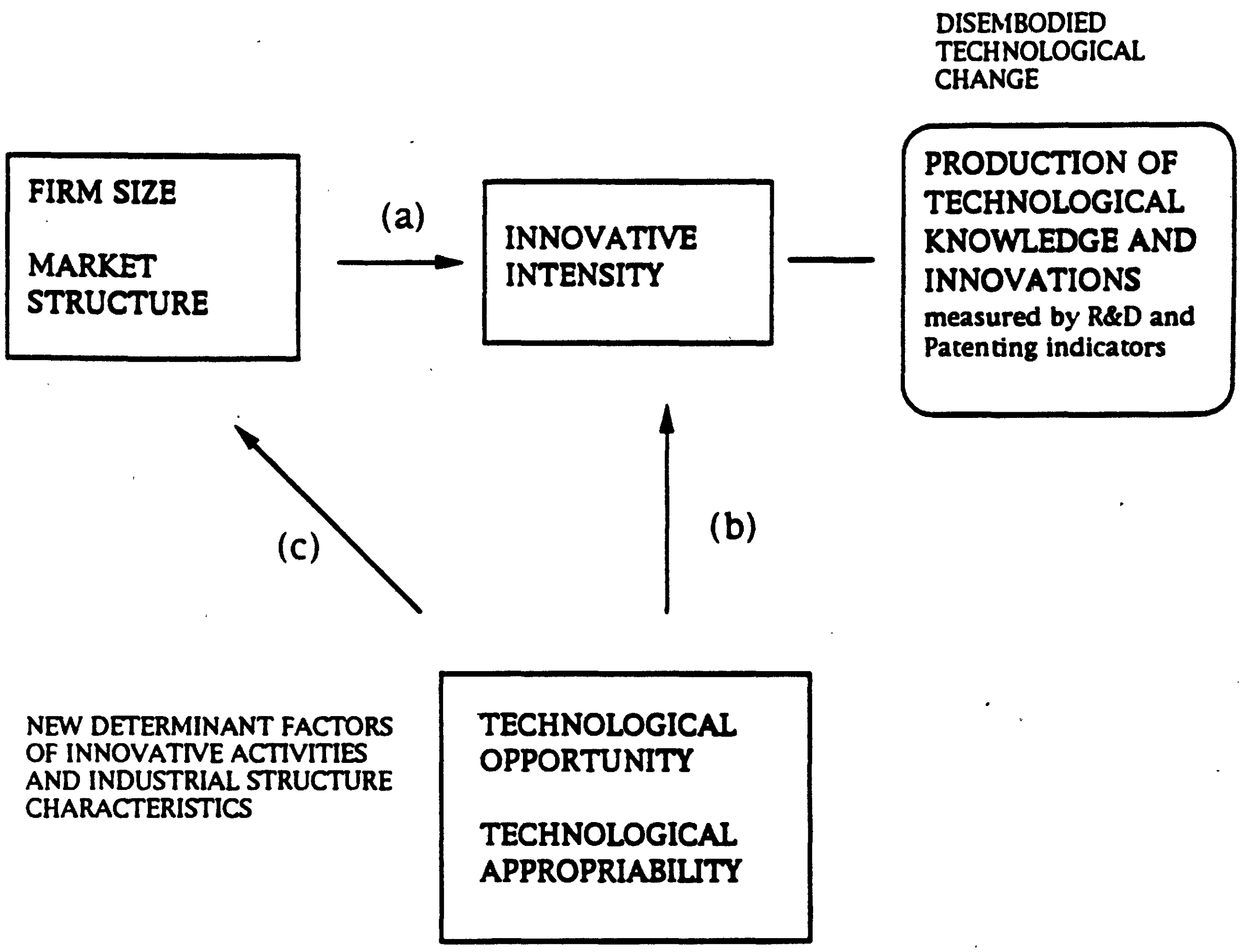


FIGURE 2

THE DISEMBODIED VIEW OF INNOVATIVE ACTIVITIES

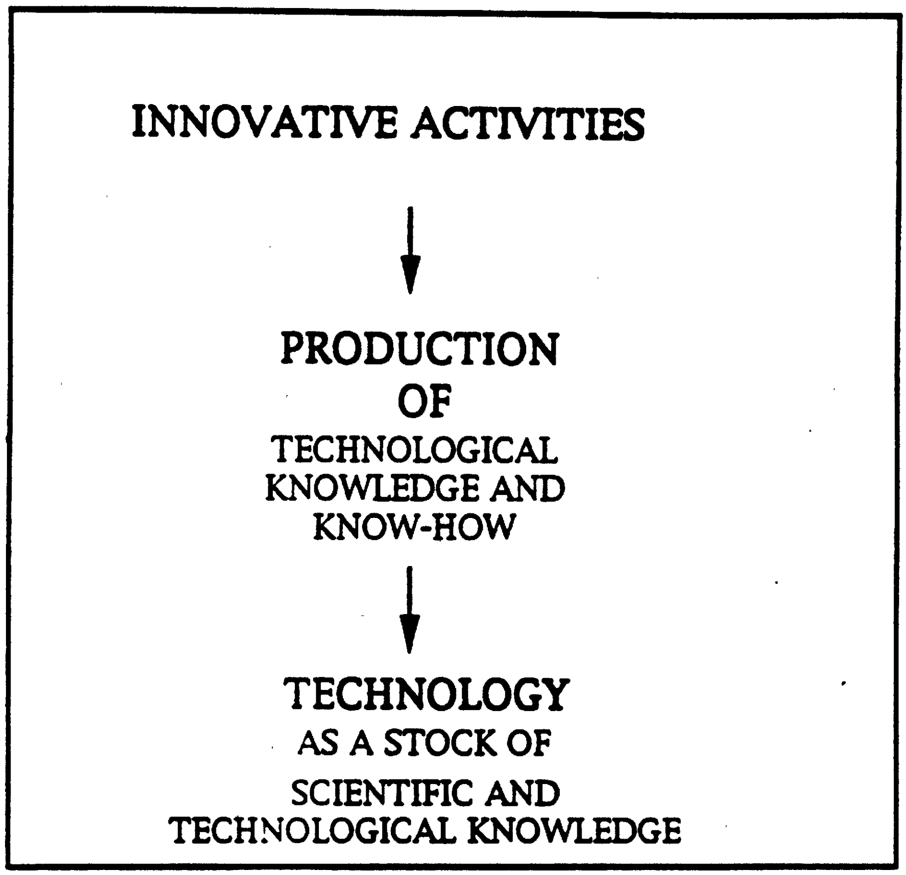


FIGURE 3

AN INTEGRATED PERSPECTIVE OF TECHNOLOGICAL CHANGE

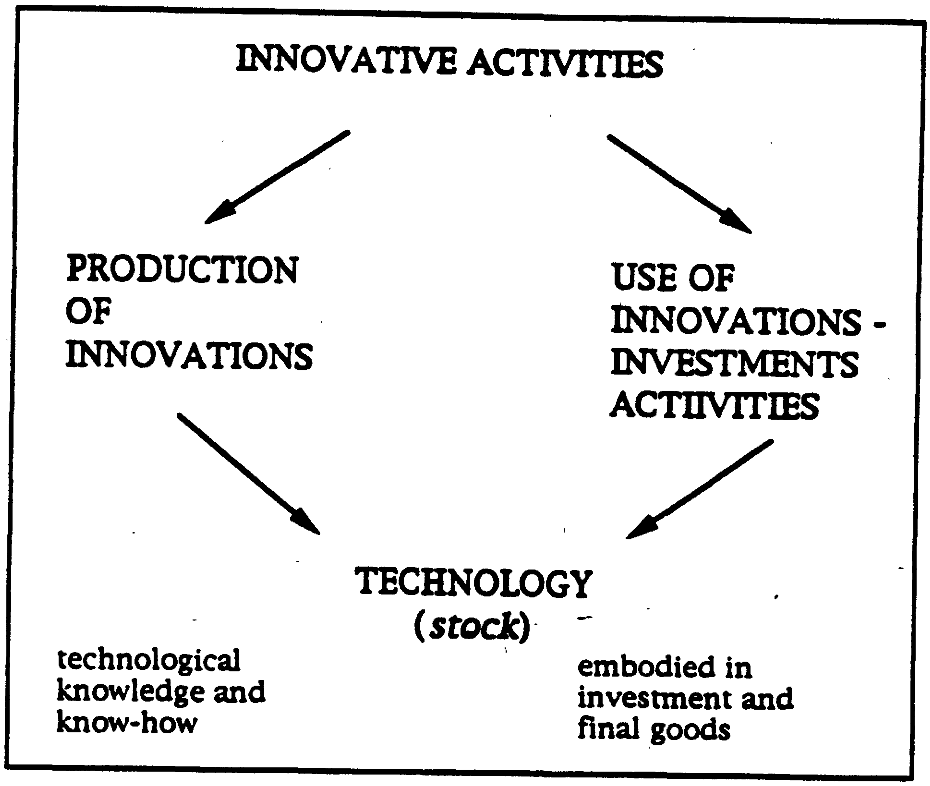
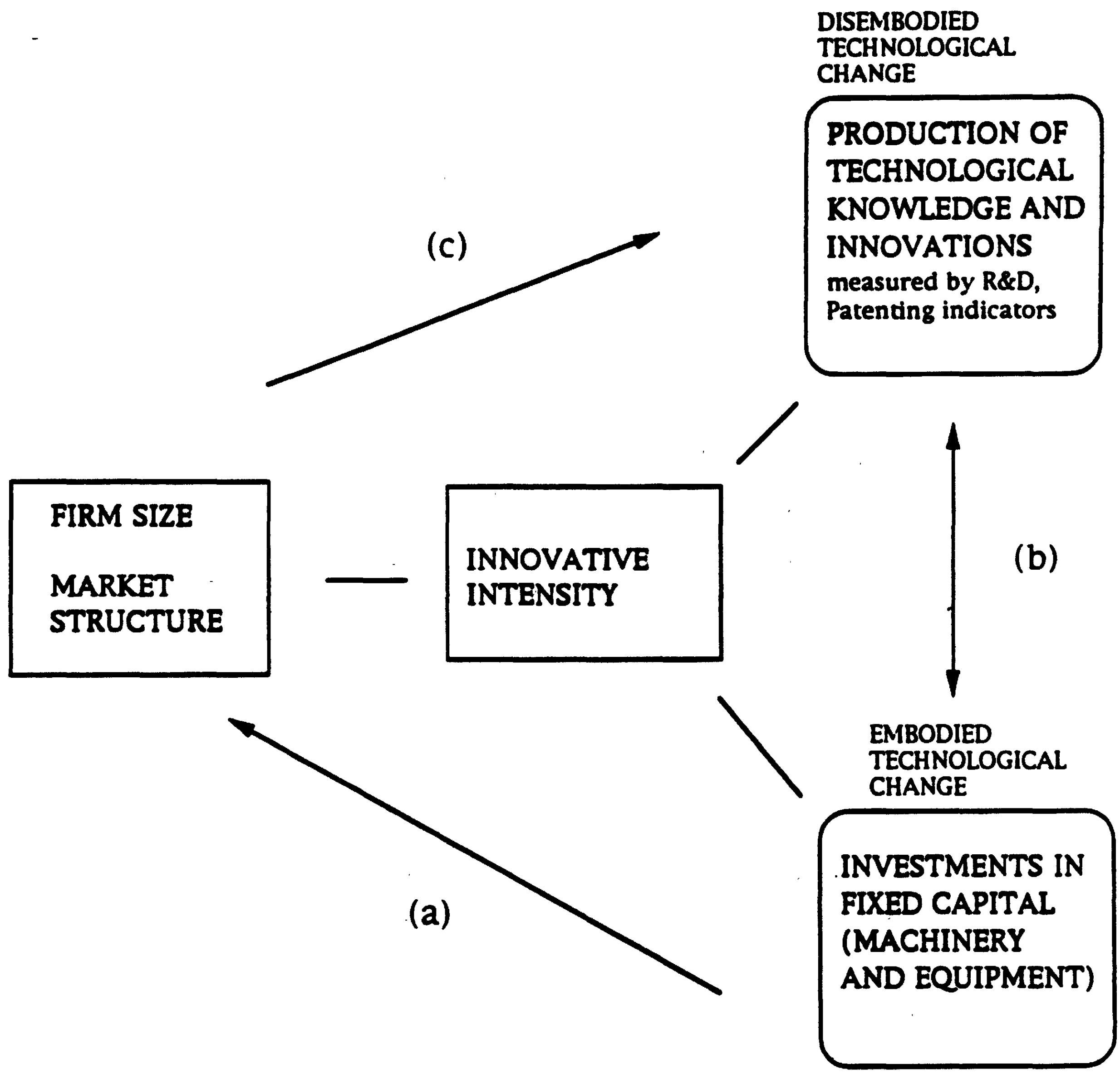


FIGURE 4

INDUSTRIAL STRUCTURE AND TECHNOLOGICAL CHANGE:
THE KEY LINKS



Chapter 2

Industrial structure and innovation in Italy: the empirical study

In order to make progress on the questions raised in Chapter 1, the new approach needs to be tested on an adequate empirical evidence on industrial innovation. The empirical work we carried out refers to the case of Italy and uses a variety of new indicators as well as traditional economic and technological variables. Our research had access to data from the Cnr-Istat (National Research Council of Italy - Italian National Statistical Institute) survey on innovation in the Italian manufacturing industry for 1981-85. This survey has considered individual enterprises (rather than consolidated industrial groups) and was designed to provide reliable quantitative evidence on individual firms on a wide range of innovative activities undertaken by a large sample of Italian firms as well as to give additional information on the main technological sources of innovative activities, their inducement factors and economic effects[4].

The Cnr-Istat database provides, for 8,220 firms, technological data such as the expenditure on innovative activities related to Research and Development (R&D), Design and Engineering (D&E), Investment and Marketing. These data have been

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[4] In October 1987 - April 1988 the Italian Central Statistical Office (ISTAT), in collaboration with the Institute for Studies on Scientific Research and Documentation of the Italian National Research Council (ISRDS-CNR), carried out a survey of technological innovation in Italian manufacturing industry. The aim of the survey was to investigate the process of technological innovation and its impact on firms. The period referred to was the five years 1981-1985.
A preliminary survey was carried out in 1985 by means of a questionnaire mailed to about 35,000 manufacturing firms with more than 20 employees; 16,701 firms - 69.3 per cent of the 24,104 firms which answered the questionnaire - declared that they had introduced technological innovations in the period 1981-1985.
On the basis of the answers to the above-mentioned preliminary survey, these firms were subdivided into two groups. One, comprising 3,200 firms, included those firms which had introduced both product innovations and process innovations based on in-house innovative activities (in particular, R & D and patents held). These firms, deemed the most innovative on the basis of the preliminary survey, were then subjected to direct interview using a 33 item questionnaire. The second group of firms, numbering about 13,000, were those having declared that they had innovated mainly by purchasing technology from outside the firm through capital goods. This second group was mailed a simplified 21 item questionnaire.
Overall, 8,220 firms responded to the questionnaire, 5,519 of which by post and 2,701 by direct interview.
The fall-off in the number of firms actually participating in the survey compared with the total number of 16,701 innovating firms originally identified can be explained both by the comparative complexity of the new questionnaire and the more rigourous criteria used in the innovation survey to define technological innovation.
The 8,220 firms included in the innovation survey represent about 27 per cent of the 30,449 manufacturing companies included in industrial survey. They account for an even higher percentage of employees, more than 52 per cent. Overall, the average size of Italian innovating firms appears larger as compared to the average size of Italian manufacturing firms.

matched with 1985 data of the Gross Industrial Product survey which provides economic data such as firm size, fixed investment, sales, value added for a larger sample of firms.[5] Data on innovation cost incurred by firms between 1981-85 have been divided by 5 in order to make them comparable with the industrial survey data. The matching of the two database makes it available innovation and economic data for 6,839 firms (which cover more than 50% of the Italian manufacturing industry in terms of sales and employees). This makes it possible to describe more adequately the technological structure and performance of Italian industry as well as to investigate some of the theoretical issues and key relationships addressed in the previous chapter.

This database allows us to identify two disembodied components of innovative activity: R&D and Design and Engineering expenditure.

The database provides also information about the embodied components represented by the total fixed investment in machinery and plants, and the innovative investments. Whereas the former can be considered as a proxy of the capital intensity of production processes, the latter represents more directly the innovative effort to enhance the technological efficiency of productive processes.

A preliminary overview of Italy's industrial structure is offered by the sectoral breakdown of the firms surveyed, which highlights the large differences across industries of both economic variables (firm size, value added, investment) and indicators of innovative activities (R&D, Design and Engineering, Innovative investment expenditure).

Table 1 shows the average values of these variables for 30 industrial sectors.

Major characteristics of Italian industry include the following:

i) the great importance of traditional industries and the small average size of firms in many sectors. In particular, Food, Sugar and Drinks, Textile, Leather, Footwear and Clothing, Wood and Furnitures, Paper and Printing, Plastic, Metal products and Other industries account for more 32% of total manufacturing sales in 1985; technologically important sectors such as Specialized Machinery (General mechanical machinery, Metal machinery, Textile machinery and Precision instruments), and Electric and Electronics industries (Office machinery computing, Electronic equipment and components, Radio/Tv and Communication components) account for less than 20% of Italian industry sales. The average size is very small in Metal and Non metal products, all machinery sectors and in the

5 A new innovation survey is being started in 1993 and a more updated analysis will be possible shortly.

traditional sectors mentioned above. These are all industries where the average number of employees per firm is below 200.

Such a strong variability in structural characteristics goes hand in hand with a more even distribution across fields of both productivity indicators (value added per employee) and investment intensity (investment in machinery per employee). Besides Office machinery computing, traditional fields such as Food, Sugar and Drinks, Metal and Non metals have an above average investment intensity.

ii) Table 1 also shows that innovative investment is very important in all sectors. Average expenditures for innovative investment in all manufacturing industry is close to 2 millions Lire per employee while for R&D and D&E activities firms have spent on average 0.93 and 1.56 millions Lire respectively. It is interesting to note that the importance of innovative investment is relevant even in high R&D intensive sectors such as Office machinery computing, Radio/Tv and Communication components, Precision Instruments.

A relatively high innovative effort incorporated into innovative investment is also shown by sectors with a low R&D and D&E innovative intensity such as Non metals, Food, Wood and Furniture, Textile, Paper and Printing, Plastic.

This evidence points out the danger of relying exclusively on R&D expenditures as the key indicator of innovative activities in industrial firms, and confirms the need for a broader view of innovative efforts including D&E and investment activities.

iii) A wide variety of patterns emerge when the nature and relevance of different elements of innovative activities are examined.

Table 1 shows that in all the traditional sector listed above the average expenditure per employee in both R&D and D&E is below 300,000 Lire (at 1985 prices).

On the other hand, Metals, Metal machinery, Textile machinery, Aircraft have a low R&D intensity and a much higher D&E intensity.

Industrial sectors with a higher R&D intensity (from 1 to 5 millions Lire per employee) include Pharmaceuticals, Office machinery computing, Electronic equipment and components, Precision instruments, Rubber.

D&E intensity is over 2 millions of Lire per employee in the case of Textile machinery, Office machinery computing, Radio/Tv and Communication components, Aerospace, Rubber.

TABLE 1: FIRM SIZE, INVESTMENT AND INNOVATIVE INTENSITY BY INDUSTRIAL SECTORS (SECTORAL AVERAGE VALUES)

Industrial sectors	Number of firms	Firm size: Employees per firm EMPLOYEES	Firm size: Sales per firm (bn. of Lit) SALES	Sales: Sectoral percentages	Value added per employee: Value added per employee (mil. of Lit) ADDVALUE	Investment intensity (A): Investment in machinery per employee (mil. of Lit) INVMAC	Innovative intensity (mil. of innovative exp. per employee) (B): R&D	Innovative intensity (B): Design and Engineering	Innovative intensity (B): R&D plus Engineering RDENG	Innovative intensity (B): Innovative investment INNINV	Disemb./Embod. (B)/(A): R&D + Eng./ Invest. in mach. DIS/EMB
Energy & Gas	17	779	1,469	10.52	107.2	25.92	0.52	0.45	0.97	2.63	0.04
Metals	137	748	125	7.22	39.6	9.52	0.17	1.07	1.24	1.18	0.13
Non metals, Minerals	495	136	16	3.24	43.8	6.39	0.19	0.34	0.53	3.29	0.08
Chemicals	274	335	89	10.32	60.0	8.90	0.64	0.42	1.06	1.50	0.12
Pharmaceutical	135	356	65	3.71	66.7	5.91	1.40	0.58	1.98	1.15	0.33
Syntetic fibres	9	1,236	222	0.84	49.0	11.01	0.26	0.22	0.48	1.69	0.04
Metal products	864	100	11	3.93	40.6	4.21	0.14	0.34	0.48	1.53	0.11
Gen. Mechan. engin.	853	155	22	7.73	45.5	3.74	0.41	0.76	1.17	1.22	0.31
Metal machinery	231	97	10	0.97	43.1	3.25	0.72	1.36	2.08	1.28	0.64
Textile machinery	82	148	16	0.54	39.8	3.79	0.37	2.14	2.51	2.06	0.66
Office machinery computing	11	3,413	786	3.64	107.2	17.11	5.00	3.86	8.86	3.56	0.52
Electrical Comp.	308	336	26	3.38	43.7	3.30	0.31	0.47	0.78	1.05	0.24
Electronic Eq. & Comp.	68	626	62	1.77	48.3	4.24	2.13	2.72	4.85	1.47	1.14
Radio Tv & Comun. Eq.	92	418	56	2.17	46.2	7.95	1.65	2.35	4.00	3.34	0.50
Electrical Appl.	58	295	32	0.79	27.4	2.76	0.17	0.34	0.50	0.91	0.18
Motorvehicles Comp.	146	1,009	25	1.54	42.6	4.50	0.43	0.68	1.11	1.62	0.25
Motorvehicles	9	13,093	1,936	7.34	44.3	6.43	0.98	1.50	2.48	3.79	0.39
Other transport	73	806	43	1.31	35.3	2.00	0.18	0.33	0.51	0.63	0.26
Aircrafts	15	1,797	174	1.10	47.1	4.63	0.31	6.69	6.99	6.31	1.51
Precision instruments	110	130	12	0.56	41.2	4.17	1.06	1.39	2.45	2.27	0.59
Food	268	174	43	4.83	44.6	7.39	0.10	0.17	0.27	2.34	0.04
Sugar, Drinks	177	347	96	7.17	48.9	6.23	0.20	0.24	0.44	1.33	0.07
Textiles	610	128	15	3.75	40.5	4.67	0.13	0.15	0.28	1.71	0.06
Leather	97	73	11	0.47	38.8	3.03	0.06	0.15	0.21	1.28	0.07
Footwear, Clothing	343	144	15	2.10	33.8	1.62	0.04	0.12	0.16	0.49	0.10
Wood, Furnitures	469	62	7	1.34	36.1	3.41	0.16	0.24	0.40	1.50	0.12
Paper, printing	369	192	28	4.38	55.0	5.81	0.13	0.13	0.25	2.52	0.04
Plastic	316	90	13	1.74	46.9	5.81	0.31	0.56	0.88	2.25	0.15
Rubber, Plastic	73	325	34	1.04	37.3	4.96	3.17	2.43	5.60	1.68	1.13
Other manufacturing	130	65	10	0.57	36.0	3.88	0.26	0.32	0.58	1.38	0.15
Total	6,839	213	35	100.00	46.7	5.93	0.63	0.93	1.56	1.93	0.26

Chapter 3

Sectoral differences in firm size, innovation and investment

The descriptive evidence presented in the previous chapter has shown that industrial sectors largely differ in terms of the nature and intensity of their innovative activities. They differ also in terms of their average firm size, while a much lower variance emerges in productivity levels.

In this chapter average data for 30 sectors are considered, providing new evidence on the relationships at the sectoral level between different forms of innovative activities (R&D, D&E, and Investment) and between them and firm size and performance. In chapter 4 the same issues will be explored using data on individual firms within different sectoral aggregations.

The key relationships investigated here at the sectoral level are those already identified in the first chapter (Figure 4):

i) the relationship between firm size and investment intensity (embodied technological change);

ii) the relationship between disembodied and embodied innovative activities;

iii) the relationship between firm size and the intensity of disembodied innovative activities (R&D and D&E).

The key variables considered here include:

The expenditure on R&D and Engineering activities per employee used as an indicator of "disembodied" innovative intensity;

The expenditure on investment in machinery and equipment per employee used as an indicator of the "embodied" innovative intensity;

The ratio between the expenditure on R&D and Engineering, and the expenditure on investments in machinery and equipment used as an indicator of the embodied/disembodied composition of innovative activities.

The first relationship (i) points out the inter-sectoral differences in firm size and intensity of investment in machinery and plants. A positive correlation at the sectoral level is expected, as investment intensity represents a proxy for the intensity in the use of technology embodied in fixed capital, the importance of economies of scale in the production processes, the complexity of industrial organization models.

Secondly, the relationship between disembodied and embodied innovative intensity (ii) shows the different combinations of the two components at the sectoral level, and their complementary or alternative relationship.

Thirdly, the traditional relationship between disembodied innovative intensity and firm size (iii) is considered. Rather than looking for a general correlation between the two variables, different groups of sectors will be identified: sectors where innovative intensity increases with firm size, sectors where the scale of production grows independently of the intensity of innovative activities; and sectors where the latter is not associated to an increase of firm size.

The results of these analyses are summarized here. A few broad aggregations of sectors are identified on the basis of the different inter-sectoral combinations of the three dimensions mentioned above.

Firm size and capital intensity

Figure 5 shows how the average values of the sectors of Italian industry are distributed along the two variables of firm size and investment intensity. The Figure excludes the sectors of Motor-vehicles, Office machinery and computing and Energy and Gas. The latter cannot be fully considered as manufacturing industry, while Office machinery and computing and Motor-vehicles are outliers showing firms size and investment intensity values (for Office machinery only) much higher than the rest of the sectors.

The existence at the sectoral level of a positive association between firm size and the intensity of investment in machinery emerges quite clearly from Figure 5. The regression line has been drawn and the R square value is equal to 0.44 and highly significant. The inclusion of Office machinery computing makes the R square value even higher, this sector being characterized by both a very high sectoral average firm size and a very high investment intensity. On the other hand, results are less significant if Motor-vehicles is included, as it shows the highest sectoral firm size together with an investment intensity only slightly above the average.

Most of the *consumer goods* and *mechanical-engineering* sectors are characterized by a low firm size and a low investment intensity. This reflects a low capital intensity (embodied technological change), as well as weak opportunities to exploit economies of scale.

At the other extreme of the regression line, there are industrial sectors characterised by high capital intensity such as Chemicals, Metals (production and transformation of), Synthetic fibres, (Motor-vehicles and Office Machinery are outside the scattergram, the former showing the highest sectoral firm size and the latter a very high investment intensity).

Sectors which combine average values of firm size and investment intensity include Electronics components, Pharmaceuticals, Sugar and Drink, Rubber, Paper and Printing, Food, and Radio/Tv components.

Looking at the industrial sectors more distant from the regression line, we find Textile, Plastic and Minerals where average levels of investment are associated to industrial organizational models based on small firms. An opposite pattern is shown by the Aircraft industry where the presence of large firms is combined with a relatively modest capital intensity. In interpreting such patterns, the particular structure of Italian industry, described in the previous chapter, should be kept in mind.

Capital intensity and disembodied innovative intensity

The descriptive evidence just presented shows that the intensity of investment in machinery widely differs across industrial sector; and that a robust positive association with firm size emerges.

The position of each industrial sector according to the values of investment in machinery per employee and disembodied innovative intensity is shown in Figure 6.

Comparing this picture to the previous one, we find that most traditional sectors remain, as in Figure 5, close to the origin, as they are characterized by low firm size, low investment and innovative intensity.

There are two groups of sectors that have significantly scaled up their position; both are characterised by low firm size and low investment intensity. The first one includes Rubber and Electronics components and equipment, which move close to

Aircraft in the level of innovative intensity. The second one includes Machinery and Precision instruments sectors (Metal and Textile Machinery, Precision Instruments) which show an average disembodied innovative intensity. Both groups consist of industrial sectors where a consistent effort towards innovative activities aimed at producing technological knowledge and know-how is not associated to a high investment intensity.

The scattergram also shows a group of sectors where a high intensity of investment activities is associated with a low propensity to carry out disembodied innovative activities based on R&D and D&E. They include Synthetic fibres, Metals, Chemicals, Food, Minerals, Sugar and Drinks. Office machinery is the sector which shows both a very high investment intensity and very high levels of R&D and D&E innovative activities.

Firm size and disembodied innovative intensity

Finally, Figure 7 shows the distribution of the sectors according to the values of firm size and disembodied innovative intensity. Also in this case Office machinery computing and Motor-vehicles fall far outside the scattergram.

No general relationship between the two variables emerges, confirming the existence of wide inter-sectoral differences in the way structural characteristics such as firm size are associated to the levels of innovative intensity, technological opportunity, efforts for the production of knowledge and technological capability, and the proximity to "technological frontiers".

In this respect sectors such as Rubber, Electronics components and equipment, Radio/Tv components, show a small-medium average firm size associated to a high innovative intensity. Besides these higher technology sectors, there are mechanical sectors such as Textile machinery, Metal machinery and Precision instruments that even if based on small firms show a high disembodied innovative intensity because of the high relevance of Engineering and Design innovative activities.

Sectors such as Synthetic fibres, Metals, Sugar and Drink, Chemicals show an opposite pattern. They are characterized by medium-large firms and medium-low disembodied innovative activities. In these sectors firms innovate mainly through investment in machinery, and process and organizational innovations.

This descriptive evidence shows that no general association between innovative intensity and firm size exists. However, different groups of industrial sectors have been identified according to different combinations of the variables considered so far.

In particular, a key role in the explanation of such a lack of linear relationship across sectors is played by the sector specific combination of the technological opportunities and the characteristics of production processes and organizational structures. In some cases high technological opportunities require, in order to be exploited, a large amount of investment, the development of complex organizations, and large volumes of production. These factors, far from being external to technological change, have a key technological dimension.

According to this view, three *specific combinations of structural conditions and innovative patterns* can be identifyed.

The first one includes sectors like Rubber, Electronics components and equipment, Radio Tv components, Textile machinery, Metal machinery and Precision instruments which are characterized by a small firm size and a high disembodied innovative intensity (mainly D&E) largely because of the low level of investment intensity and the low relevance of economies of scale. Innovative activities are mainly aimed at enhancing internal Design and Engineering capability rather than at exploiting economies of scale through the introduction of new process technologies.

A second pattern is shown by industrial sectors such as Synthetic fibres, Metals, Sugar and Drink, Chemicals (and partially Motor-vehicles) where a combination of a low disembodied innovative intensity and a high firm size is due to the fact that the technical characteristics of the productive process require high investment in fixed capital. In other words, in these sectors in order to benefit from new technological opportunities large investment in process innovations is needed.

A special case here is represented by the Office machinery sector which is characterized by the development of internal technological capabilities, and at the same time by the need of large investment in fixed capital to exploit the technological advances developed internally. This can explain the presence in this sector of large firms, large volumes of production related both to high expenditure for production investment and R&D activities.

A third pattern is shown by traditional consumer goods sectors, where economic performance and structural conditions are not strongly linked to specific technological and investment patterns. There is a wide variety of efficient organizational forms which not necessarily require a specific technological effort. The key role is played by organizational factors and by other firm-specific advantages related to the nature of production in these largely traditional sectors.

Towards a sectoral taxonomy

It is possible to synthesize the descriptive evidence emerged so far by grouping the industrial sectors according to their similarity (proximity) in terms of firm size, disembodied innovative intensity and investment intensity. In order to group the sectors a Cluster Analysis based on the *complete linkage method* has been used.[6]

The clustering statistical procedure has been stopped at the level of 9 clusters, chosen on the basis of both the statistical and technological significance of the clusters already formed. The most numerous cluster (both in terms of firms, sectors, and employees) has been split up in two, identifying two quite distinct and still very numerous groups of sectors (see clusters 1 and 2 in Figure 8).

It is impossible to represent the clusters in a three-dimensional space; in Figure 8 they are positioned along indicators of technological dimension, that is both the *innovative intensity* and the relative importance of the *disembodied innovative activities* (R&D and D&E) (vertical axis) and indicators of structural dimension, that is *investment intensity,firm size,* and the *relevance of economies of scales* (horizontal axis).

In Figure 8 the two axes reflect also the levels of technological barriers to entry related to the presence of different types of cumulative processes in innovation.

The vertical axis represents the relevance of barrier to entry related to the *cumulative process of disembodied and tacit technological knowledge* where the horizontal axis shows the relevance of the barriers to entry related to the *amount of fixed capital and embodied technology accumulated,* as well as to the complexity of industrial organization models.

Figure 8 can therefore represent a methodological framework making the distances between sectors and clusters more visible. The vertical and horizontal distances between clusters can be considered as an indicator of, respectively, technological and structural distances among sectors. These distances can be seen also as barriers to inter-sectoral movements and to diversification strategies. Moving from one sector to another requires indeed to face structural, technological

6 In the Cluster analyses the jointing procedure is based on the distances between the different cases or clusters. There are several clustering methods according to how the distances are estimates. The essential aim however consist of grouping the original observations in more aggregated groups in order to minimize the internal variance (within each group) and maximize inter-groups one. With *the complete linkage method* the distance between two clusters are calculated as the distances between their two furthest points. The use of other clustering methods (i.e. single linkage, average linkage methods) has given the same results.

and organizational barriers to entry and to exit, whose nature and importance vary according to the starting point and the direction of movement.

The main sectoral patterns

The groups of sectors resulting from the cluster analysis based on sectoral differences in industrial structure characteristics, nature and intensity of innovative activities, can be described as follows:

Technology users and traditional sectors:

In the bottom-left side of the Figure 8 cluster 1 and 2 are found, including sectors that in all previous Figures where close to the origin. These are the *low innovative intensity* sectors characterized by a *low disembodied and embodied innovative intensity* and with a *large prevalence of small firms.* Cluster 2 is slightly more innovative than cluster 1 showing a higher propensity to carry out some type of research or design-engineering activities and showing a higher ratio of disembodied to embodied innovative activities. Both clusters are characterized by a relatively low level of value added per employee probably related both to a low technological content of final products and to a low capital intensity of the production processes.

Investment intensive sectors

Clusters 3 and 4 are both characterized by a high capital intensity and a low innovative intensity. The combination of small firm size and a medium-high investment intensity in Cluster 3 is the result of the specific characteristics of the production processes in these industries. Also in the case of small production units the "continuous process" nature of production requires capital intensive structures.

The automobile industry (Cluster 5) is clearly an outlier of this group as far as firm size is concerned. This reflects the fact that the automobile industry is the sector where mass-production systems have been more extensively exploited. Investment expenditure in machinery per employee is high but the relevance of economies of scale is related not only to the amount of fixed capital invested but also to the organizational complexity of the productive processes. R&D and D&E expenditure per employee are higher than in clusters 3 and 4. In all these industries however innovation incorporated in fixed capital has a key role in the innovative performance.

In-house innovators

At the top-right side of the Figure, far from other sectors, we find cluster 9, consisting of the Electronics-Office machinery industry. Large firms, high expenditure on R&D and Engineering activities and a surprisingly high investment intensity are the characteristics of this high-tech sector. Even in the presence of the highest R&D and Engineering intensity, the particular high level of investment in machinery per employee makes the ratio between the two components not as high as that of other innovative sectors. The value added per employee is also very high, being related to the high technological content of products and to the high capital intensity.

A similar pattern, but with less extreme values, is shown by clusters 6, 7 and 8, where a high disembodied innovative intensity is associated to a low-medium firm size. Cluster 6 includes the most innovative *mechanical-engineering* sectors. Firm size and investment intensity are very low. The relatively high disembodied innovative intensity is due to the relevance of D&E innovative activities.

Clusters 7 and 8 include industrial sectors where innovative activities aimed at producing new technological knowledge represent a large part of total innovative activities. The ratio between R&D plus Engineering expenditure and the investments in machinery is very high. The high innovative intensity might explain the above average value added per employee of these sectors.

In summary Figure 8 highlights the main different pattern found across sectors in the link between technology and industrial structure. However within each of the 3 major aggregations of sectors, *technology users* (Clusters 1 and 2), *Investment intensive sectors* (Clusters 3, 4, and 5), and *In-house innovators* (Clusters 6, 7, 8 and 9), simultaneous positive relationships can be identified between firm size, innovative intensity and, to a lesser extent, investment intensity.

FIG. 5 - INVESTMENT INTENSITY AND FIRM SIZE

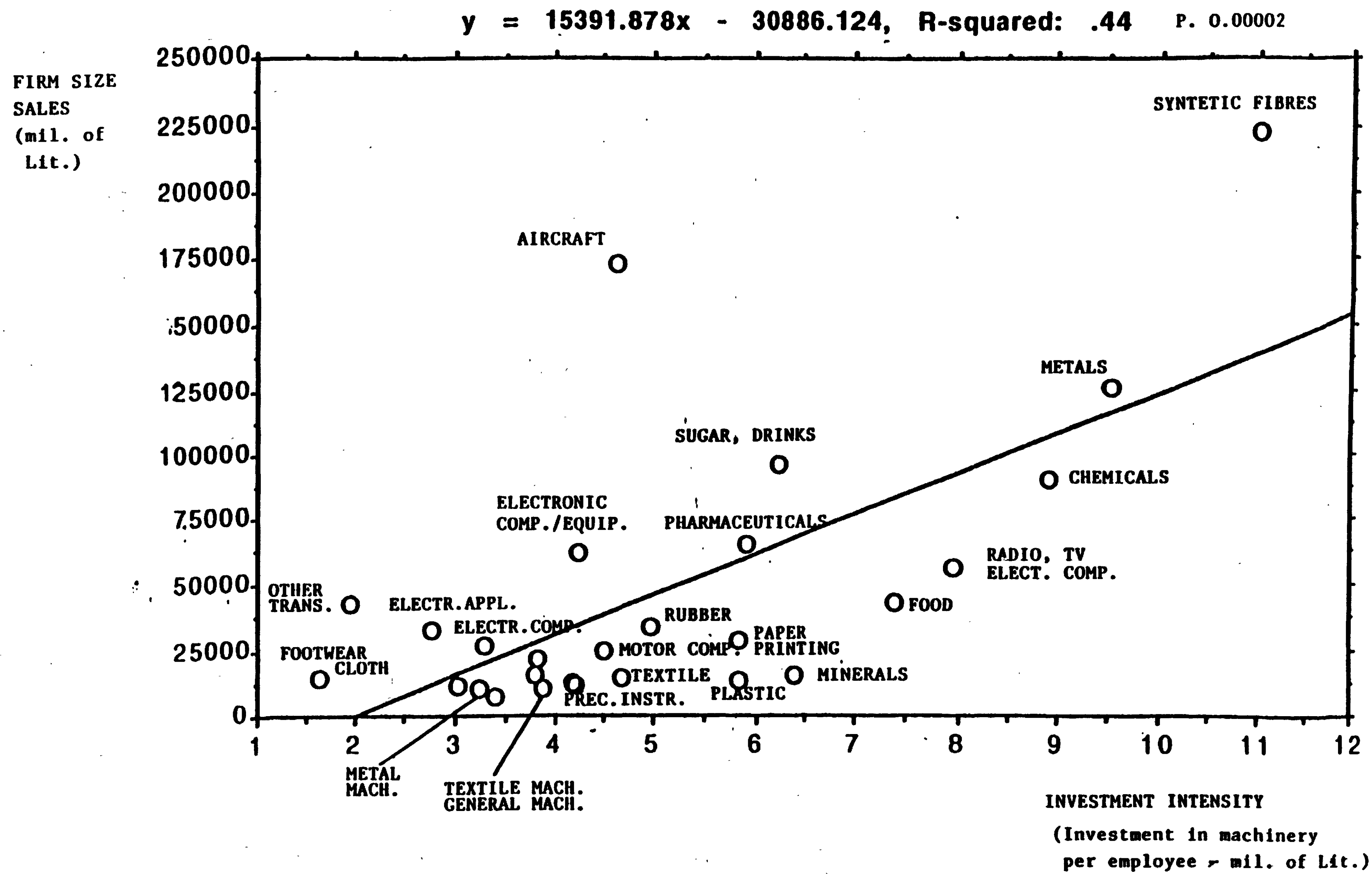


FIG. 6 - DISEMBODIED INNOVATIVE INTENSITY AND INVESTMENT INTENSITY

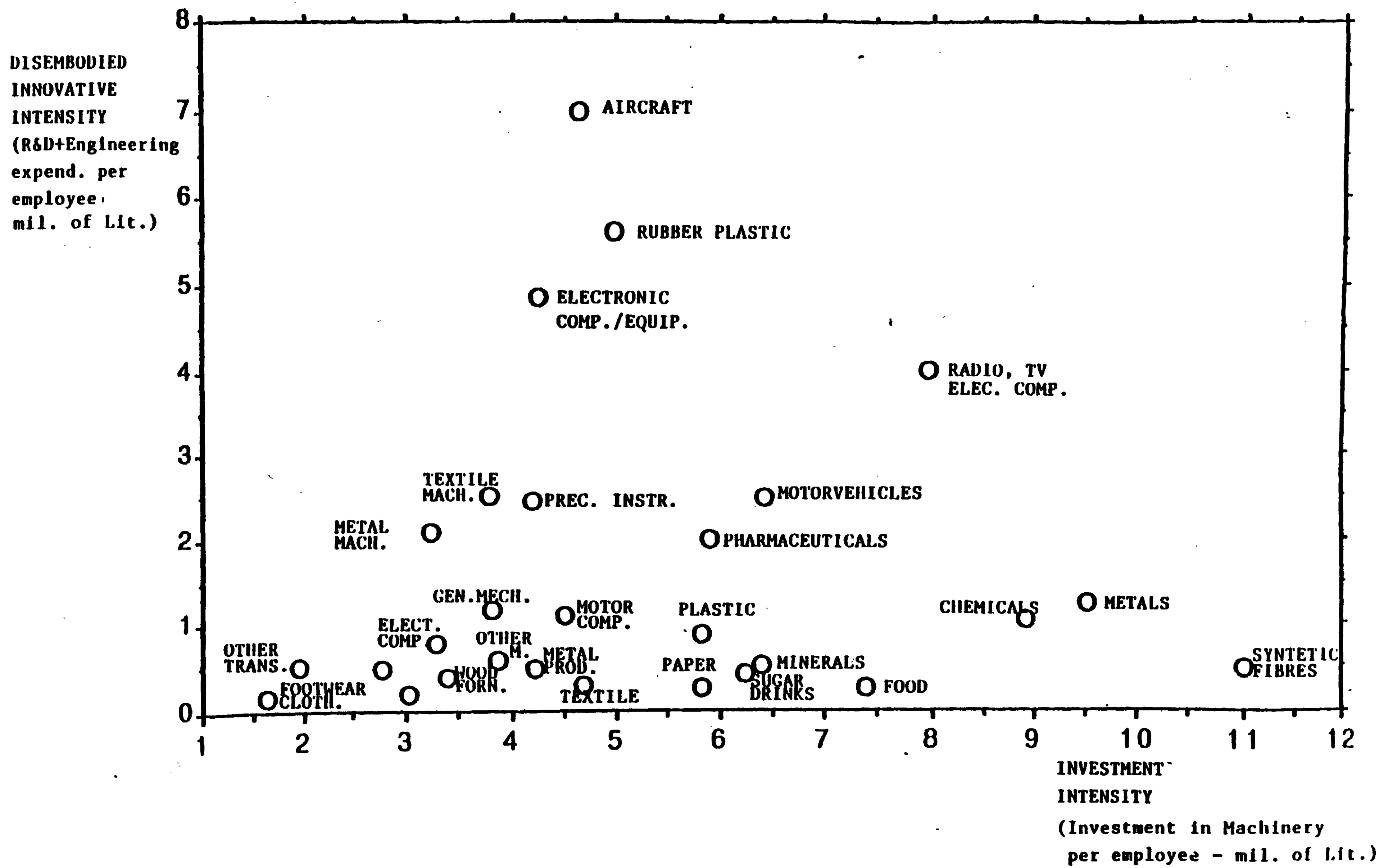


FIG. 7 - DISEMBODIED INNOVATIVE INTENSITY AND FIRM SIZE

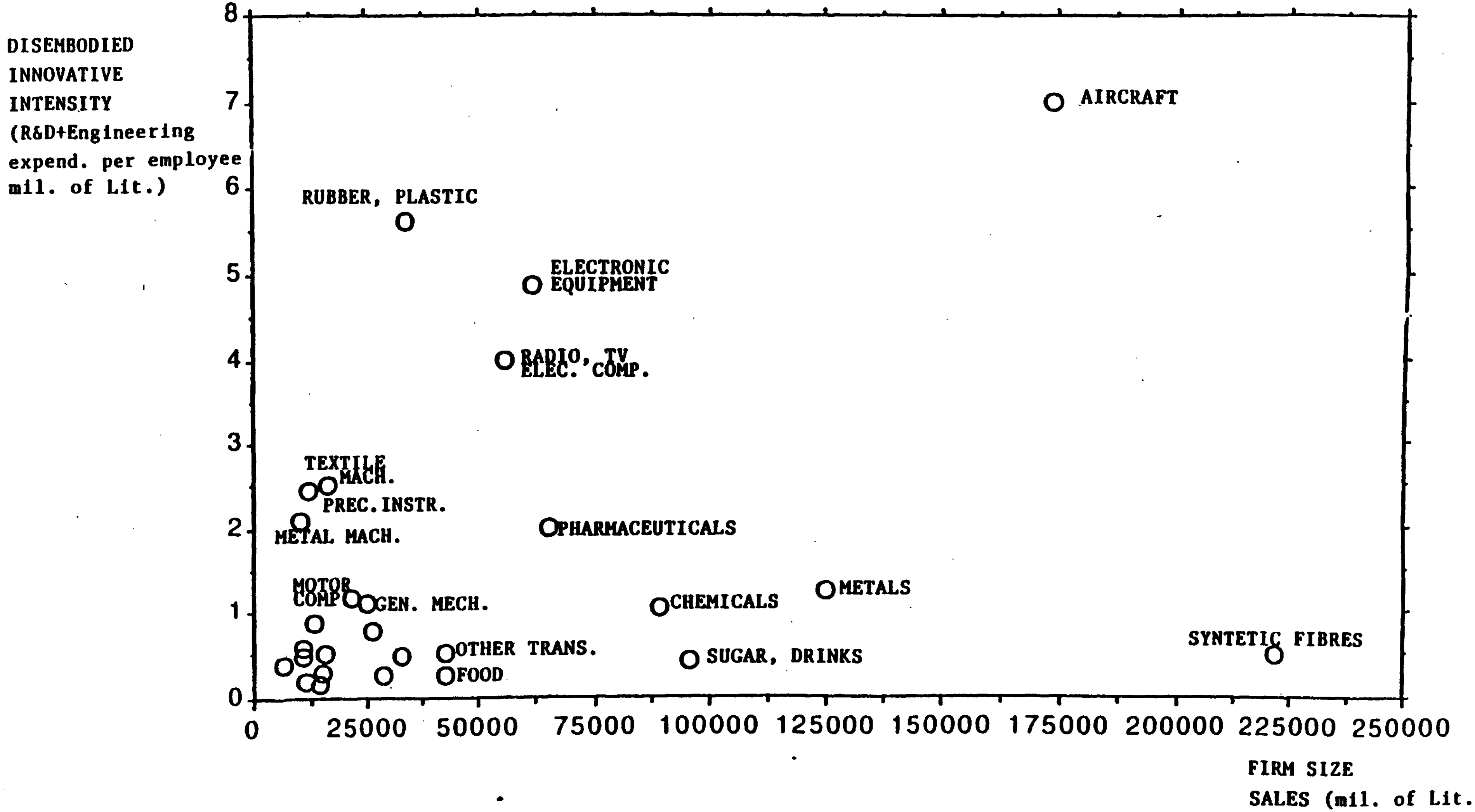


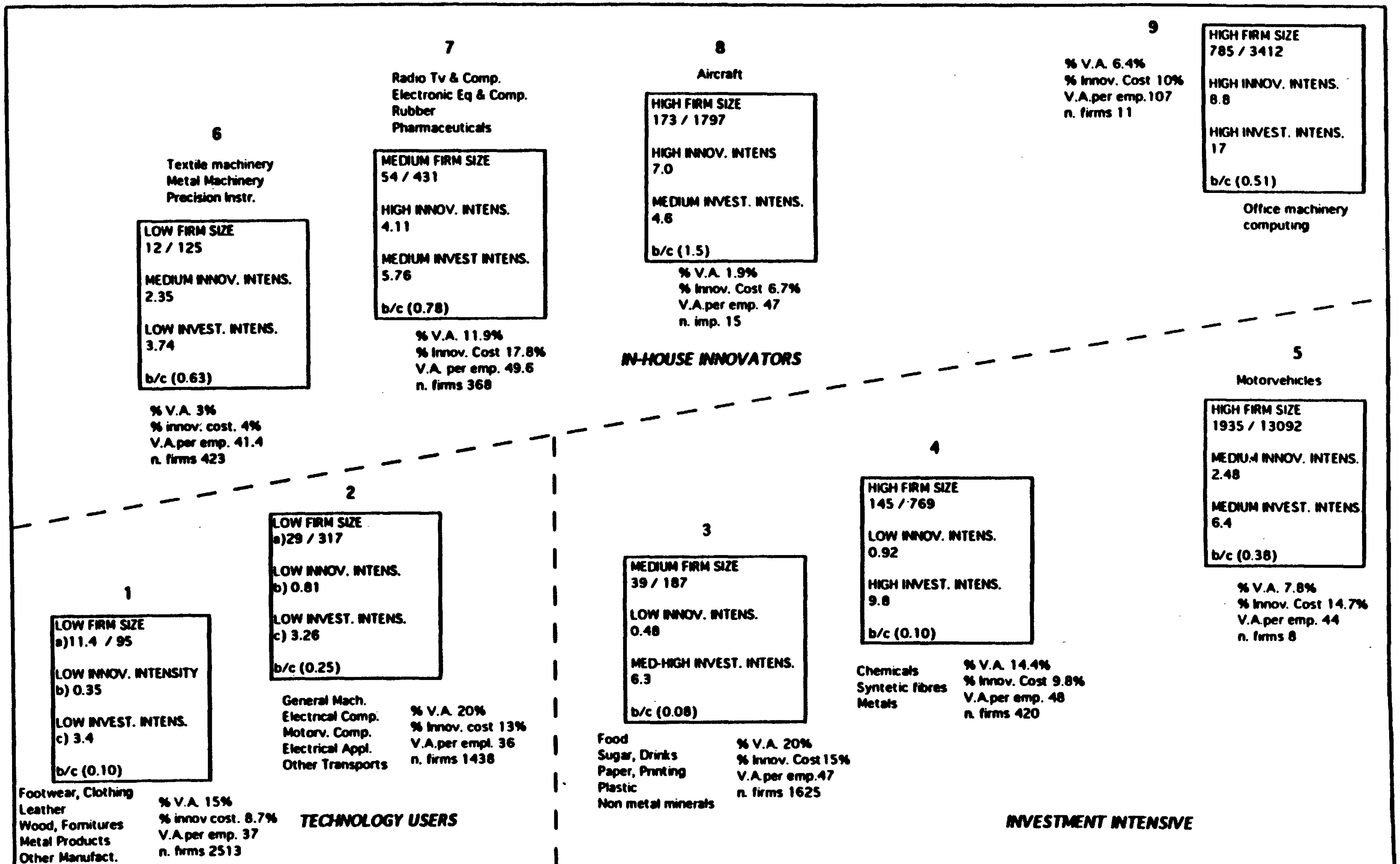
FIGURE 8 - INDUSTRIAL STRUCTURE, INVESTMENT AND INNOVATIVE PATTERNS: A SECTORAL TAXONOMY

Innovative intensity

and importance of R&D and D&E

HIGH

LOW



a: Sales per firm (Billions of Lire) / number of employees per firm
b: R&D + Engineering-Design expenditure per employee (Mil. of Lire)
c: Investments in Machinery and Equipment per employee (Mil. of Lire)

LOW

HIGH

Investment intensity and relevance of scale factors

The horizontal axis measures also barriers to entry related to disembodied technological capability and disembodied technological cumulative processes

The vertical axis measures also barriers to entry related to the capital intensity of productive processes, the importance of economies of scale and

Chapter 4

Inter-firm differences in innovation and structure

In this chapter the same analysis carried out in chapter 3 at the sectoral level (using average values for 30 industrial sectors) is developed on individual firm data (6,839 firms), considering a larger number of technological and economic variables. The analysis has been carried out within the three major aggregations identified in the previous chapter and on selected industrial sectors (at the 3 digit level).

The analysis of the main aggregations

The following variables are considered here:

- SALES: billion Lire
- EMPLOYEES: number of employees
- ADDVALUE: Value added per employee
- INVMACH: Fixed investment in machinery per employee
- INNCOST:Total innovation cost (including R&D, D&E, Innovative investment, Marketing) per employee
- RDENG: R&D plus D&E expenditures per employee
- INNINVEST: Innovative investment per employee

Due to the very large number of small firms included in the database, those firms with sales below 50 billion Lire in 1985 have been excluded. For the *Technology users* sectors, where average size is particularly low, the cut-off point was set at 25 billion Lire of sales in 1985.

A preliminary analysis has been carried out using linear correlations in order to show the general regularities in the relationships between innovative and structural variables.

Tables 2, 3 and 4 show the correlation matrixes for the three major aggregations of sectors: *Technology users, Investment intensive sectors* and *In-house innovators.*

A surprising general result is the absence in all three groups of any significant relationship between firm size (measured both by sales and employees) and technological and economic variables. Even the positive relationship between investment intensity and firm size, emerged as highly significant in the previous chapter, is not significant when data at the firm level are considered. This probably reflects the large inter-firm variance at this level of aggregation and the use of data for individual enterprises rather than for industrial groups.

The most significant relationships are the (positive) associations between investment intensity (INVMAC) on the one hand and total innovation cost and innovative investment intensity (INNINVEST) on the other (from 0.30 to 0.43).

Correlation coefficients are higher for *Technology users* and *Investment intensive* sectors than for the *In-house innovators*; this confirms that, for the former, innovative activities are strongly related to innovative investment in fixed capital. These results are confirmed when we look at the correlations between total innovation cost (INNCOST) on the one side and the innovative investment intensity (INNINVEST) and the R&D-Engineering expenditure (RDENG) on the other (the latter are included in the former). For *Technology users* and *Investment intensive sectors* total innovation cost are correlated with innovative investment at the level of 0.86 and 0.94 respectively, while *In-house innovative sectors* show a high level of the correlation (0.9) between total innovation cost (INNCOST) and the disembodied innovative intensity (RDENG).

However, the complementary relationship between the disembodied and embodied forms of technological change is much stronger in the *In-house innovative sectors* than in the other sectors. The correlation coefficient between innovative investment intensity (INNINVEST) and the R&D-Engineering expenditure per employee (RDENG) is 0.53 for the first group of sectors and 0.14 and 0.09 for *Technology users* and *Investment intensive* sectors respectively. This may suggest that, especially for the most innovative sectors, *production* and *use* of technology are both important.

Finally, in all three groups of sectors productivity (value added per employee, ADDVALUE) is only slightly positively correlated to investment intensity (INVMAC) and to total innovation cost per employee (INNCOST). Higher correlation coefficients are shown by *Technology users* sectors only. This result should be seen in the context of the particular aspects of Italian industry, including the strong relevance of small and medium firms. In addition, the relationship between productivity and innovative intensity can be weakened by the importance in the Italian industry of large state-owned firms active in high R&D intensive fields which have shown in the last decade a lower productivity performance, while on the other hand, small and medium firms in lower technological sectors have been quite successful in terms of economic performance.

The analysis of selected industrial sectors

The generally weak associations emerged from this first firm-level analysis depend on the very high sectoral aggregation used. The same analysis has been carried out for selected sectors (at the three digit level). The following additional variables have been taken into account:

- PROFIT: [Gross product - (Wages + Depreciation)] * 100 / Gross product
- DIS/EMB: R&D plus D&E divided by Fixed investment in machinery
- RDENG%: R&D plus D&E expenditure as a percentage of the total innovation cost

While for some sectors the results show little improvement, confirming the permanence, even at the level of individual industries, of a very high inter-firm variance, for some industries important, and in some cases contrasting associations, emerge.

- The relationship between *firm size and disembodied innovative intensity* (RDENG), which was never significant in the previous analysis is positive and very significant for the Rubber sector (0.8 - Table 5), due to dualistic structure with the largest firms specialized in the most innovative productions and the small-medium firms concentrating on lower technology productions.

- As far as the relationship between *investment intensity and innovative intensity* is concerned,, Metal products shows a correlation coefficient between total innovation cost (INNCOST) and investment in machinery (INVMACH) (0.61 - Table 6) higher than the other *Investment intensive* sectors. This suggests that especially in this sector innovative activities are carried out by investing heavily in fixed capital. Even the less innovative *technology users* (those included in cluster 1) show a high positive correlation between investment and innovative intensity (0.43 - Table 7). Even if characterized by low investment intensity the high reliance upon technology incorporated in fixed capital make their innovative patterns conditioned by the purchasing of process technologies from specialized mechanical sectors.

- A relatively high correlation between *investment intensity* (INVMACH)and the *value added per employee* (ADDVALUE) is shown by the Textile machinery sector (0.56 - Table 8), and more in general by all specialized mechanical sectors. This positive association is combined with a negative correlation between *size* (both SALES and EMPLOYEES) *and profitability* (PROFIT) (-0.46, -059, Table 7). In these sectors, and related technologies, small firms seem able to obtain high returns, suggesting that the specific nature of innovative activities, largely based on Engineering activities together with other characteristics of these markets, offer a favourable environment for the success of small firms.

The simultaneous presence of positive associations between *investment intensity, innovative intensity and productivity* can be found in the Electronic components sector (Table 9). The innovative pattern of this sector seems also characterized by a strong complementarity between disembodied (RDENG) and embodied (INVMAC) innovative activities (0.65 - Table 9). As already observed for the Office machinery and computing sector in the previous chapter, even when internal technological sources are crucial, a high investment effort is required. Especially in the electronics field, *production* and *utilization* of innovations are not alternative to one another: both seem to be crucial.

TABLE 2: CORRELATION MATRIX - TECHNOLOGY USERS (CLUSTERS 1, 2)

	SALES	EMPLOYEES	ADDVALUE	INVMACH	INNCOST	RDENG	INNINVEST
SALES	1.00	0.84	0.06	-0.02	-0.02	0.04	0.05
	0.000	0.000	0.004	0.433	0.420	0.081	0.031
EMPLOYEES	0.84	1.00	-0.07	-0.05	-0.06	0.00	0.07
	0.000	0.000	0.001	0.018	0.009	0.863	0.001
ADDVALUE	0.06	-0.07	1.00	0.33	0.27	0.17	0.24
	0.004	0.001	0.000	0.000	0.000	0.000	0.000
INVMACH	-0.02	-0.05	0.33	1.00	0.37	0.08	0.44
	0.433	0.018	0.000	0.000	0.000	0.000	0.000
INNCOST	-0.02	-0.06	0.27	0.37	1.00	0.67	0.87
	0.420	0.009	0.000	0.000	0.000	0.000	0.000
RDENG	0.04	0.00	0.17	0.08	0.67	1.00	0.22
	0.081	0.863	0.000	0.000	0.000	0.000	0.000
INNINVEST	-0.05	-0.07	0.24	0.44	0.87	0.22	1.00
	0.031	0.001	0.000	0.000	0.000	0.000	0.000

The first row shows the correlation coefficients and the second row the statistical significance.
The number of cases considered is 2156.

TABLE 3: CORRELATION MATRIX - INVESTMENT INTENSITY SECTORS (CLUSTERS 3, 4, 5)

	SALES	EMPLOYEES	ADDVALUE	INVMACH	INNCOST	RDENG	INNINVEST
SALES	1.00	0.94	-0.02	0.00	-0.02	0.03	-0.03
	0.000	0.000	0.435	0.986	0.546	0.283	0.323
EMPLOYEES	0.94	1.00	-0.05	-0.02	-0.01	0.04	-0.03
	0.000	0.000	0.105	0.603	0.654	0.158	0.353
ADDVALUE	-0.02	-0.05	1.00	0.16	0.14	0.05	0.13
	0.435	0.105	0.000	0.000	0.000	0.120	0.000
INVMACH	0.00	-0.02	0.16	1.00	0.42	0.10	0.43
	0.986	0.603	0.000	0.000	0.000	0.003	0.000
INNCOST	-0.02	-0.01	0.14	0.42	1.00	0.41	0.94
	0.546	0.654	0.000	0.000	0.000	0.000	0.000
RDENG	0.03	0.04	0.05	0.10	0.41	1.00	0.10
	0.283	0.158	0.120	0.003	0.000	0.000	0.003
INNINVEST	-0.03	-0.03	0.13	0.43	0.94	0.10	1.00
	0.323	0.353	0.000	0.000	0.000	0.003	0.000

The first row shows the correlation coefficients and the second row the statistical significance.
The number of cases considered is 990.

TABLE 4: IN-HOUSE INNOVATORS (CLUSTERS 6, 7, 8, 9)

	SALES	EMPLOYEES	ADDVALUE	INVMACH	INNCOST	RDENG	INNINVEST
SALES	1.00 0.000	0.89 0.000	0.12 0.020	0.19 0.000	0.11 0.032	0.13 0.015	0.06 0.251
EMPLOYEES	0.89 0.000	1.00 0.000	0.01 0.808	0.12 0.029	0.14 0.007	0.17 0.001	0.07 0.183
ADDVALUE	0.12 0.020	0.01 0.808	1.00 0.000	0.27 0.000	0.13 0.014	0.10 0.062	0.16 0.002
INVMACH	0.19 0.000	0.12 0.029	0.27 0.000	1.00 0.000	0.24 0.000	0.18 0.001	0.31 0.000
INNCOST	0.11 0.032	0.14 0.007	0.13 0.014	0.24 0.000	1.00 0.000	0.91 0.000	0.81 0.000
RDENG	0.13 0.015	0.17 0.001	0.10 0.062	0.18 0.001	0.91 0.000	1.00 0.000	0.53 0.000
INNINVEST	0.06 0.251	0.07 0.183	0.16 0.002	0.31 0.000	0.81 0.000	0.53 0.000	1.00 0.000

The first row shows the correlation coefficients and the second row the statistical significance.
The number of cases considered is 354.

TABLE 5: CORRELATION MATRIX - RUBBER

	SALES	EMPLOYEES	ADDVALUE	PROFIT	INVMACH	INNCOST	RDENG	ININVEST	DIS/EMB	RDENG%
SALES	1.00	1.00	-0.04	-0.08	0.02	0.65	0.80	0.08	0.58	0.22
	0.000	0.000	0.791	0.588	0.881	0.000	0.000	0.605	0.000	0.132
EMPLOYEES	1.00	1.00	-0.08	-0.11	0.01	0.66	0.81	0.07	0.58	0.23
	0.000	0.000	0.602	0.481	0.949	0.000	0.000	0.639	0.000	0.112
ADDVALUE	-0.04	-0.08	1.00	0.81	0.22	0.02	-0.09	0.16	-0.02	-0.21
	0.791	0.602	0.000	0.000	0.141	0.913	0.537	0.268	0.874	0.151
PROFIT	-0.08	-0.11	0.81	1.00	0.10	0.13	-0.03	0.31	0.08	-0.22
	0.588	0.481	0.000	0.000	0.505	0.381	0.843	0.032	0.607	0.143
INVMACH	0.02	0.01	0.22	0.10	1.00	0.17	0.12	0.18	-0.15	-0.08
	0.881	0.949	0.141	0.505	0.000	0.267	0.427	0.222	0.308	0.593
INNCOST	0.65	0.66	0.02	0.13	0.17	1.00	0.88	0.71	0.61	0.17
	0.000	0.000	0.913	0.381	0.267	0.000	0.000	0.000	0.000	0.267
RDENG	0.80	0.81	-0.09	-0.03	0.12	0.88	1.00	0.30	0.73	0.44
	0.000	0.000	0.537	0.843	0.427	0.000	0.000	0.040	0.000	0.002
ININVEST	0.08	0.07	0.16	0.31	0.18	0.71	0.30	1.00	0.11	-0.29
	0.605	0.639	0.268	0.032	0.222	0.000	0.040	0.000	0.458	0.050
DIS/EMB	0.58	0.58	-0.02	0.08	-0.15	0.61	0.73	0.11	1.00	0.47
	0.000	0.000	0.874	0.607	0.308	0.000	0.000	0.458	0.000	0.001
RDENG%	0.22	0.23	-0.21	-0.22	-0.08	0.17	0.44	-0.29	0.47	1.00
	0.132	0.112	0.151	0.143	0.593	0.267	0.002	0.050	0.001	0.000

The first row shows the correlation coefficients and the second row the statistical significance.
The number of cases considered is 47.

TABLE 6: CORRELATION MATRIX - METALS

	SALES	EMPLOYEES	ADDVALUE	PROFIT	INVMACH	INNCOST	RDENG	INNINVEST	DIS/EMB	RDENG%
SALES	1.00	0.97	-0.11	-0.17	0.01	-0.04	0.03	-0.07	0.03	0.16
	0.000	0.000	0.246	0.063	0.937	0.642	0.748	0.449	0.777	0.070
EMPLOYEES	0.97	1.00	-0.17	-0.22	-0.01	-0.05	0.05	-0.10	0.06	0.21
	0.000	0.000	0.057	0.014	0.898	0.546	0.556	0.291	0.531	0.017
ADDVALUE	-0.11	-0.17	1.00	0.61	0.22	0.13	-0.10	0.20	-0.15	-0.07
	0.246	0.057	0.000	0.000	0.013	0.148	0.261	0.025	0.103	0.463
PROFIT	-0.17	-0.22	0.61	1.00	0.07	-0.17	-0.52	0.08	-0.55	-0.22
	0.063	0.014	0.000	0.000	0.430	0.055	0.000	0.394	0.000	0.013
INVMACH	0.01	-0.01	0.22	0.07	1.00	0.62	0.06	0.68	-0.06	-0.10
	0.937	0.898	0.013	0.430	0.000	0.000	0.475	0.000	0.538	0.284
INNCOST	-0.04	-0.05	0.13	-0.17	0.62	1.00	0.52	0.88	0.38	0.02
	0.642	0.546	0.148	0.055	0.000	0.000	0.000	0.000	0.000	0.826
RDENG	0.03	0.05	-0.10	-0.52	0.06	0.52	1.00	0.05	0.93	0.50
	0.748	0.556	0.261	0.000	0.475	0.000	0.000	0.571	0.000	0.000
INNINVEST	-0.07	0.10	0.20	0.08	0.68	0.88	0.05	1.00	-0.06	-0.25
	0.449	0.291	0.025	0.394	0.000	0.000	0.571	0.000	0.498	0.005
DIS/EMB	0.03	0.06	-0.15	-0.55	-0.06	0.38	0.93	-0.06	1.00	0.34
	0.777	0.531	0.103	0.000	0.538	0.000	0.000	0.498	0.000	0.000
RDENG%	0.16	0.21	-0.07	-0.22	-0.10	0.02	0.50	-0.25	0.34	1.00
	0.070	0.017	0.463	0.013	0.284	0.826	0.000	0.005	0.000	0.000

The first row shows the correlation coefficients and the second row the statistical significance.
The number of cases considered is 124.

TABLE 7: CORRELATION MATRIX - LESS INNOVATIVE TECHNOLOGY SECTORS (CLUSTER 1)

	SALES	EMPLOYEES	ADDVALUE	INVMACH	INNCOST	RDENG	INNINVEST
SALES	1.00	0.88	0.13	-0.02	-0.05	0.01	-0.06
	0.000	0.000	0.000	0.404	0.092	0.784	0.028
EMPLOYEES	0.88	1.00	-0.11	-0.09	-0.11	-0.02	-0.12
	0.000	0.000	0.000	0.002	0.000	0.405	0.000
ADDVALUE	0.13	-0.11	1.00	0.35	0.32	0.16	0.30
	0.000	0.000	0.000	0.000	0.000	0.000	0.000
INVMACH	-0.02	-0.09	0.35	1.00	0.43	0.10	0.47
	0.404	0.002	0.000	0.000	0.000	0.000	0.000
INNCOST	-0.05	0.11	0.32	0.43	1.00	0.59	0.90
	0.092	0.000	0.000	0.000	0.000	0.000	0.000
RDENG	0.01	-0.02	0.16	0.10	0.59	1.00	0.18
	0.784	0.405	0.000	0.000	0.000	0.000	0.000
INNINVEST	-0.06	-0.12	0.30	0.47	0.90	0.18	1.00
	0.028	0.000	0.000	0.000	0.000	0.000	0.000

The first row shows the correlation coefficients and the second row the statistical significance.
The number of cases considered is 1248.

TABLE 8: CORRELATION MATRIX - TEXTILE MACHINERY

	SALES	EMPLOYEES	ADDVALUE	PROFIT	INVMACH	INNCOST	RDENG	INNINVEST	DIS/EMB	RDENG%
SALES	1.00 0.000	0.94 0.000	-0.05 0.638	-0.46 0.000	0.02 0.896	0.16 0.173	0.12 0.287	0.16 0.175	-0.07 0.542	0.22 0.057
EMPLOYEES	0.94 0.000	1.00 0.000	-0.18 0.122	-0.59 0.000	-0.05 0.677	0.05 0.675	0.10 0.375	-0.01 0.956	-0.04 0.752	0.26 0.025
ADDVALUE	0.05 0.64	-0.18 0.12	1.00 0.00	0.70 0.00	0.56 0.00	0.32 0.00	0.05 0.65	0.50 0.00	-0.14 0.23	-0.21 0.07
PROFIT	-0.46 0.000	-0.59 0.000	0.70 0.000	1.00 0.000	0.22 0.054	0.22 0.055	0.05 0.669	0.31 0.006	0.02 0.849	-0.22 0.054
INVMACH	0.02 0.896	-0.05 0.677	0.56 0.000	0.22 0.054	1.00 0.000	0.23 0.041	0.05 0.689	0.35 0.002	-0.23 0.044	-0.17 0.142
INNCOST	0.16 0.173	0.05 0.675	0.32 0.004	0.22 0.055	0.23 0.041	1.00 0.000	0.84 0.000	0.78 0.000	0.34 0.003	0.04 0.739
RDENG	0.12 0.287	0.10 0.375	0.05 0.649	0.05 0.669	0.05 0.689	0.84 0.000	1.00 0.000	0.31 0.006	0.45 0.000	0.35 0.002
INNINVEST	0.16 0.175	-0.01 0.956	0.50 0.000	0.31 0.006	0.35 0.002	0.78 0.000	0.31 0.006	1.00 0.000	0.08 0.488	-0.31 0.006
DIS/EMB	0.07 0.542	0.04 0.752	-0.14 0.230	0.02 0.849	-0.23 0.044	0.34 0.003	0.45 0.000	0.08 0.488	1.00 0.000	0.30 0.008
RDENG%	0.22 0.057	0.26 0.025	-0.21 0.074	-0.22 0.054	-0.17 0.142	0.04 0.739	0.35 0.002	-0.31 0.006	0.30 0.008	1.00 0.000

The first row shows the correlation coefficients and the second row the statistical significance.
The number of cases considered is 76.

TABLE 9: CORRELATION MATRIX - ELECTRONIC COMPONENT

	SALES	EMPLOYEES	ADDVALUE	PROFIT	INVMACH	INNCOST	RDENG	INNINVEST	DIS/EMB	RDENG%
SALES	1.00	0.99	-0.13	-0.06	0.05	0.01	0.05	-0.04	-0.09	0.14
	0.000	0.000	0.370	0.693	0.710	0.969	0.710	0.797	0.543	0.816
EMPLOYEES	0.99	1.00	-0.16	-0.07	0.01	-0.02	0.02	-0.06	-0.08	0.14
	0.000	0.000	0.268	0.639	0.928	0.872	0.878	0.690	0.589	0.344
ADDVALUE	-0.13	-0.16	1.00	0.61	0.48	0.51	0.37	0.53	-0.10	-0.22
	0.370	0.268	0.000	0.000	0.000	0.000	0.008	0.000	0.479	0.129
PROFIT	-0.06	-0.07	0.61	1.00	0.21	0.23	0.14	0.27	0.04	-0.24
	0.693	0.639	0.000	0.000	0.146	0.112	0.320	0.058	0.807	0.094
INVMACH	0.05	0.01	0.48	0.21	1.00	0.77	0.66	0.71	-0.28	-0.02
	0.710	0.928	0.000	0.146	0.000	0.000	0.000	0.000	0.053	0.916
INNCOST	0.01	-0.02	0.51	0.23	0.77	1.00	0.92	0.76	0.06	0.11
	0.969	0.872	0.000	0.112	0.000	0.000	0.000	0.000	0.663	0.468
RDENG	0.05	0.02	0.37	0.14	0.66	0.92	1.00	0.45	0.16	0.33
	0.710	0.878	0.008	0.320	0.000	0.000	0.000	0.001	0.273	0.018
INNINVEST	-0.04	-0.06	0.53	0.27	0.71	0.76	0.45	1.00	-0.13	-0.29
	0.797	0.690	0.000	0.058	0.000	0.000	0.001	0.000	0.355	0.042
DIS/EMB	-0.09	-0.08	-0.10	0.04	-0.28	0.06	0.16	-0.13	1.00	0.51
	0.543	0.589	0.479	0.807	0.053	0.663	0.273	0.355	0.000	0.000
RDENG%	0.14	0.14	-0.22	-0.24	-0.02	0.11	0.33	-0.29	0.51	1.00
	0.316	0.344	0.129	0.094	0.916	0.468	0.018	0.042	0.000	0.000

The first row shows the correlation coefficients and the second row the statistical significance.
The number of cases considered is 50.

Chapter 5

Conclusions

The evidence presented in this report, based on the empirical findings of the Italian survey on industrial innovation, has pointed out the variety of the sources of innovative activities in different industrial sectors and in particular the different role played by formalized R&D activities, Design and Engineering efforts and investment. It has been shown that technological differences across sectors are not limited to the relative amount of resources devoted to innovative activities aimed at creating or improving technological knowledge, but they are also related to the amount of investment required for the acquisition and use of these technologies on an industrial scale. These differences are strongly associated (at sectoral level) to industrial structural factors such as firm size.

In the first section of this report we have pointed out the need for a conceptual framework where both the disembodied and embodied dimensions of technological change play a role. The complex set of relationships between technological change and industrial structure has been outlined in order to guide the empirical analysis. In particular, we have stressed that an analysis including the embodied side of innovative activities provides a more adequate perspective on the technological determinants of industrial structure and performance.

In other words, in order to understand why and how firms innovate and grow, it is not enough to look for explanatory technological factors referred to the "technological opportunity and appropriability conditions" as most of current literature does. It is also important to fully acknowledge and investigate the role played by investment and its relationship with technological change and economic performance.

A preliminary sectoral taxonomy based both on the nature of innovative patterns and on structural characteristics related to firm size and investment intensity has been developed and used in the empirical analysis.

Using a cluster analysis, based on sectoral differences in industrial structure characteristics, nature and intensity of innovative activities three broad aggregations of sectors have been identified:

Technology users and traditional sectors, characterized by a *low innovative intensity,* a *low disembodied and embodied innovative intensity* and with a *large prevalence of small firms.*

In-house innovators, characterized by an internal technological capability based either on R&D or on D&F activities (or on both of them). The average firm size of these sectors largely depends on the importance of scale factors and relevance of investment in fixed capital. In most of these sectors however we find a strong complementarity between disembodied innovative efforts and investment efforts.

Investment intensive sectors show a high capital intensity, while disembodied innovative efforts are relatively modest, especially when compared to the large scale of production and to the effort made to acquire and use process technologies.

Within each of the 3 major groupings of sectors mentioned above broadly parallel positive relationships can be identified between firm size, innovative intensity and, to e lesser extent, investment intensity.

A key original investigation of this study has been the use of data for individual enterprises (not consolidated industrial groups) in order to test the relationships between nature innovative activities, industrial structure and economic performance. The analysis has been carried out both within the three aggregations of sectors and 3-digit industrial classes.

The major findings have been the following:

(i) No significant relationships between firm size and all other technological and economic variables have been found at the level of the three major sectoral aggregations. The strong positive relationship between investment intensity and firm size found using sectoral analysis, has not been confirmed by individual firm data. Only one industry, Rubber, has shown a strong relationship between *firm size* (SALES) and *disembodied innovative intensity* (RDENG).

(ii) A positive and significant association between total innovation cost and investment in fixed capital has emerged for all three aggregation of sectors. At the level of industrial classes, Metal products industry and the less innovative *technology users* have shown a correlation between total innovation cost (INNCOST) and investment in machinery (INVMACH) higher than other investment intensive and technology users sectors.

(iii) The association between the fixed investment in machinery and innovative investment is higher in the case of *Technology users* and *Investment* *intensive sectors* as the reliance on outside sources of embodied technological change is greater.

(iv) For *In-house innovators* the complementary relationship between the disembodied and embodied forms of technological change is much stronger than in the other sectors. Such a complementarity is particularly evident in the Electronic components class. In the latter also a positive link between *investment intensity, innovative intensity and productivity* is found.

(v) Productivity is weakly positively associated to total innovative activities and investment in fixed capital in the three aggregations. Innovative efforts do not seem therefore to play a key role in explaining differences across firms in economic performances. *Investment intensity and the value added per employee* are highly correlated in the Textile machinery sector, and more in general in all specialized mechanical sectors. In these sectors also a negative correlation between *size* and *profitability* has been found. These results are probably due to the peculiar characteristics of the Italian industrial and technological structure, and first of all, to the technologically and economically dynamic performances of small and medium firms in the 80s not matched by similar performance by larger firms (both private and state-owned.

Building on this evidences, further analysis may include new efforts to explain the high variability across firms, using different levels of sectoral disaggregation. There is no doubt that some of the industrial classes analysed in this paper are still too heterogeneous in terms of both types of innovative patterns and structural characteristics. A higher level of disaggregation would allow to identify much more clear-cut and consistent types of industrial sectors as well as to obtain new insights in the nature of the relationships between innovation and industrial structure, using data on individual firms. Structural and technological characteristics of top performers will also be explored.

The internal homogeneity of the industrial sectors considered may be further examined using the analysis of variance, comparing the inter-sectoral variance with the intra-sectoral one. Additional cluster analyses based on different technological and economic variables will also be carried out, testing the technological consistence of the industrial classification.

Finally, despite the lack of internationally comparable data, especially at a high level of sectoral disaggregation, an attempt may be made to test whether and to what extent the findings for Italian industry can be generalized to other industrial systems.

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