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# Analyzing literature-based innovation output indicators: the Italian experience [1]

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**Abstract**

This paper presents the results of a study on the product innovations introduced in the Italian market in 1989 and reported in a selected number of trade journals. The analysis of data collected by means of this literature-based counting procedure confirms that R&D oriented industries and large firms do not in Italy have a marked competitive advantage in innovation. The country appears to be instead characterized by a significant presence of consumer goods industries and small firms in innovation. Our data indicate a statistically significant association between trade competitiveness and strength in product innovation, and show the comparatively higher capacity for product innovation of some of the industries in which Italy achieves a positive performance in international trade. Moreover, the presence of spillovers at the regional level from both private and public R&D expenditures proves to be positively correlated with the development of product innovations. Finally, small firms with fewer than 50 employees appear to be more innovative than is usually believed to be the case.

## 1. Introduction

The nature of the data available for analysis affects the understanding of the technological structure and innovative capability of a country. For example, the R&D and patent indicators which, since the late 1950s and the early 1960s, have been conventionally employed in studies of the economic role of technological change do not provide a satisfactory account of this process. R&D expenditures are a proxy measure for the resources devoted to obtaining innovation, but they do not reflect the actual amount of innovative activity undertaken by firms and industries, since this also includes informal and occasional R&D not reported in official data (Santarelli, 1994a). Patents, for their part, are a purely technological measure of new knowledge, but they do not explain

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the economic value of this knowledge (Acs and Audretsch, 1993).

In the light of the shortcomings of traditional indicators, the actual economic significance of new technology can be better understood by means of a direct measure of innovation output. Accordingly, this paper presents the results of an attempt to develop a measure of innovation output based on the new industrial products which were introduced in the Italian market in 1989 and reported in a selected number of trade journals spanning every industry in manufacturing.

The paper is organized as follows. Section 2 reviews innovation output indicators and discusses their points of strength and weakness. Section 3 outlines the procedure used to count and to distinguish, according to their degree of complexity and type of novelty, the new products placed on the Italian market during 1989. Section 4 analyzes the sectoral distribution of the innovations identified by this method and compares among the innovation outputs of industries with different commitments to R&D activities in terms of degree of complexity and type of novelty. Section 5.1 examines the distribution of foreign innovations marketed in Italy during 1989 by country of origin, in order to test its consistency with the hypotheses of 'technology gap' theory concerning the relation between technological strength and trade performance of countries in certain industries. In Section 5.2 the new products introduced by Italian firms are divided according to region of origin. It thus becomes possible to compare the regional distribution of innovation output with that of R&D expenditures and patents. Section 6 takes account of the size distribution of the Italian firms included in the database. Finally, Section 7 sets out some concluding remarks.

## 2. The measurement of innovation output

A direct measure of innovation output is the most reliable means to capture the economic significance of the innovation process. In effect, it indicates whether an idea for a new or improved product (represented, for example, by a patented invention) starts to have a real economic value. While a patent accounts for an invention exploiting a certain set of knowledge, the output from the overall innovation process acquires economic importance only if and when it results in the placement of a new product on the market. This product constitutes an innovation in the economic sense, i.e. what Freeman (1982) has termed "the first commercial transaction involving the new product, process, system or device" (p. 7).

Their limited heuristic value notwithstanding, patents are widely employed in studies dealing with the output side of the innovation process (Patel and Pavitt, 1992). In addition to inter- and intra-industry studies of technology and productivity growth (Griliches, 1990), patent statistics have also been employed (along with or in alternative to R&D data; Hughes, 1986) in international comparisons of technological capability (Archibugi and Pianta, 1992a,b) and in analyses of sectoral specialization in both international trade and technology by countries which display a marked preference for extending their patents abroad (Archibugi and Santarelli, 1989, Amendola et al., 1991, 1993). Nonetheless, concern is expressed in the innovation literature about the use of patents as reliable indicators of the output from innovative activities (Cohen and Levin, 1989; Archibugi, 1992). This concern stems from at least five considerations:

(a) the technological level and the economic value of patents are highly heterogeneous;

(b) the tendency to bundle claims together in one or more patents varies widely among countries;

(c) not all innovations are patented;

(d) not all patents become innovations (Griliches, 1990; Kleinknecht et al., 1991);

(e) the propensity to patent varies greatly across firms belonging to different size classes.

The main implications of point (a) are that the actual economic value of a patent is difficult to assess, and that cross-industry comparisons carried out with this indicator rely upon unrealistic assumptions concerning the homogeneous technological content and economic significance of patents in different industries.

As regards point (b), a patent may plausibly consist of several related claims, each of which may be filed as a separate patent. It is therefore likely that in countries where inventors prefer to bundle a series of related claims together in one patent (e.g. the US) this indicator leads to underestimation of the output from innovative activity with respect to countries which typically file separate patents for each claim (e.g. Japan). A possible solution is the use of databases comprising 'high quality' patents, such as those of the European Patent Office (EPO) (Patel and Pavitt, 1992) and the Office of Technology Assessment and Forecasts (OTAF) of the US Patent Office. Both of these sources represent a viable alternative to the data collected through the various national patent systems, especially because EPO and the US Patent Office offer better guarantees of protection and are highly selective in granting patents. Moreover, it is likely that innovations identified from these sources are more homogeneous in their economic value than those registered in the national patent systems, and this represents a partial solution to the problems identified in point (a) above.

With respect to point (c), it should be borne in mind that, when applying for patent, a patentee discloses the technical features of his/her invention to potential competitors and imitators. Thus patents are sometimes an inefficient means to protect the private returns from invention, in particular in those industries (e.g. micro-electronics and other high-tech industries) in which secrecy is favored.

Point (d) highlights the importance of pre-emptive patents. These are used by incumbent monopolists or oligopolists in some industries to prevent competition by potential entrants when other non-technology-related barriers to entry are absent (Gilbert and Newbery, 1982; Vickers, 1985). Thus patent holders in certain cases do not follow a market-oriented behavior, and the invention is never commercialized. [2]

In the case of point (e), it should be noted that firms of different size (although belonging to the same industry) have a different propensity to apply for either national or foreign patents. In particular, small firms usually present a larger number of applications for national patents.

Since the early 1980s at least six indicators complementary or alternative to patent data have been developed and used in empirical analyses (OECD, 1992; Santarelli, 1993). These are:

(1) the patent-based counting of innovations;

(2) citation counts of patents;

(3) the collection of innovation cases by means of interviews with experts and firm insiders;

(4) self-assessment by managers of the number of innovations introduced by their firm;

(5) the share of innovative products in a firm's total sales;

(6) the counting of innovations reported in trade journals.

The aim of the first two methods is to enrich the information gathered from patent data. In particular, the patent-based counting of innovations collects additional information on each patent by asking patent holders if their invention has led to commercialized innovations. The citation count of patents is also a method for the ex post evaluation of the economic value of a patent (Albert et al., 1991). In this case the indicator is constructed by counting the citations obtained by the relevant patent in subsequent patents. Nonetheless, irrespective of their endeavour to improve the validity and significance of patent data, these methods share a serious limitation with that source: they do not provide any information about those innovations which, although placed on the market, are not patented.

The third method consists in asking experts and firm insiders in each industry to describe innovations (either patented or not) of significant economic value introduced in their industries over a given period. This method was used at the Science Policy Research Unit (SPRU) in Sussex University to collect information on more than 4000 innovations commercialized in the UK from 1945 to 1983 (Pavitt et al., 1987). The main criticism of this alternative concerns the heterogeneous economic value of the innovations thus identified, since the assembling of the data entails various unexamined biases (Cohen and Levin, 1989).

The fourth alternative has been widely employed in recent years among OECD countries and is based on the assessments of firm insiders with respect to the innovations developed by their company (OECD, 1992, Smith, 1992). In this case, unless precise questions are asked which give unambiguous specification of the objective characteristics of new products, it may happen that firm insiders, in particular marketing personnel, define as 'new' and technologically advanced almost everything they sell. As a

[2] In Italy, for example, only 50% of national patents are actually utilized (Napolitano and Sirilli, 1990).

consequence, this method could be associated with overestimation of the output of innovative activity. [3]

The fifth method, used by Brouwer and Kleinknecht (1994) in The Netherlands, consists in asking firms to report for a certain period (e.g. 1 year or a few years) the percentages of their sales which are due to: (i) products essentially unchanged with respect to previous period; (ii) products incrementally improved; (iii) products radically changed or newly introduced. The latter two categories identify innovative products in a broad sense, which can in turn be divided into two sub-categories: (a) products 'new to the firm' and already known in the industry; (b) products 'new to the industry' and not introduced earlier by another firm. Although representing a promising alternative to any patent-based procedure, concern about employment of this method stems from the fact that, as is often the case with the methods based on self-assessment by firm-insiders, it is likely to overestimate the innovative content of most products. However, as firms become more accustomed to answer questions on their products it may be predicted that data deficiencies will be reduced and this method will set a new standard in analyses of innovation output.

The 'counting of innovations' method employed in the present paper is based on the selection of innovations introduced during a given year and reported in the 'product news' columns of trade journals. This procedure was used for the first time by The Futures Group (Edwards and Gordon, 1984) (under contract by the US Small Business Administration) which examined more than 100 technical and trade journals to develop a database consisting of 8074 innovations introduced in the United States in 1982. The same method was adopted by Kleinknecht et al. (1993) who, by inspecting 35 trade journals, identified 6325 innovations introduced in The Netherlands in 1989; Coombs et al. (1994) who, for the first 3 months of the same year, selected 974 new products introduced in the UK and reported in 35 journals; Cogan (1993) who, for year 1991, collected information concerning 747 novelties marketed in Ireland and reported in 12 journals. A slightly modified procedure was instead applied by Fleissner et al. (1993) to the Austrian case. [4]

The assumption behind the use of the literature-based counting of innovations is that firms prefer to disclose their products to the public (because, for instance, innovations signal technological competence to potential customers or even to suppliers of capital) and that journal editors make a thorough selection of products which are really new for the industry or at least the country. This indicator has at least five merits: first, it provides information about commercially introduced innovations; second, data collection can be carried out without any direct contact with the innovating firms, and this reduces the amount of unexamined biases in the database; third, the whole procedure is relatively cheap compared with the others; fourth, the collection and use of data at the firm level is not hampered by secrecy problems; fifth, technical and trade journals report information also about innovations in software and in the service sector, which being excluded from patent files have been traditionally ignored in analyses of innovation output. [5]

A first shortcoming of the literature-based counting of innovations lies in the selection of the relevant journals and in the features of the new products section in each of them. It is probable that the number of innovations identified will be positively correlated with the number of journals selected or, in any case, with the total number of journals reporting this kind of information for the relevant country and the length of the new product section in each of them. As regards the first point, one may contend that the adoption of a standardized procedure (like

[3] In this respect, the recent Community Innovation Survey (CIS) jointly supported and implemented by Eurostat and DGXIII of the European Commission, SPRINT programme, and European Innovation Monitoring System (EIMS) represents an important progress. In particular, this major action to collect new data on innovation activity and innovation output does not seem to incur in overestimation problems (ISTAT, 1993).

[4] In effect, they scanned a huge amount of journals for editorial material on product and process innovations, thereby identifying 1355 innovations presented in 400 Austrian periodicals during 1989.

[5] However, since our interest was mostly in manufacturing, innovations in the service sector are not included in the currently available version of the database.

the one proposed in Section 3 of the present paper) in the selection process should in any case reduce the effects of unavoidable sampling errors. The second point has implications for cross-country comparisons: in effect, the number and the characteristics of technical and trade journals vary greatly from one country to another, without displaying any precise pattern. Moreover, the usefulness of such publications is unevenly perceived by firms of different countries: for example, Italian firms apparently consider technical and trade journals to be less important than their counterparts in the US and The Netherlands normally do. This implies that Italian firms have a lower propensity to submit their innovations for inclusion in the new products section of national technical journals, whereas it is plausible that US, Dutch, and other foreign firms consider the inclusion of their new products in Italian trade journals as a way to boost their sales in Italy. Accordingly, the number of domestic innovations that one would expect to identify by applying this counting method to Italy is smaller than in the case of US and The Netherlands, whereas that of foreign innovations placed on the Italian market would be even higher than expected. As a consequence, use of data concerning innovations reported in technical and trade journals for international comparisons would incur the same problems which emerge when information contained in *national* patent files is used for this purpose. Such problems might be escaped by selecting *only* international journals and taking the innovations there reported as 'high quality' ones. This procedure would therefore rely upon the same rationale which stands behind the use for international comparisons of the EPO and OTAF sources of patent data mentioned earlier in the present section.

Another weakness in the literature-based counting of innovations procedure relates to the distinction between product and process innovations. For example, consistently with the 'firm level approach' (Archibugi et al., 1996), innovations may be classified from the perspective of the innovating firm. Thus each firm considers its new or improved products which can be sold on the market as product innovations, while changes in its production techniques are process innovations. At a sectoral level this approach identifies process innovations only when the sector of production coincides with the sector of use of the new product (De Bresson and Townsend, 1978; Pavitt, 1984) and neglects completely process innovations developed exclusively for internal use. Of course, the choice of this approach leads to identification of a small number of process innovations. Alternatively, one might use the 'final demand approach' (Archibugi et al., 1994). In this case, innovations which are directly beneficial to consumers are classified as product innovations, whereas those which are used as either capital or intermediate goods by other firms are classified as process innovations. At a sectoral level this approach always identifies process innovations when the sector of production is specialized in goods which are directed towards other firms. As a consequence, this 'final demand' perspective results in the definition as process innovations of a very large portion of those reported in trade journals.

Some other drawbacks to the literature-based procedure are shared with the patent indicator and relate: (a) to the heterogeneous technological level and economic value of the innovations; (b) to the fact that not all innovations are reported in trade journals; (c) to the great variability of the propensity to submit innovations for inclusion in trade journals across industries and across size classes. [6] Whereas problems under headings (b) and (c) at the present stage still represent serious shortcomings of this procedure, problem (a) can be overcome through the classification scheme presented in the next section.

## 3. Methodology and classification scheme

The above shortcomings and problems notwithstanding, we experimented with the literature-based counting of innovations to create a database on product innovations introduced in Italian industry in 1989. The database (called PRODIN89) comprises all innovations reported in the complete 1989 volume of a sample composed by 25 Italian technical

[6] It is possible that small firms (which have higher expectations of exploiting their innovations commercially in the domestic market) are more eager to have their novelties included in trade journals than large firms which are more integrated in international trade.

and trade journals. [7] Product and process innovations have been distinguished on the basis of the 'firm level approach' described in Section 2. [8] The journals considered contain technical information on 15 industrial sectors and were selected from a much larger number of similar Italian publications (most of which are listed in the *Guida Monaci*, a catalog which enumerates Italian periodicals as well as providing a variety of business information) according to the following criteria:

(i) the presence of a distinct 'new products' column or section;

(ii) the provision of detailed technical information about each innovation presented;

(iii) the specification of the name and address of the innovating firm;

(iv) continuity of publication and the ready availability of the journal throughout the country upon payment of a subscription. [9]

In order to detect differences in the innovativeness of various industries, a classification scheme was adopted analogous to that introduced by Kleinknecht et al. (1993) (cf. also Kleinknecht et al., 1991). This scheme is useful for distinguishing innovations according to their degree of complexity and type of novelty.

'Degree of complexity' is a dimension of the knowledge base upon which the innovation relies. In effect, producing an innovation may involve the integration of different scientific disciplines and technologies, and it may require various skills, either internal or external to the innovating firm (Malerba and Orsenigo, 1993). Accordingly, the idea of complexity referred to here does not entail any estimate of the difficulties connected to the innovation process.

'Type of novelty' is a measure, within a given technological regime, of the complementarities between a new innovation and the product that it is to replace (Santarelli, 1995a).

The degree of complexity of each innovation can be classified into three levels:

(1) High complexity: this denotes a new system, i.e. an innovation consisting of several parts or components each of which relies upon a knowledge base deriving from a different discipline (e.g. a flexible manufacturing system, a new automobile, etc.).

(2) Medium complexity: in this case the innovation is a unit, although it consists of more than one part or component, and its development requires the integration of different disciplines (e.g. a new textile machine whose relevant knowledge base results from the integration of mechanical engineering and electronics).

(3) Low complexity: the innovation is a unit consisting of only one part and requiring a knowledge base which results from a single discipline (e.g. a new woollen fabric).

Five classes of type of novelty were identified:

(I) a product which is totally new for the industry and which may involve a paradigmatic shift from a technological regime to a subsequent one (e.g. a hydraulic device which replaces the pneumatic hammer);

(II) a modestly or slightly improved product (e.g. an energy saving production machine);

(III) a new or improved accessory for an existing product of medium or high complexity (e.g. a more reliable controlling device for a production machine);

(IV) a product differentiation (this category comprises pseudo-innovations, i.e. incremental innovations such as a soap with a new perfume);

(V) a process innovation identified from the prospective of the innovating firm (e.g. a new knit-

[7] The journals selected are the following: *Largo Consumo, Il Pesce, Industrie Alimentari, La Nuova Selezione Tessile, L'Informobili, LM – L'industria del Legno e del Mobile, L'Italia Grafica, Il Poligrafico Italiano, Annunciatore Poligrafico, Rassegna Grafica, Cellulosa e Carta, Rassegna Chimica, Il Farmacista Moderno, Il Giornale del Farmacista, Industria della Gomma, Il Mondo della Calzatura, L'Industria Meccanica, Management e Informatica, Bit, Rivista di Informatica, Tecniche dell'Automazione e Robotica, Automazione Oggi, Elettronica e Telecomunicazioni, L'Automobile.*

[8] As already stressed in Section 2 above, the difficulty to identify a viable definition of process innovation represents a serious weakness of the literature-based procedure. Thus, also identification of process innovations from the perspective of innovating firms is a source of bias. In effect, larger firms have a greater amount of in-house innovation activity, as compared with that of smaller firms, and most of their processes are protected by secrecy. As a consequence, their process innovations will be probably severely underestimated with this counting method.

[9] This criterion determined the rejection of most journals which were not easily accessible, circulated only at a local level, or issued at irregular intervals.

ting machine developed by a firm belonging to the clothing industry).

This classification scheme (although not completely free from potential sampling errors) measures the economic value of innovations and, as such, is no less rigorous than the procedures used for the valuation of patents and innovation output in general surveyed in the previous section.

## 4. The sectoral distribution of innovations in Italian industry

The procedure described above was used to identify 1602 innovations; and a database consisting of innovations by two-digit standard industrial classification (SIC) industries was created (Table 1). For the machinery and the office & professional equipment industries, which account for the highest number of innovations, Table 1 presents more disaggregated data at the four-digit level, whereas for the chemical industry the disaggregation is at the three-digit level. [10]

Immediately evident is the overwhelming importance of the machinery and the office & professional equipment industries, which account for 27.40% and 21.85% of total innovations, respectively. Ranking third is the electrotechnical & electronics industry (12.55%), fourth the instruments industry (9.68%) and fifth the chemical industry (9.11%).

The result for the machinery industry is consistent with previous research (Scherer, 1982; Robson et al., 1988; Santarelli, 1993; Santarelli and Sterlacchini, 1994b). It demonstrates the importance of the capital goods industry in general (i.e. machinery and capital equipment) as the main source of innovations for the entire production system and, in particular, for *supplier dominated firms* (as defined by Pavitt, 1984) belonging to traditional consumer goods industries (clothing & textiles, wood & furniture, leather & footwear), which in Italy account for a significant share of total industrial employment and value added. These firms are relatively weak in terms of autonomous innovative capability and derive most of their innovations from suppliers of equipment and intermediate inputs, whereas in-house R&D is almost irrelevant (Santarelli, 1993; Kleinknecht et al., 1993). In this respect, of great significance are the branches specialized in the production of machinery for the food & beverages and the clothing & textiles industries, which account for 5.81% and 5.12% of total innovations, respectively. [11]

The figures for the office & professional equipment, electrotechnical & electronics, and instruments industries show that these microelectronics-based productions underwent major innovations during the year in question, punctuated by a significant flow of new products (Antonelli, 1988). For analytical convenience, the office and professional equipment group of products includes the software industry, which by the second half of the 1980s had overtaken hardware in terms of total sales within the overall data processing industry (Datamation, 1988). In our database, in fact, software accounts for almost 39% of the new products identified in the office & professional equipment industry, thereby confirming the

[10] As regards machinery, the four-digit level of disaggregation allows identification of the main sector of use of each new machine. The reason for this disaggregation is straightforward: for many sectors, technology derives in a significant measure from R&D activities embodied in new machinery and capital equipment. Thus, with our data disaggregated at the four-digit level, it becomes possible to provide a rough measure of the links between *industry of origin* (i.e. the various branches of the machinery industry) and *industry of use* of the new capital goods identified (Scherer, 1984). In the case of chemicals, the three-digit level of disaggregation permits instead the distinction between primary chemical products and pharmaceuticals on the one hand, and soap, polishes & sanitation goods on the other. The reason for dividing the overall two-digit industry into three branches is that, whereas a wide and heterogeneous range of active principles is employed in primary chemical products, pharmaceuticals and soap, polishes & sanitation goods employ two relatively smaller families of active principles: hence it follows that in each of these three branches the innovation process relies upon a different set of knowledge, and they can therefore be examined separately.

[11] Inserted in a hypothetical input–output matrix of invention flows analogous to the one first proposed by Schmookler (1966), this finding confirms that the total amount of technology *used* by the consumer goods industries mentioned above is probably much higher than one would expect on the basis of their autonomous innovative capability alone. Accordingly, the new products introduced by firms belonging to these industries embody an amount of R&D which is much higher than that resulting from their autonomous innovative activity.

Table 1
Total innovations by standard industrial classification code

| SIC code | Industries | Total innovations | |
|---|---|---|---|
| | | abs. value | % |
| 20–21 | Food & beverages | 38 | 2.37 |
| 22–23 | Clothing & textiles | 40 | 2.50 |
| 24–25 | Wood & furniture | 17 | 1.06 |
| 26–27 | Paper, printing & publishing | 43 | 2.68 |
| 28–29 | Chemicals | 146 | 9.11 |
| | (a) Primary chemical products | 68 | 4.24 |
| 283 | (b) Pharmaceutical products | 37 | 2.31 |
| 284 | (c) Soap, polishes & sanitation goods | 41 | 2.56 |
| 30 | Rubber & plastics | 41 | 2.56 |
| 31 | Leather & footwear | 9 | 0.56 |
| 33 | Extractive | 3 | 0.19 |
| 34 | Metal products | 38 | 2.37 |
| 35 | Machinery | 439 | 27.40 |
| 3551 | (a) Food & beverages mach. | 93 | 5.81 |
| 3552 | (b) Clothing & textiles mach. | 82 | 5.12 |
| 3553 | (c) Woodworking mach. | 28 | 1.75 |
| 3554–3555 | (d) Printing mach. | 68 | 4.24 |
| | (e) Leatherworking mach. | 11 | 0.69 |
| | (f) Footwear mach. | 36 | 2.25 |
| | (g) Rubber & plastics mach. | 31 | 1.94 |
| | (h) Other mach. | 90 | 5.62 |
| 357 | Office & professional equipment | 350 | 21.85 |
| 3572-3-4-9 | (a) Electronic-computing, etc. | 214 | 13.36 |
| 7372 | (b) Computer programm. & software ind. | 136 | 8.49 |
| 36 | Electrotechnical & electronics industry | 201 | 12.55 |
| 37 | Motor vehicles, parts & accessories | 67 | 4.18 |
| 38 | Instruments | 155 | 9.68 |
| | Other manufacturing | 15 | 0.94 |
| Total | 1602 | 100.00 | |

strategic function of the suppliers of standard and customized software packages in the development of that industry. In the case of the office & professional equipment, electrotechnical & electronics, and instruments industries the high number of innovations reflects the propensity of firms belonging to these industries to invest heavily in R&D, and to rely upon autonomous innovative capability as their main source of technological knowledge. In fact, within these high-tech industries, an important function is played by *science-based* firms in Pavitt's sense, which produce internally most of the technology they use.

As regards chemicals, in Italy during the relevant year the demand for primary chemical products and for soap & polishes grew significantly with respect to the previous year, [12] whereas that for pharmaceuticals remained substantially unchanged. These differences in the dynamics of internal demand are presumably responsible for the relatively low share (25.33%) of new pharmaceuticals in all new chemicals placed on the Italian market in 1989.

The above results become even more significant if one restricts the focus to the 536 innovations developed and marketed by Italian firms, which represent 33.46% of the total. In this case (Table 2) all the innovations introduced in the clothing & textiles industry have a low degree of complexity, whereas

[12] Conversely, in 1989 the market performance of sanitation goods was not particularly positive.

Table 2
Distribution of Italian innovations by degree of complexity and industry

| Industries | High | | Medium | | Low | | Total |
|---|---|---|---|---|---|---|---|
| | Abs.v. | % | Abs.v. | % | Abs.v. | % | Abs.v. |
| Food & beverages | | | 1 | 5.26 | 18 | 94.74 | 19 |
| Clothing & textiles | | | | | 18 | 100.0 | 18 |
| Wood & furniture | | | 1 | 8.33 | 11 | 91.67 | 12 |
| Paper, printing & publishing | | | | | | | 8100.08 |
| Chemicals | 1 | 2.86 | | | 34 | 97.14 | 35 |
| (a) Primary chemical products | | | | | 11 | 100.0 | 11 |
| (b) Pharmaceutical products | 1 | 7.14 | | | 13 | 92.86 | 14 |
| (c) Soap, polishes & sanitation goods | | | | | 10 | 100.0 | 10 |
| Rubber & plastics | | | 2 | 11.11 | 16 | 88.89 | 18 |
| Leather & footwear | | | 2 | 25.00 | 6 | 75.00 | 8 |
| Extractive | | | 1 | 100.0 | | | 1 |
| Metal products | | | | | 20 | 100.0 | 20 |
| Machinery | 2 | 0.83 | 189 | 78.42 | 50 | 20.75 | 241 |
| (a) Food & beverages mach. | | | 50 | 92.59 | 4 | 7.41 | 54 |
| (b) Clothing & textiles mach. | | | 37 | 78.72 | 10 | 21.28 | 47 |
| (c) Woodworking mach. | | | 8 | 66.67 | 4 | 33.33 | 12 |
| (d) Printing mach. | | | 13 | 92.86 | 1 | 7.14 | 14 |
| (e) Leatherworking mach. | | | 9 | 81.82 | 2 | 18.18 | 11 |
| (f) Footwear mach. | 1 | 3.03 | 26 | 78.79 | 6 | 18.18 | 33 |
| (g) Rubber & plastics mach. | | | 16 | 80.00 | 4 | 20.00 | 20 |
| (h) Other mach. | 1 | 2.00 | 30 | 60.00 | 19 | 38.00 | 50 |
| Office & professional equipment | | | 23 | 42.59 | 31 | 57.41 | 54 |
| (a) Electronic-computing, etc. | | | 19 | 79.17 | 5 | 20.83 | 24 |
| (b) Computer programm. & software ind. | | | 4 | 13.33 | 26 | 86.67 | 30 |
| Electrotechnical & electronics industry | 1 | 2.04 | 15 | 30.61 | 33 | 67.35 | 49 |
| Motors vehicles, parts & accessories | 19 | 95.0 | | | 1 | 5.00 | 20 |
| Instruments | | | 18 | 64.29 | 10 | 35.71 | 28 |
| Other manufacturing | | | | | 5 | 100.0 | 5 |
| Total | 23 | 4.29 | 252 | 47.01 | 261 | 48.69 | 536 |

this share drops to 91.67% in the case of wood & furniture and 75% in that of leather & footwear.

Conversely, the technological strength of the Italian suppliers of specialized machinery (as evidenced by several studies; Cainarca et al., 1989) is confirmed by the fact that only 20.75% of the new products identified for this industry display a low degree of complexity, with the category 'medium degree of complexity' representing 78.42% of the total.

More controversial is the case of electronic-computing: Italian producers (Olivetti) are specialized in the production of complex, although not necessarily advanced from a technological viewpoint, equipment (with the exception of photocopy machines) than they are in simple parts, accessories, and peripherals. This peculiarity provides a plausible explanation for the small (20.83%) share of domestic innovations with a low degree of complexity identified for this industry, which apparently contrasts with its relatively low R&D intensity in Italy.

Inspection of the type of novelty reveals that the attribute 'product differentiation' applies to 61.11% of total Italian innovations in clothing & textiles, 75% of those introduced in wood & furniture, and 62.50% of those identified for leather & footwear (Table 3).

The incremental nature of innovations developed by Italian firms belonging to traditional consumer goods industries is therefore confirmed. However, Table 4 also shows that these industries introduced 7.69% of the 536 Italian innovations identified for

Table 3
Distribution of Italian innovations by type of novelty and industry

| Industries | (1) % | (2) % | (3) % | (4) % | (5) % | Total abs. v. |
|---|---|---|---|---|---|---|
| Food & beverages | | 5.26 | | 78.95 | 15.79 | 19 |
| Clothing & textiles | 16.67 | 16.67 | 5.56 | 61.11 | | 18 |
| Wood & furniture | | | 16.67 | 75.00 | 8.33 | 12 |
| Paper, printing & publishing | 25.00 | 12.50 | 25.00 | 37.50 | | 8 |
| Chemicals | 2.86 | 2.86 | 11.43 | 82.86 | | 35 |
| (a) Primary chemical products | | 9.09 | 36.36 | 54.55 | | 11 |
| (b) Pharmaceutical products | 14.29 | | | 85.71 | | 14 |
| q(c) Soap, polishes & sanitation goods | | | | 100.0 | | 10 |
| Rubber & plastics | 11.11 | 50.00 | | 38.89 | | 18 |
| Leather & footwear | 25.00 | | | 62.50 | 12.50 | 8 |
| Extractive | 100.0 | | | | | 1 |
| | 0 | | | | | |
| Metal products | 15.00 | 10.00 | 20.00 | 55.00 | | 20 |
| Machinery | 10.37 | 40.66 | 14.11 | 34.02 | 0.83 | 241 |
| (a) Food & beverages mach. | 12.96 | 27.78 | 5.56 | 53.70 | | 54 |
| (b) Clothing & textiles mach. | 10.64 | 31.91 | 23.40 | 34.04 | | 47 |
| (c) Woodworking mach. | 8.33 | 50.00 | 25.00 | 16.67 | | 12 |
| (d) Printing mach. | 7.14 | 14.29 | 14.29 | 64.29 | | 14 |
| (e) Leatherworking mach. | 18.18 | 72.73 | 9.09 | | | 11 |
| (f) Footwear mach. | 6.06 | 54.55 | 12.12 | 21.21 | 6.06 | 33 |
| (g) Rubber & plastics mach. | 15.00 | 50.00 | 15.00 | 20.00 | | 20 |
| (h) Other mach. | 8.00 | 48.00 | 14.00 | 30.00 | | 50 |
| Office & professional equipment | 5.56 | 27.78 | 22.22 | 44.44 | | 54 |
| (a) Electronic-computing, etc. | 4.17 | 45.83 | 16.67 | 33.33 | | 24 |
| (b) Computer programm. & software ind. | 6.67 | 13.33 | 26.67 | 53.33 | | 30 |
| Electrotechnical & electronics industry | 4.08 | 24.49 | 40.82 | 30.61 | | 49 |
| Motors vehicles, parts & accessories | 30.00 | 30.00 | | 35.00 | 5.00 | 20 |
| Instruments | 3.57 | 25.00 | 25.00 | 46.43 | | 28 |
| Other manufacturing | | 20.00 | 20.00 | 60.00 | | 5 |
| Total | 51 | 156 | 87 | 234 | 8 | 536 |
| % | 9.51 | 29.10 | 16.23 | 43.66 | 1.49 | 100.00 |

(1), Product totally new for the industry; (2), modestly improved product; (3), new or improved accessory product; (4), product differentiation; (5), process innovation.

the relevant year, although in 1989 they were responsible for only 0.33% of total R&D expenditures in Italian manufacturing. This finding yields better understanding of the features of the innovative process in Italian traditional industries. In effect, it confirms the results obtained by Santarelli and Sterlacchini (1990) using official data from the first Italian survey on innovation diffusion (ISTAT-CNR, 1987); namely, that not only are innovations implemented by firms belonging to traditional consumer goods industries of the incremental type, they also result

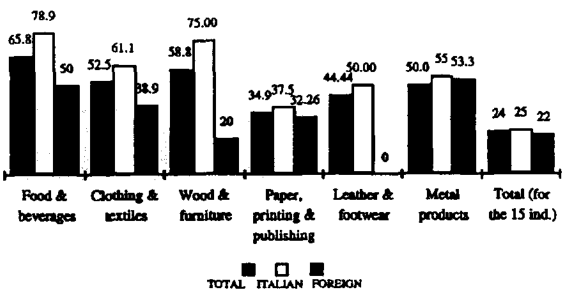


Fig. 1. Share of incremental innovations in some selected industries.

from a production process which does not require any particular commitment to structured R&D activities. Thus, in terms of innovation output, these industries appear to be more innovative than is usually believed to be the case when only their commitment to formal R&D is considered.

'Modestly improved products' represent 40.66% of the novelties developed by Italian firms in the machinery industry, whereas the category 'products totally new for the industry' accounts in this case for 10.37% of the total. The machinery industry therefore has a competitive advantage also in relation to the type of novelty of its innovations. The fact that 33.33% of the new products marketed by the Italian electronic-computing industry are 'pseudo-innovations' and that only 4.17% are 'products totally new for the industry' confirms instead that, in this strategic production, Italian firms are technologically backward.

A simple cross-tabulation of degree of complexity and type of novelty shows even more incontrovertibly that traditional consumer goods industries and other industries with scant commitment to coordinated R&D activities (food & beverages, metal products, and paper, printing & publishing) account for a proportion of incremental innovations (i.e. product differentiations with a low degree of complexity) which is much higher than in the sample as a whole (Fig. 1).

As was to be expected, among Italian innovations alone (Fig. 1), this feature of traditional consumer goods and other non R&D-oriented industries is even more marked, thereby confirming the peculiarity of innovative activity in firms belonging to those

Table 4
R&D expenditures and innovations in Italian industry

| Industries | R&D expenditures '89 | | Innovations '89 [a] (%) |
|---|---|---|---|
| | Millions of lire | % | |
| Food & beverages | 70432 | 1.06 | 3.85 |
| Clothing & textiles; Leather & footwear | 11964 | 0.18 | 5.26 |
| Wood & furniture | 9784 | 0.15 | 2.43 |
| Paper, printing & publishing | 2302 | 0.03 | 1.62 |
| Chemicals | 1713497 | 25.73 | 7.09 |
| (a) Primary chemical products | 456570 | 6.86 | 2.23 |
| (b) Pharmaceutical products | 1200613 | 18.03 | 2.83 |
| (c) Soap, polishes & sanitation goods | 56314 | 0.85 | 2.02 |
| Rubber & plastics | 176186 | 2.65 | 3.64 |
| Extractive | 205719 | 3.09 | 1.62 |
| Metal products | 227249 | 3.41 | 0.20 |
| Machinery [b] | 558419 | 8.38 | 48.79 |
| Food & bever., rubber & plastics mach. | 107020 | 1.61 | 14.98 |
| Clothing & textiles, leatherwork, mach. | 54598 | 0.82 | 11.74 |
| Woodwork, printing and footwear Mach. | 94327 | 1.42 | 11.94 |
| Other mach. | 119263 | 1.79 | 10.12 |
| Office & professional equipment [c] | 532572 | 8.00 | 4.86 |
| Electrotechnical & electronics industry | 1755983 | 26.37 | 9.92 |
| Motor vehicles, parts & accessory | 1307768 | 19.64 | 4.05 |
| Instruments | 83552 | 1.25 | 5.67 |
| Other manufacturing | 4528 | 0.07 | 1.01 |
| Total | 6659955 | 100.00 | 100.00 |

[a] The per cent distribution in this column refers to the 536 domestic innovations listed in PRODIN89.
[b] The amount of R&D expenditures refers to the sector as a whole, according to the ISTAT classification (SIC code 35).
[c] Computer programming & software industry not included.
Source: ISTAT (1992) and PRODIN89

industries. In particular, the results for the clothing & textiles and the wood & furniture industries are highly significant: in the former 61.11% of Italian innovations are product differentiations with a low degree of complexity, whereas only 38.89% of foreign ones combine these attributes; in the latter the proportion is 75% and 20% respectively. Moreover, the proportion of incremental innovations of this kind in total Italian innovations (25.4%) is higher than that for foreign innovations (22.2%), and this provides even stronger support for the interpretation that technological innovation in Italian manufacturing is mostly of the incremental type.

## 5. The geography of innovation output

The output data reported in PRODIN89 also shed light on the spatial dimension of innovation output. In effect, they allow foreign innovations to be distinguished by country of origin, and domestic ones by the region (and the province) in which the innovating firm is located. It is thus possible to compare the figures arising from our data with the general hypothesis of technology gap theory concerning the positive relation at the industry level between a country's technological strength and its trade performance. And our data also enable comparison be-

Table 5
Foreign innovations by industry and country of origin

| Industries | Not allocable | Europe | | US | JAPAN | Other states | Foreign not allocable | Total |
|---|---|---|---|---|---|---|---|---|
| | | EC | non-EC | | | | | |
| Food & beverages | 1 | 16 | | 2 | | | | 19 |
| Clothing & textiles | 4 | 8 | 5 | 3 | | 2 | | 22 |
| Wood & furniture | | 5 | | | | | | 5 |
| Paper, printing & publishing | 4 | 16 | 2 | 4 | 2 | 1 | 6 | 35 |
| Chemicals | 27 | 46 | 2 | 14 | | | 22 | 111 |
| (a) Primary chemical products | 10 | 25 | 1 | 11 | | | 10 | 57 |
| (b) Pharmaceutical products | 9 | 9 | 1 | | | | 4 | 23 |
| (c) Soap, polishes & sanitation goods | 8 | 12 | | 3 | | | 8 | 31 |
| Rubber & plastics | 4 | 9 | 2 | 5 | | | 3 | 23 |
| Leather & footwear | | 1 | | | | | | 1 |
| Extractive | | 2 | | | | | | 2 |
| Metal products | 3 | 2 | 6 | | | | 7 | 18 |
| Machinery | 31 | 95 | 21 | 14 | 7 | 6 | 24 | 198 |
| (a) Food & beverages mach. | 8 | 21 | 5 | 1 | 1 | | 3 | 39 |
| (b) Clothing & textiles mach. | | 22 | 7 | 2 | 4 | | | 35 |
| (c) Woodworking mach. | 1 | 13 | 2 | | | | | 16 |
| (d) Printing mach. | 13 | 12 | 5 | 6 | | 6 | 12 | 54 |
| (e) Leatherworking mach. | | | | | | | | |
| (f) Footwear mach. | 1 | 2 | | | | | | 3 |
| (g) Rubber & plastics mach. | 3 | 4 | | 1 | 1 | | 2 | 11 |
| (h) Other machinery | 5 | 21 | 2 | 4 | 1 | | 7 | 40 |
| Office & professional equipment | 65 | 67 | 8 | 114 | 25 | 3 | 14 | 296 |
| (a) Electronic-computing, etc. | 40 | 38 | 5 | 71 | 25 | 3 | 8 | 190 |
| (b) Computer programm. & software ind. | 25 | 29 | 3 | 43 | | | 6 | 106 |
| Electrotechnical & electronics industry | 45 | 50 | 12 | 22 | 7 | 1 | 15 | 152 |
| Motor vehicles, parts & accessories | | 31 | 2 | 8 | 6 | | | 47 |
| Instruments | 44 | 49 | 3 | 10 | 5 | | 16 | 127 |
| Other manufacturing | 2 | 3 | 1 | 1 | | | 3 | 10 |
| Total | 230 | 400 | 64 | 197 | 52 | 13 | 110 | 1066 |
| % | 21.58 | 37.52 | 6.00 | 18.48 | 4.88 | 1.22 | 10.32 | 100.00 |

Table 6
Strength in product innovation, revealed technological comparative advantage, and contribution to trade balance indicators

| Industries | SPIN | RTCA | CTB |
|---|---|---|---|
| Food & beverages | 1.49 | 1.006 | −4.04 |
| Clothing & textiles | 1.34 | 1.943 | 6.91 |
| Wood & furniture | 2.11 | n.a. | 1.59 |
| Paper, printing & publishing | 0.56 | n.a. | −0.85 |
| Chemicals | 0.72 | n.a. | −4.35 |
| (a) Primary chemical products | 0.48 | 0.979 | n.a. |
| (b) Pharmaceutical products | 1.13 | 2.734 | 0.52 |
| (c) Soap, polishes & sanitation goods | 0.73 | 0.275 | −0.18 |
| Rubber & plastics | 1.31 | 1.167 | 0.44 |
| Leather & footwear | 2.66 | n.a. | 4.48 |
| Extractive | 1.00 | 0.402 | −9.66 |
| Metal products | 1.57 | 0.669 | 3.07 |
| Machinery | 1.64 | 2.159 | 9.33 |
| (a) Food & beverages mach. | 1.74 | n.a. | 0.13 |
| (b) Clothing & textiles mach. | 1.71 | n.a. | 0.75 |
| (c) Woodworking mach. | 1.28 | n.a. | n.a. |
| (d) Printing mach. | 0.62 | n.a. | −0.04 |
| (e) Leatherworking mach. | 2.99 | n.a. | n.a. |
| (f) Footwear mach. | 2.74 | n.a. | n.a. |
| (g) Rubber & plastics mach. | 1.93 | n.a. | n.a. |
| (h) Other mach. | 1.66 | n.a. | n.a. |
| Office & professional equipment | 0.46 | n.a. | n.a. |
| (a) electronic-computing, etc. | 0.34 | 0.744 | −0.77 |
| (b) Computer programm. & software ind. | 0.66 | n.a. | n.a. |
| Electrotechnical & electronics industry | 0.73 | 1.159 | −0.69 |
| Motors vehicles, parts & accessories | 0.89 | 1.081 | −1.73 |
| Instruments | 0.54 | 0.661 | n.a. |
| Other manufacturing | 1.00 | n.a. | n.a. |

tween the regional distribution of Italian innovations and that of R&D expenditures and patents. Such comparisons serve to test the reliability of our literature-based indicator as a proxy for the innovative capability of Italian firms.

### *5.1. The sectoral distribution of foreign innovations*

Among the 1602 innovations listed in PRODIN89, 1066 (more than 66%) are new products introduced on the Italian market by foreign firms (Table 5). On aggregate, the EC countries and the US are the most important suppliers of new products, although a significant share is also accounted for by Japan. At the sectoral level, the EC countries as a whole emerge as the main foreign suppliers of product innovations, with the sole exception of the office & professional equipment industry. In effect, of the 296 foreign innovations identified for this industry, 114 (more than 38%) have been developed by US firms, and only 67 (22.64%) by EC ones, with the Japanese firms ranking third (8.45%). These results confirm that technological change in the office & professional equipment industry originates mainly from US companies and then spreads to other countries through exports of new products (Santarelli, 1995b).

The share of US firms is very significant in the primary chemical products (19.30%) and rubber & plastics (21.74%) industries as well, whereas it proves to be almost irrelevant in traditional consumer goods industries. [13]

Disaggregation of EC innovations by country of origin, shows that Germany contributed 48.50% and France 21.75% of these new products marketed in

[13] With the partial exception of the clothing & textiles industry, where US firms account for 13.64% of foreign innovations.

Italy, with the other member countries accounting for a less significant share.[14] This result is consistent with the fact that Germany is by far the most important commercial partner for Italy, whereas France is ranked second: in 1989 imports from Germany and France amounted (in value) to 37.36% and 25.90%, respectively, of total Italian imports from EC countries.

To test the reliability of our data as a proxy for the technological capability of Italy a simple index of the relative strength of each industry in product innovation (SPIN) can be constructed using the formula:

$$\mathrm{SPIN}_j = \frac{Inn_{Ij}/Inn_{Wj}}{Inn_I/Inn_W}$$

where:

$Inn_{Ij}$ = Italian innovations in industry $j$;

$Inn_{Wj}$ = total innovations commercialized in Italy in industry $j$;

$Inn_I$ = Italian innovations in all industries;

$Inn_W$ = total innovations commercialized in Italy in all industries.

The index is greater than 1 for those industries in which Italian firms have a share of product innovations on total innovations higher than the industry aggregate, lower than 1 for the other industries. Of course, SPIN does not represent a specialization index, since construction of such an index would have required information on Italian innovations commercialized abroad which cannot be collected through inspection of Italian technical and trade journals. As a consequence, SPIN is intended to be a simple measure of the proness of a country to use innovations produced abroad.

In Table 6, the SPIN index computed for the various industries in our database is compared with an index of revealed technological comparative advantage (RTCA) constructed from data on Italian patents extended to the US during the period 1982–1985.[15] This indicator is analogous to the well-known Balassa (1965) specialization index and assumes values greater than 1 when a country's share of US patents in a given industry is greater than its share in total US patents. The aim of the comparison between SPIN and RTCA is to identify whether industries characterized by a significant presence of national firms in product *innovations* commercialized in the domestic market are equally strong in developing *inventions* of a technological level sufficiently high to suggest the extension of the corresponding patent to the US.

The two indicators provide contrasting figures for only three industries: the electrotechnical & electronics and the motor vehicles industries reveal significant technological strength only with the RTCA indicator, whereas the opposite result emerges for the metal products industry. As regards the first two industries, one may argue that the nature and the scale of product innovation within them is such that (small) innovations presented in trade journals do not have any connection with (big) innovations for which patent protection is requested and extended to the US. Exactly the opposite result is obtained for the metal products industry: in this case the contrasting figures provided by the SPIN and the RTCA indicators support the view that most of the innovations developed in Italy do not have a technological level sufficiently high to suggest the extension of patent protection to the US. Most of the innovations identified for this industry are in effect of the incremental type (cf. Fig. 1 above).

The SPIN index is higher than 1 for all the traditional consumer goods industries and all the branches of the machinery industry, with the sole exception of printing machinery.[16] Unfortunately, the patent data used to construct the RTCA index are not available for these industries, and thus no comparisons between the two indicators can be made.

The reliability of our data can be tested more rigorously by checking whether the strength in product innovation (SPIN) emerged for particular industries is associated, for those same industries, with a favourable trade performance. Data from the National Statistical Office of Italy (ISTAT, 1989b) were

[14] The UK, ranked third, was responsible for 16.5% of the new products.

[15] This indicator is widely employed in studies of technological competitiveness, also as regards Italy (Archibugi, 1988; Archibugi and Santarelli, 1989, Archibugi and Pianta, 1992a). Its merits (and shortcomings) have been examined by Pavitt (1988).

[16] Our data show this branch to be dependent on imports of innovations from Germany and Israel.

Table 7
Distribution of Italian innovations by industry and region

| Regions | 1 | 2 | 3 | 4 | 5 | 5(a) | 5(b) | 5(c) | 6 | 7 | 8 | 9 | 10 | 10(a) | 10(b) | 10(c) | 10(d) | 10(e) | 10(f) | 10(g) | 10(h) | 11 | 11(a) | 11(b) | 12 | 13 | 14 | 15 | Total | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lombardia | 8 | 11 | 6 | 3 | 22 | 7 | 6 | 9 | 14 | 4 | | 12 | 139 | 21 | 29 | 3 | 8 | 2 | 26 | 17 | 30 | 26 | 11 | 15 | 40 | 2 | 17 | 3 | 304 | 57.96 |
| Emilia Romagna | 5 | 1 | | | 5 | 1 | 4 | | 1 | | | 5 | 45 | 23 | 5 | 6 | | 2 | 1 | 2 | 9 | 4 | 2 | 2 | 1 | 4 | 6 | | 80 | 15.09 |
| Piemonte | 1 | 3 | 3 | 1 | 3 | 1 | 2 | | | | | 2 | 16 | 3 | 4 | | 3 | | | 1 | 5 | 19 | 9 | 10 | 5 | 13 | 1 | | 67 | 12.64 |
| Veneto | 1 | 1 | 1 | 1 | 4 | 2 | 1 | 1 | 1 | | | 1 | 13 | 3 | 1 | | | 5 | 3 | | 1 | 1 | | 1 | | 1 | 1 | 1 | 27 | 5.09 |
| Toscana | 1 | | | 1 | 1 | | 1 | | | 1 | | | 15 | 1 | 5 | 2 | 2 | 2 | 3 | | | | | | | | 2 | | 21 | 3.96 |
| Marche | | | 2 | | | | | | 2 | 3 | | | 3 | | | 1 | | | | | 2 | 1 | 1 | | | | | | 11 | 2.08 |
| Friuli V.G. | | | | | | | | | | | | | 3 | 1 | 2 | | | | | | | | | | 2 | | | 1 | 6 | 1.13 |
| Liguria | 1 | | | | | | | | | | | | 1 | | 1 | | | | | | | | | | | | 1 | | 3 | 0.57 |
| Trentino A.A. | | | | | | | | | | | | | 3 | 1 | | | | | | | 2 | | | | | | | | 3 | 0.57 |
| Umbria | | | | | | | | | | | | | 2 | 1 | | | 1 | | | | | 1 | 1 | | | | | | 3 | 0.57 |
| Abruzzo | | 1 | | | | | | | | | | | 1 | | | | | | | | 1 | | | | | | | | 2 | 0.38 |
| Campania | 1 | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | 2 | 0.38 |
| Puglia | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | 1 | 0.19 |
| Total | 18 | 17 | 12 | 6 | 35 | 11 | 14 | 10 | 18 | 8 | 1 | 20 | 241 | 54 | 47 | 12 | 14 | 11 | 33 | 20 | 50 | 52 | 24 | 28 | 49 | 20 | 28 | 5 | 530 | 100.00 |
| Not allocable | 1 | 1 | | 2 | | | | | | | | | | | | | | | | | | 2 | | 2 | | | | | 6 | |
| Total | 19 | 18 | 12 | 8 | 35 | 11 | 14 | 10 | 18 | 8 | 1 | 20 | 241 | 54 | 47 | 12 | 14 | 11 | 33 | 20 | 50 | 54 | 24 | 30 | 49 | 20 | 28 | 5 | 536 | |

1–Food & beverages; 2–Clothing & textiles; 3–Wood & furniture; 4–Paper, printing & publishing; 5–Chemical, (a) primary chemical products, (b) pharmaceutical products, (c) soap, polishes, etc.; 6–Rubber & plastics; 7–Leather & footwear; 8–extractive; 9–metal products; 10–Machinery, (a) food & beverages mach., (b) clothing & textiles mach., (c) woodworking mach., (d) printing mach., (e) leatherworking mach., (f) footwear mach. (g) rubber & plastics mach., (h) other; 11–office & professional, (a) electronic-computing, etc., (b) computer programm. & software ind., 12–electrotechnical & electronics; 13–motor vehicles, parts & accessories; 14–instruments; 15–other.

used to compute the indicator of contribution to the trade balance (CTB) for the relevant industries:

$$CTB_j = \left\{ \frac{X_j - M_j}{(X+M)/2} - \left[ \frac{X-M}{(X+M)/2} \cdot \frac{X_j + M_j}{X+M} \right] \right\} \cdot 100$$

where:
$X_j$ = exports in industry $j$;
$M_j$ = imports in industry $j$;
$X$ = total exports in all industries;
$M$ = total imports in all industries.

This indicator yields values greater than 0 (less than 0) when the relevant industry makes a contribution to the overall trade balance of the country which is higher (lower) than its percentage share in the country's total trade (Amendola et al., 1991). It is therefore helpful to identify industries of specialization and industries of despecialization.

In fact, in 1989 the CTB index (Table 6) was 6.91 for the clothing & textiles industry, 1.59 for wood & furniture, 4.48 for leather & footwear, and 9.33 for the aggregate machinery industry. These findings and the results provided by computation of the SPIN index suggest a further explanation of the relation between strength in product innovation and trade specialization for certain industries. One can in fact argue that (consistently with the technology gap approach; Fagerberg, 1987, 1988; Soete, 1987; Amendola et al., 1993) there is a positive relation between strength in innovation and trade performance for most industries. A formal test for this relation can be carried out by calculating the Spearman rank correlation. This test shows a strong (0.648) positive correlation between SPIN and CTB, significant at a 1% level at a one-tailed test, and seems

Table 8
R&D expenditures, innovations, and patents extended to the US by region

| Regions | R&D exp. in 1986 | | Innovations '89 | | Patents '86 | |
|---|---|---|---|---|---|---|
| | Millions of lire | % | Abs.v. | % | Abs.v. | % |
| Piemonte | 1805390 | 30.36 | 67 | 12.64 | 124 | 18.67 |
| Valle d'Aosta | 1472 | 0.02 | | | | |
| Lombardia | 2045855 | 34.41 | 304 | 57.36 | 274 | 41.27 |
| Trentino Alto Adige | 18239 | 0.31 | 3 | 0.57 | | |
| Veneto | 190415 | 3.20 | 27 | 5.09 | 29 | 4.37 |
| Friuli Venezia Giulia | 83331 | 1.40 | 6 | 1.13 | 20 | 3.01 |
| Liguria | 293558 | 4.94 | 3 | 0.57 | 11 | 1.66 |
| Emilia Romagna | 254355 | 4.28 | 80 | 15.09 | 89 | 13.40 |
| Toscana | 254277 | 4.28 | 21 | 3.96 | 23 | 3.46 |
| Umbria | 26098 | 0.44 | 3 | 0.57 | 2 | 0.30 |
| Marche | 19064 | 0.32 | 11 | 2.08 | 5 | 0.75 |
| Lazio | 607460 | 10.22 | | | 50 | 7.53 |
| Abruzzo | 47424 | 0.80 | 2 | 0.38 | 5 | 0.75 |
| Molise | | | | | | |
| Campania | 176898 | 2.98 | 2 | 0.38 | 12 | 1.81 |
| Puglia | 34418 | 0.58 | 1 | 0.19 | 1 | 0.15 |
| Basilicata | 5334 | 0.09 | | | | |
| Calabria | 8652 | 0.15 | | | 1 | 0.15 |
| Sicilia | 45961 | 0.77 | | | 18 | 2.71 |
| Sardegna | 27456 | 0.46 | | | | |
| Italy | 5945657 | 100.00 | 530 | 100.00 | 664 | 100.00 |

Sources: R&D expenditures (ISTAT, 1989a): patents (SPRU data base).

Table 9
Correlation matrix

| | INN | R&D | PAT |
|---|---|---|---|
| INN | 1.00 | – | – |
| R&D | 0.595 | 1.00 | – |
| PAT | 0.877 | 0.805 | 1.00 |

therefore to support the general hypothesis of technology gap theory.

### 5.2. Innovation output, patents, and the spillovers from R&D activities in Italian regions

Five hundred and thirty of the 536 Italian innovations contained in PRODIN89 were broken down according to the region of the innovating firms. Only 13 out of 20 Italian regions recorded at least one resident firm introducing new products in 1989.

Table 7 shows the overwhelming importance of the Lombardia region in terms of product innovations in almost all industries. The principal exceptions are in the leather & footwear industry (where the Marche region performs particularly well), the industry producing food & beverages machinery (cf. Emilia Romagna), and motor vehicles (cf. Piemonte). These regional portions of product innovations reflect the industrial specialization of the above-mentioned regions, and this finding indirectly confirms the reliability of the results obtained through application of the literature-based indicator.

For all regions, it was possible to compare our innovation output data with R&D expenditures and the number of patents extended to the US in 1986 (Table 8). [17]

In order to control for the relative size of the various Italian regions, each measure is divided by resident population. [18] Immediately evident from the correlation matrix presented in Table 9 is the high coefficient of linear correlation (0.877) between product innovations (INN) and patents (PAT). This finding confirms that innovation output in Italy, irrespective of the measurement procedure adopted, concentrates in a well defined group of regions, with some significant exceptions. In fact, regions where traditional consumer goods industries predominate (Veneto, Emilia Romagna, Toscana, Marche) appear to be more innovative when the PRODIN89 indicator is used, whereas the opposite result is obtained for those regions (like Piemonte and Liguria) in which scale intensive industries are more developed.

The case of Lombardia and Lazio is curious. In Italy, Lombardia is by far the most technologically advanced region. As a consequence, irrespective of their size, firms resident in this region benefit from a number of technological spillovers which engender radical (patented) and incremental (not patented) innovations. In the case of Lazio, previous studies (Sirilli, 1986; Santarelli and Sterlacchini, 1989) have instead shown that firms with their legal offices in the Rome metropolitan area but with their production facilities located in other regions account for a very large share of the total patents attributed to this region by official sources. The actual contribution of Lazio to overall innovation output is therefore less significant than one would deduce from patent data, although the literature-based procedure (with which no innovations were identified) would certainly have underestimated product innovations developed by firms with their production facilities in this region.

Looking at the spillovers from R&D activities (Table 9), the linear correlation coefficient between patents (PAT) and total R&D expenditures (0.805) is higher than that between product innovations (INN) and R&D expenditures (0.595). These results indicate that there is a close linkage between formal research activities and innovations whatever indicator of innovation output is used. Nevertheless, the differences between the patent and the innovation output correlation coefficients suggest that, when a direct measure of innovation output is employed, the innovative activity of industrial firms seems also to be based on both external or internal sources of informal knowledge which are not captured by traditional input indicators.

[17] We are grateful to Marco Vivarelli for allowing us to use the data on patents employed in Audretsch and Vivarelli (1993). The data source for patents is the SPRU database at Sussex University and is based on the US OTAF Patent Office.

[18] The measure for the resident population is obtained as the mean of the values at the beginning and the end of the year.

Table 10
Distribution of innovations and employment by size class and industry [a]

| Industries (% by row) | 1–19 | | 20–49 | | 50–199 | | 200–499 | | 500–999 | | 1000 and more | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | INN | EMP | INN | EMP | INN | EMP | INN | EMP | INN | EMP | INN | EMP | INN | EMP |
| Food & bever. | | | | | 22.22 | 6.20 | 11.11 | 4.60 | 44.44 | 29.36 | 22.22 | 59.84 | 9 | 4629 |
| Clothing & ... | | | 23.08 | 0.66 | | | 15.38 | 7.53 | | | 61.54 | 91.81 | 13 | 11015 |
| Wood & furnit. | 28.57 | 2.58 | 14.29 | 4.97 | 57.14 | 92.45 | | | | | | | 7 | 543 |
| Paper, print ... | 50.00 | 0.13 | | | | | | | 50.00 | 99.87 | | | 2 | 771 |
| Chemicals | | | 6.25 | 0.68 | 43.75 | 20.26 | 31.25 | 12.27 | 6.25 | 14.88 | 12.50 | 51.91 | 16 | 4442 |
| (a) Primary ... | | | 16.67 | 4.93 | 83.33 | 95.07 | | | | | | | 6 | 608 |
| (b) Pharmaceut. | | | | | 14.29 | 7.52 | 71.43 | 28.27 | | | 14.29 | 64.21 | 7 | 1928 |
| (c) Soap, ... | | | | | 33.33 | 9.29 | | | 33.33 | 34.68 | 33.33 | 56.03 | 3 | 1906 |
| Rubber & ... | | | 6.67 | 0.18 | 33.33 | 2.30 | | | | | 60.00 | 97.53 | 15 | 16337 |
| Leather & ... | 33.33 | 7.02 | | | 66.67 | 92.98 | | | | | | | 3 | 242 |
| Extractive | | | | | 100.0 | 100.0 | | | | | | | 1 | 80 |
| Metal products | 18.18 | 0.74 | 36.36 | 9.48 | 27.27 | 35.59 | 18.18 | 54.19 | | | | | 11 | 812 |
| Machinery | 24.06 | 1.52 | 26.32 | 5.51 | 29.32 | 18.76 | 16.54 | 27.30 | 3.76 | 13.90 | 1.50 | 33.00 | 135 | 18979 |
| (a) Food & bev. | 28.57 | 1.40 | 32.14 | 7.94 | 21.43 | 21.57 | 14.29 | 36.59 | | | 3.57 | 32.50 | 28 | 3148 |
| (b) Clothing ... | 5.00 | 0.15 | | | 40.00 | 8.06 | 30.00 | 17.73 | 20.00 | 21.32 | 5.00 | 52.73 | 20 | 9937 |
| (c) Woodw. m. | | | 27.27 | 17.83 | 27.27 | 34.97 | 45.45 | 47.20 | | | | | | 11572 |
| (d) Printing m. | 71.43 | 8.33 | 14.29 | 5.95 | | | 14.29 | 85.71 | | | | | 7 | 420 |
| (e) Leatherw. m. | 50.00 | 16.36 | 20.00 | 18.18 | 30.00 | 65.45 | | | | | | | 10 | 330 |
| (f) Footwear m. | 36.36 | 9.78 | 36.36 | 29.33 | 22.73 | 37.44 | 4.55 | 23.44 | | | | | 22 | 900 |
| (g) Rubber & ... | 28.57 | 2.76 | 28.57 | 7.00 | 28.57 | 39.12 | 14.29 | 51.12 | | | | | 14 | 1342 |
| (h) Other mach. | 4.35 | 0.69 | 34.78 | 10.73 | 43.48 | 34.46 | 13.04 | 31.80 | 4.35 | 22.32 | | | 23 | 2330 |
| Office & pro ... | 3.85 | 0.11 | 23.08 | 1.67 | 11.54 | 2.23 | 3.85 | 3.54 | 19.23 | 5.36 | 38.46 | 87.09 | 26 | 13293 |
| (a) Electronic ... | 6.25 | 0.12 | 6.25 | 0.42 | 12.50 | 1.91 | | | 31.25 | 6.27 | 43.75 | 91.28 | 16 | 11359 |
| (b) Comp. prog. | | | 50.00 | 9.00 | 10.00 | 4.14 | 10.00 | 24.35 | | | 30.00 | 62.51 | 10 | 1934 |
| Electrotechnical | 9.38 | 0.17 | 21.88 | 0.84 | 31.25 | 3.58 | 21.88 | 8.46 | | | 15.63 | 86.95 | 32 | 13635 |
| Motor vehicles | | | | | | | | | | | 100.0 | 100.0 | 13 | 77828 |
| Instruments | | | 50.00 | 14.35 | 37.50 | 47.79 | 12.50 | 37.86 | | | | | 8 | 655 |
| Total (abs. v.) | 14.43 | 0.22 | 21.31 | 1.05 | 27.15 | 4.48 | 14.09 | 5.56 | 5.50 | 3.76 | 17.53 | 84.92 | 292 | 163261 |

[a] Totals are absolute values, all the others are percentages.

## 6. The size distribution of Italian innovating firms

The Italian firms responsible for the development of the 536 'national' innovations contained in PRODIN89 were interviewed in order to obtain information about their size (in terms of number of employees) in 1989. Unfortunately, data were forthcoming for only 292 innovations, due to the firms' reluctance to disclose information concerning their employees. [19] Table 10 shows the distribution of innovations by size class and industry of the innovating firm.

By focusing on specific branches of the machinery industry, the innovative capability of small firms emerges in an uncontroversial manner (Table 10): 72.73% of the total innovations identified for the industry producing footwear machinery were introduced by firms with fewer than 50 employees, which account for 39.11% of the employees in the firms identified for this industry. Significantly, the share of innovations introduced by firms with fewer than 50 employees was 70% in the case of leather machinery, and 60.71% in that of food & beverages machinery, whereas these firms represented 34.55% and 9.34% of total employment in their industry respectively. Different results emerge in the case of the clothing & textiles filiere. In effect, 45% of new machines were introduced by firms with fewer than 200 employees (and this share drops to 5% for firms with fewer than 50 employees) whereas 61.54% of total new clothing & textiles products may be attributed to large firms with more than 1000 employees. Firms with fewer than 200 employees accounted for only 23.08% of the total. As regards the industry producing machinery for these traditional consumer goods, firms having less than 200 employees accounted for more than 8% of total employment, whereas those with 100 and more employees were responsible for about 52%. Firms with more than 1000 employees accounted instead for almost 92% of total employment in the clothing & textiles industry. The explanation for this apparently surprising prevalence of larger firms is that most of the innovations identified within this relatively low R&D spending filiere regard the textile industry in a strict sense. [20] This is a *scale intensive* industry (in Pavitt's sense) where the production process takes place in large plants: accordingly, large firms are also responsible for most of the innovations introduced in the industry.

According to the 'Schumpeterian hypothesis', within industries strongly committed to autonomous R&D activities the contribution of larger firms to innovation should be more marked. In fact, 75% of the new products identified for the electronic-computing industry were introduced by firms with more than 500 employees, which represented more than 97% of the industry total in terms of employment. This share rose to 60% in the rubber & plastics industry and to 100% in the motor vehicles, parts & accessories industry, where these size class accounted for more than 97% and 100% of the industry total employment respectively.

Conversely, our data do not support the Schumpeterian hypothesis in the electrotechnical & electronics industry, where the share of innovations introduced by firms with more than 500 employees represents only 15.63% of the total, with this size class responsible for almost 87% of the industry employment. In fact, in explaining the low innovative contribution of large firms belonging to this industry, it should be stressed that it is characterized more by *specialized suppliers* (as defined by Pavitt) of intermediate goods (usually medium sized firms) [21] than by large scale producers of standardized goods.

Although the above comparisons between shares of innovations and shares of employment represent a reliable proxy of the relation between market structure and innovation in each industry, the best measure of innovative activity when comparing firms belonging to different size classes is the innovation rate (Acs and Audretsch, 1993). Given the particular

[19] As a consequence, the results of the following analysis of the size distribution of innovative firms registered in PRODIN89 must be treated with a certain caution.

[20] Of course, articles of clothing differ in terms of design. None of them can therefore be considered as a product innovation. Innovations are instead the new fabrics and accessories utilized for either ready-made or tailor-made clothes.

[21] In fact, firms with between 50 and 499 employees account for more than 53% of total innovations identified for this industry.

Table 11
Innovation rates for large and small firms by industry, 1989

| Industries | Total innovations | Small-firm innovations | Large-firm innovations |
|---|---|---|---|
| Food & beverages | 0.19 | 0.70 | 0.16 |
| Clothing & textiles | 0.12 | 4.11 | 0.09 |
| Wood & furniture | 1.29 | 1.29 | – |
| Paper, printing & publishing | 0.26 | 100.00 [a] | 0.13 |
| Chemicals | 0.36 | 0.86 | 0.23 |
| (a) Primary chemical products | 0.99 | 0.99 | – |
| (b) Pharmaceutical products | 0.36 | 0.69 | 0.34 |
| (c) Soap, polishes & sanitation goods | 0.16 | 0.56 | 0.12 |
| Rubber & plastics | 0.09 | 1.49 | 0.06 |
| Leather & footwear | 1.24 | 1.24 | – |
| Extractive | 1.25 | 1.25 | – |
| Metal products | 1.35 | 2.42 | 0.45 |
| Machinery | 0.71 | 2.17 | 0.21 |
| (a) Food & beverages mach. | 0.89 | 2.36 | 0.23 |
| (b) Clothing & textiles mach. | 0.20 | 1.10 | 0.12 |
| (c) Woodworking mach. | 1.92 | 1.99 | 1.85 |
| (d) Printing mach. | 1.67 | 10.00 | 0.28 |
| (e) Leatherworking mach. | 3.03 | 3.03 | – |
| (f) Footwear mach. | 2.66 | 3.05 | 0.47 |
| (g) Rubber & plastics mach. | 1.04 | 1.83 | 0.29 |
| (h) Other mach. | 0.99 | 1.78 | 0.32 |
| Office & professional equipment | 0.20 | 1.54 | 0.13 |
| (a) Electronic-computing, etc. | 0.14 | 1.43 | 0.11 |
| (b) Computer programm. & software ind. | 0.52 | 1.61 | 0.24 |
| Electrotechnical & electronics industry | 0.23 | 3.20 | 0.09 |
| Motor vehicles, parts & accessory | 0.02 | – | 0.02 |
| Instruments | 1.22 | 1.72 | 0.40 |
| Total | 0.18 | 1.32 | 0.07 |

[a] One employee and one innovation.

structure of Italian industry, we can define the large-firm innovation rate as the number of innovations made by firms with at least 200 employees, divided by the number of employees (hundreds) in such firms. Analogously, the small-firm innovation rate is the number of innovations developed by firms with fewer than 200 employees divided by the number of employees (hundreds) in small firms.

The first column in Table 11 shows that the total innovation rates are higher for those industries (such as, in particular, metal products, wood & furniture, leather & footwear) shown by previous studies to be characterized by a very small average employment size (Santarelli and Sterlacchini, 1994a). Comparison of the large-firm and small-firm innovation rates for each of the industries analyzed in PRODIN89 reveals that small firms always have an innovation rate higher than that of large firms, with the sole exception of motor vehicles, where none of the innovations registered in our database were introduced by small firms. [22] This finding confirms the strength of Italian small firms in innovation [23] although it casts some doubt on the reliability of this indicator in capturing the innovative contribution of large firms. Nonetheless, in spite of this possible bias towards small firms, one cannot help but note that the results obtained with PRODIN89 are consistent with those yielded by analysis of the US Small Business Ad-

[22] Large firms have not introduced innovations in five industries: wood & furniture, primary chemical products, leather & footwear, extractive, and leather machinery.

[23] As shown by earlier field studies of certain Italian regions (Brusco, 1982; Santarelli and Sterlacchini, 1994b).

ministration Innovation Database (Acs and Audretsch, 1993). In effect, Acs and Audretsch (1993) found that in the US 14 out of 18 industries display a small-firm innovation rate which exceeds that computed for large firms. It therefore seems that, when a direct measure of innovation output is used, small firms have in general a relative innovative advantage, and that this finding applies to countries (like Italy and US) characterized by a sigificantly different industrial structure.

Therefore, although reflecting some unexamined biases, [24] analysis of the distribution of the innovations contained in PRODIN89 by size class of the innovating firms gives results consistent with those of previous studies on Italian industry. In particular, small firms specialized in niche productions appear to be even more adept than large firms in developing products which are completely new for their industry. This finding provides stronger support for the hypothesis that in certain traditional industries, with a low commitment to formal R&D, small firms are nonetheless able to carry out their innovative activities without resorting to formalized procedures (Santarelli and Sterlacchini, 1990). Italian small firms specialized in selling capital goods (i.e. those that belong to the machinery and the electrotechnical & electronics industries) to supplier dominated firms producing mostly consumer goods confirm instead their well-known competitive advantage in terms of innovative capability (Piore and Sabel, 1984).

## 7. Concluding remarks

In this paper the application of a direct, literature-based measure of innovation output has yielded more thorough understanding of the features of technological change in Italian industry. Our findings coincide with the results of previous studies, which have shown that Italy is characterized by a significant presence of consumer goods industries and small firms in innovation. Moreover, our data indicate links between trade competitiveness and strength in product innovation, confirming the comparatively higher capacity for product innovation of some of the industries in which Italy achieves favourable performance in international trade. In addition, the presence of spillovers at the regional level from both private and public R&D expenditures (also identified in other studies relying on patent statistics; Audretsch and Vivarelli, 1993) proves to be linked with the development of product innovations. Finally, these literature-based data show that small firms with fewer than 50 employees are more innovative than is usually believed to be the case, confirming the results of researches conducted by direct investigation of the innovative activities of small firms.

These results, and those obtained by earlier studies employing a similar procedure for other countries, suggest that literature-based classifications of innovation events enable adequate assessment of innovation trends at both the industry and the geographical area levels. The various national statistical offices should therefore consider the possibility of adopting this promising measurement procedure, which would be of benefit to students of technology and indeed would lead to better understanding of the dynamics of innovation.

[24] In particular, firms belonging to traditional consumers goods industries were the most reluctant to answer questions about the number of employees working in their plants.

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