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Measuring technological change through patents and innovation surveys

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Abstract

This article provides an overview of recent research using innovation surveys and patent data as indicators of technological activity. The conceptual and methodological problems of 'measuring' technology are discussed, with a classification of the types of information which can be drawn from patent databases and from surveys of both innovations and the innovative efforts of firms.

The findings and the methodological strengths and weaknesses of such studies are reviewed, considering first the evidence at the firm level, second the analysis of the industrial structure and finally the evidence at the country level and the process of globalization. The overview shows that rich and important evidence on the technological activities of firms is offered by these indicators. A summary of new departures for research based on innovation and patent data concludes the paper. Copyright © 1996 Elsevier Science Ltd

1. INTRODUCTION

The measurement of technological change is of increasing importance for business, research, and policy. Within firms, detailed information about technological advance is needed to take the right decisions concerning the amount of resources to devote to innovation, to select the fields where innovation promises economic returns and to manage innovative strategies within companies.

However, measuring technological change is a particularly demanding task. In industry, innovation depends on a variety of activities ranging from formalized R&D to production engineering. It has been stressed that innovation is not a linear process going from R&D activities to the eventual commercialization of products. On the contrary, the elements of innovation interact throughout the various stages to weave a complex web of relationships (OECD, 1991, 1992b).

Three main aspects of industrial innovation deserve to be mentioned. First, technological change impinges on codified and tacit knowledge. Second, the sources of innovation may be either internal or external to the firm. Third, innovations can either be embodied in capital goods and products or disembodied, i.e. the know-how included in patents, licences, design, R&D activities, or embodied in skilled personnel.

These aspects already indicate the complex and heterogeneous nature of technological change. They show why it is difficult to find measures that provide a satisfactory account of the dimension, intensity, rate and direction of innovative activity. This article

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reviews recent developments on the measurement of technological change by means of patent data and indicators derived from innovation surveys.

Two main issues need to be addressed: first, the extent to which available indicators overlap or provide information on different aspects of science and technology activities; second, the extent to which indicators of the same activities provide similar answers. These issues can be summarized by two questions: Which indicator answers which question? Do different indicators provide the same results?

National and international governmental agencies, as well as private companies, have devoted a substantial amount of resources to producing information and statistical sources on innovation. The 'family' of OECD manuals provides a wide array of conceptual and operational tools for developing and using the existing technological indicators and statistical sources. In particular, the Patent Manual (OECD, 1994) and the Oslo Manual on innovation surveys (OECD, 1992a) cover the methodological aspects and the state of the art in these fields. A final question emerging from this overview concerns the further development of methodological tools: What are the new efforts to be agreed upon in order to provide a common framework for expanding the information drawn from technology indicators?

This overview first sets out the key concepts and the methodological problems of investigating innovative activities (Section 2). Next, it discusses innovation and patenting strategies of firms (Section 3) and the analysis of industrial structure (Section 4). The national level and the process of globalization are then discussed (Section 5). Finally, the conclusions bring together the evidence gathered for patent and innovation survey indicators; the key methodological problems and themes of research are reviewed in the light of recent developments (see OECD, 1995), and new directions for research are suggested (Section 6).

This article is focused on the most recent literature. Previous review articles to be taken into account for a comprehensive view include Basberg (1987), Pavitt (1988) and Griliches (1990) for patenting; and Archibugi (1988), De Bresson (1990), Smith (1992a, 1992b), and Hansen (1992) for innovation surveys.

2. CONCEPTS AND METHODOLOGY

2.1 Two methods of gathering information on industrial innovation

Patents and innovation surveys are two ways to acquire information on the innovative activities of firms. Figure 1 presents a conceptual framework. A wide variety of innovative activities are carried out by firms that can be documented by innovation surveys and patent data. Using such empirical evidence, it is possible to address several issues at the levels of firms, industries and countries.

Some innovation inputs have been monitored for a long time, notably the resources devoted to R&D, which have been systematically measured in most advanced countries for over 30 years. However, despite its importance, R&D is only one source of innovation. Other innovation inputs are not yet measured, and some cannot be (on indicators, see Freeman, 1987; van Raan, 1988; van Raan *et al.*, 1989; Barré *et al.*, 1994).

Innovative activities have a variety of visible outcomes. Firms invest in technology to introduce product and process innovations into the market. Innovation surveys can account for such efforts. In order to protect their products and processes against prospective competitors, firms often apply for patents for their innovations. The key aspects of patents and innovation surveys as technology indicators are shown in Table 1. Table 2 provides an overview of their strengths and weaknesses.

Innovation can be analysed, classified and measured from several perspectives. There are, at least, four different criteria for classifying innovation, which can be used in both patenting and innovation surveys (for a formal analysis, see Archibugi, 1988):

- technology, i.e. according to the technical characteristics of the innovation;
- product, i.e. according to the nature of the product in which the innovation is likely to be embodied;
- sector of production, i.e. the main economic activity of the firm that has generated the innovation;
- sector of use, i.e. the main economic activity of the users of the innovation.

2.2 The nature of patents

The patent system is one method firms use to protect their inventions. For legal reasons, patents are systematically registered by government bodies. If they are duly processed, classified and organized, patents provide a unique source of information on industrial innovation. The OECD Patent Manual provides guidelines for the use of patents as well as a guide to the patent-based literature (see also Basberg, 1987; Pavitt, 1988; Griliches, 1990).

Like any other technological indicator, patents have advantages and disadvantages, which it is useful to summarize. Their advantages are:

- They are a direct outcome of the inventive process, and more specifically of those inventions which are expected to have a commercial impact. They are a particularly appropriate indicator for capturing the proprietary and competitive dimension of technological change.

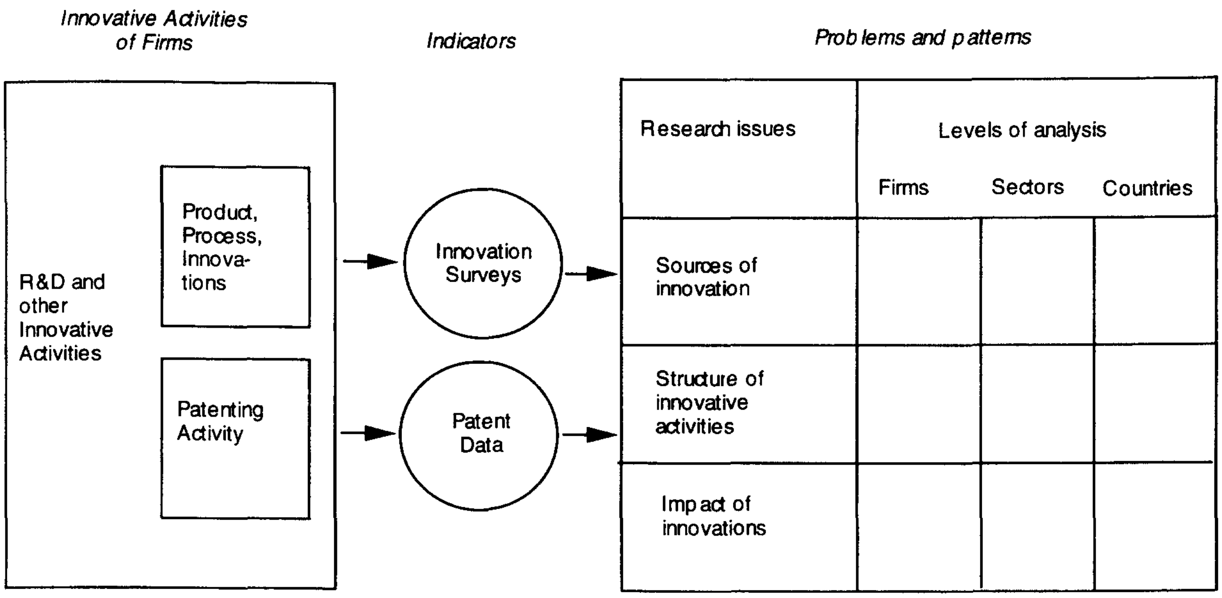

Fig. 1. A framework for the analysis of innovation and patenting activities.

TABLE 1. The nature of patents and innovation surveys

		Innovation surveys	
	Patents	'Object' approach	'Subject' approach
Unit of analysis	Patented inventions	Sample of innovations	Firms
Origin of the information	Collected for legal and administrative purposes	Collected for analytical and/or policy purposes	Collected for analytical and/or policy purposes
Method of collecting information	Patent office data on applications filed by inventors or grants. Original sources are often further reclassified and elaborated for analytical purposes	Collected from different sources such as new product announcements, expert surveys, innovation inventories, bibliometric directories	Collected at the firm level either by mail questionnaires or direct interviews
Periodicity	Regular data collection Very up-to-date information	Occasional surveys	Until now, occasional surveys Data collection is becoming periodical
Coverage	Inventions for which legal protection is sought The majority of patents are granted to the business sector	Samples of successful innovations Informs on innovations introduced by both the business and the non-profit sectors	Successful and unsuccessful innovative activities Innovating and non-innovating firms Includes manufacturing and service industries
Main criteria of classification	Technological Firm's principal economic activity	Product Firm's principal economic activity	Firm's principal economic activity Main user sector Firm size

Source: Authors.

- Because obtaining patent protection is time-consuming and costly, it is likely that applications are filed for those inventions which, on average, are expected to provide benefits that outweigh these costs.
- Patents are broken down by technical fields and thus provide information not only on the rate of inventive activity, but also on its direction.
- Patent statistics are available in large numbers and for a very long time series.
- Patents are public documents. All information, including patentees' names, is not covered by statistical confidentiality.

Their disadvantages are:

- Not all inventions are technically patentable. This is the case of software, which is generally legally protected by copyright.
- Not all inventions are patented. Firms sometimes protect their innovations with alternative methods, notably industrial secrecy.
- Firms have a different propensity to patent in their domestic market and in foreign countries, which largely depends on their expectations for exploiting their inventions commercially. In each national pat-

TABLE 2. Comparability, strengths and weaknesses of patents and innovation surveys

	Patents	Innovation survey: 'Object' approach	Innovation survey: 'Subject' approach
Time series comparability	Very high. Patent data have been collected for more than a century	Generally high within a given survey	Low, unless information is collected periodically and is standardized
International comparability	High, although it is limited by the national nature of patent institutions and the large number of domestic applications	Low. All surveys are national in scope. Difficult to compare them because of different sample method and design	Potentially high for quantitative data if identical questionnaires and methods are used
Comparability with R&D	Low at firm and industry levels. High at country level	Low, since R&D surveys are at firm level and not at innovation level	High, since surveys make it possible also to collect information on input data. Both innovation and R&D surveys collect information at firm level
Comparability with industrial statistics & national accounts	Difficult at firm and industry levels due to different sectoral classifications. High at country level	Low, because it is difficult or even impossible to relate the sampled innovation to the whole universe	High on quantitative data if innovation surveys can be related to the economic universe
Other advantages	Since patent protection is costly, it is likely that firms apply for those inventions which are likely to provide economic returns. Very detailed sectoral disaggregation	Direct measure of innovation. Provides information on technological evolution	Provides information on all innovative activities. Wide coverage of issues. Informs on both producers and users of innovation
Other disadvantages	Not all patents become innovations. Not all inventions are patented. Not all inventions are patentable. Different propensity to patent across sectors	Heterogeneous value of individual innovations. Data biased by subjective judgement. Difficult to assess the significance and representativeness of the sample	Does not inform on the technological nature of innovations. Significance and representativeness of results are tied to response rate achieved

Source: Authors.

ent office, there are many more applications from domestic inventors than from foreigners.

- Although there are international patent agreements among most industrial countries, each national patent office has its own institutional characteristics, which affect the costs, length and effectiveness of the protection accorded. In turn, this affects the interest of inventors in applying for patent protection.

Empirical surveys suggest that a large share of firms' inventions are patented. Research carried out by Mansfield (1986) on a sample of US firms showed that firms apply for a patent for about 66–87% of their patentable inventions. This does not mean that patents account for the same share of all inventions, since an unknown number of inventions are not technically patentable. Still, this suggests that firms make use of patenting for the majority of their patentable inventions.

A survey carried out by the European Patent Office (1994, p. 108) on the patenting activity of European firms with up to 1000 employees found that 25% of the sampled firms filed patent applications for more than 90% of their patentable inventions and that another 25% applied for a patent for 50–90% of their patentable inventions. These shares tend to increase with the size of firms. Cost and lack of advantages are given as reasons for not patenting an invention.

A large-scale survey of firms' behaviour with respect to innovation and appropriability (the PACE survey) has recently been completed in Europe (Arundel *et al.*, 1995) and is under way in the United States and Japan. The survey was designed as a follow-up to the Yale survey of the 1980s (Levin *et al.*, 1987), and the first results broadly confirm previous evidence on firms' innovative strategies and the relevance of patents.

The PACE survey of European firms found that 15% of firms apply for patents for 80–100% of their product innovations, while 37% patent less than 19%. For process innovations, only 7% of firms made extensive use of patents and 57% apply very rarely. The firms covered by the PACE survey, however, made extensive use of patents; only 14% did not apply for a patent in the previous three years; 79% applied at the EPO and 78% at the national patent office; 66% applied in the United States and 53% in Japan (Arundel *et al.*, 1995, pp. 60–61).

A related question is whether patented inventions actually become innovations. Old (Scherer *et al.*, 1959) and new (Sirilli, 1987; Napolitano and Sirilli, 1990) empirical evidence show very similar results: the share of patents actually used by firms ranges from 40% to 60% of total applications. Similarly, the EPO survey found that 47% of European firms used commercially or licensed more than 90% of their patented inventions, and another 16% used between 50 and 90% of their patents. These shares are higher for smaller firms and show substantial variations across countries and industries (EPO, 1994, pp. 117–119).

In the EPO survey, when firms were asked about their usual means of protecting new products and processes, 84% of patenting firms cited patents in the case of products and 71% in the case of processes. Secrecy was mentioned by about 50% of patenting firms and by about 63% of non-patenting firms. Getting to market ahead of competitors was reported by about 41% of both patenting and non-patenting firms (EPO, 1994, pp. 88–91).

It has often been argued that the value of individual patents is highly skewed (see Swann, 1993). In fact, several methods have been used to assess the individual 'quality' and 'impact' of patents. Four different measures have been used to increase the accuracy of patent counts.

- *Patent citations*: the count of citations of a patent in subsequent patent literature. This is an indicator of the technological impact of the patented invention (see Narin and Olivastro, 1988b; Trajtenberg, 1990).
- *Renewal fees*: the total cost and the number of years for which the patentee pays renewal fees to maintain the legal value of the patent. This gives information on the economic value attributed to the invention (see Pakes and Simpson, 1989).
- *Patent families*: mapping the number of countries to which a single patent application has been extended makes it possible to identify the subset of patents applied for in all major markets. This shows the areas of exploitation of an invention and offers a more accurate database for international comparisons (for an application to the US, Japanese and the European Patent Offices, see Grupp, 1993; Schmoch and Kirsch, 1993).
- *Patent claims*: the number of claims made in each patent application, which gives information on the range of novelties in the patent document. Recent research has shown that the average number of claims per patent has considerably increased over the last 20 years and that significant differences are found across countries (Tong and Frame, 1994).

2.3 The nature of innovation surveys

Contrary to patent data, innovation surveys have been developed from the outset with the specific aim of acquiring information on innovative activities carried out in firms. Until very recently, innovation surveys were organized by government agencies, statistical offices or academic institutions for their own specific needs. In consequence, the results achieved differ quite significantly and are not easy to compare (for an attempt to do so, see Acs and Audretsch, 1991; Hansen, 1992; Smith, 1992a, 1992b; Kaminski, 1993). Tables 1 and 2 summarize the nature of the information drawn from innovation surveys and its strengths and weaknesses.

Innovation surveys have also to face up to the very heterogeneous nature of innovations. A jet engine, a microprocessor, but also a corkscrew or a hairpin, might all be classified as innovations. Several attempts have been made to classify innovations according to their economic and/or technological significance. Innovations have been divided into 'improvement' versus 'basic', 'incremental' versus 'discrete', 'minor' versus 'major', and Freeman (1992) has proposed a detailed taxonomy of innovations. Innovation surveys have also distinguished between innovations that are new at world level and those that are new for an individual country, industry or firm.

Recently, the OECD and other national and international organizations have made an effort to standardize the methodology and the information collected by innovation surveys. The Oslo Manual (OECD, 1992a) provides guidelines on the method and issues to be covered by innovation surveys. In collaboration with the OECD, EUROSTAT has prepared a harmonized questionnaire, and in 1993–94 the EU-sponsored Community Innovation Survey (CIS) was carried out. For the first time, innovation surveys which are, to some extent, internationally comparable, have been completed in most OECD member countries (see EUROSTAT, 1994; Archibugi *et al.*, 1995). The first preliminary national findings to be available were those of France (see Lhuillery, 1995), Italy (ISTAT, 1995; Archibugi *et al.*, 1995), Germany (Licht, 1994), and Canada (Baldwin and Da Pont, 1995).

As Tables 1 and 2 indicate, there are two different approaches to innovation surveys. The first collects information at the level of individual innovations; this is the 'object' approach. The information collected in this way is classified according to the 'technological' or 'product' criteria listed above (Section 2.1). The second collects information at the level of the firm producing and/or adopting the innovation; this is the 'subject' approach. The information collected in this way is classified according to the 'sector of production' of innovations as defined above (Section 2.1).

2.3.1 The 'object' approach: innovation counts

In this approach, the individual innovation is the analytical unit of the survey. Additional information can also be collected and recorded, such as the size and main product line of the firm that introduced it. The object approach originated in order to acquire information on the dynamics of technological change in the context of the link between innovations and the long-run swings of the economy.

The SPRU innovation database, which contains information on 4800 radical innovations in the United Kingdom since World War II (Townsend *et al.*, 1981) constituted a major development of this approach. The US Small Business Administration has collected information on 8000 innovations commercialized in the United States in 1982 from technical and scientific journals and magazines (see Acs and Audretsch, 1990). A similar approach has also been used in some European countries (see Wallmark and McQueen, 1991; Kleinknecht and Bain, 1993; Santarelli and Piergiovanni, 1995; Coombs *et al.*, 1995).

The object approach has much in common with patent analysis since both represent innovation counts. Comanor and Scherer (1969), Achilladelis *et al.* (1987, 1990) and Acs and Audretsch (1989) have compared patents with innovation counts. They aim to acquire information on the same target population, i.e. the innovations introduced into the economic system, although the methodology used to select the sampled observations is very different. While patents constitute a well-defined population—the inventions registered to secure legal protection—the same cannot be said for the population of innovation counts. In fact, none of the available databases claims to collect information on all innovations introduced, nor on a statistically significant sample. In general, counts of innovations monitor fewer observations than patents, but record a larger amount of information for each of them.

The advantages of innovation surveys based on the object approach are:

- They represent a direct measure of innovation, and they only include innovations considered to be technologically and/or economically significant.
- They provide significant information on the evolution of technology, since they make it possible to record precisely when and how a certain innovation was introduced.

Their disadvantages are:

- The definition of the sample is arbitrary. Experts may have different perceptions of the relevance of individual innovations.
- It is very difficult to develop internationally comparable databases. Each of the surveys has used its own design, sample definition and implementation.

2.3.2 The 'subject' approach: surveys of firms

This is an alternative method of acquiring direct information on innovation in industry, in which firms are surveyed to learn the inputs, outputs and characteristics of their innovative activities. While both patenting and innovation counts collect information on innovations *per se*, the subject approach also allows one to gather information on various aspects related to innovative activities, as well as on non-innovating firms and on the factors that hamper innovation. It also makes it possible to collect information on innovative activities that do not lead to the introduction of actual innovations, because, for example, they resulted in failures.

Depending on the design of individual surveys, the nature and amount of information collected may vary considerably; only recently has an attempt been made to collect standardized information. The data drawn from the subject approach can be treated as part of industrial statistics, since they provide information at the firm level on both the inputs and outputs of innovative activities.

The Oslo Manual (Chapter 5, pp. 137–140) has listed the limits of the object approach, which are due to the heterogeneous nature of individual innovations. Following the Oslo Manual and the Community Innovation Survey launched in Europe, the subject approach is becoming the standard method for collecting direct information on innovation in industry.

Its main advantages are:

- The information collected can be related to the industrial structure. Innovations can be matched to economic data on production, value added, employment, etc., at the firm and industry level.
- It provides coverage of both innovating and non-innovating firms. This allows the factors preventing innovation to be explored.
- It gives information both on the firms generating and on those using innovations. This allows one to treat not only manufacturing but also the service industries.

Its main disadvantages are:

- In spite of recent efforts, it is not yet easy to gather internationally comparable data.
- Since the monitoring of innovation according to this method is still in its infancy, time-series comparisons are not yet possible.
- This method does not collect information on the technological nature of the innovations introduced in firms.

Considering the different advantages and disadvantages of technology indicators, it is important to compare the findings for a particular indicator to the picture provided by other data, including the more widely used R&D expenditure. Åkerblom *et al.* (1995) compare R&D, total innovation expenditure and sales according to innovative products and patents for Finland, and Grenzmann and Greif (1995) compare R&D inputs and patent outputs for Germany. Baldwin *et al.* (1995) compare R&D to innovation expenditure for Canada. For France, a study of patents and innovation survey results can be found in Kabla (1994).

2.4 The industrial classifications of technology data

When comparing different technology indicators among themselves and/or to economic variables such as production and trade, the comparability of the classifications employed raises a serious problem.

Innovation counts can provide different aggregations of the data collected, but a standardized classification has not been used so far. Innovation surveys of firms provide data at firm level which are consistent with the sources of industrial statistics. Provided that the survey is representative of the universe of firms, these data can be easily arranged in order to be comparable with information on production, value added, employment, etc., at all levels of aggregation, from individual firms to sectors of industrial activity.

Patent data are aggregated according to the International Patent Classification (IPC) and, in the United States, according to the US Patent Office Classification (USPOC) for which a cross-classification concordance to the Standard Industrial Classification (SIC) has been established.

Economic indicators on production and trade are generally available according to the International Standard Industrial Classification (ISIC), the Statistical Classification of Economic Activities of the European Community (NACE) and the Standard International Trade Classification (SITC). Depending on the type of analysis planned, different classifications have to be matched, and several efforts have been made in this direction.

Full information on the concordances with patent data that are available is provided in the Patent Manual (OECD, 1994). Patent data by SIC classes have been related to SITC data on trade (Soete, 1981, 1987; Grupp, 1991, 1992; Amendola *et al.*, 1992). A concordance between IPC and ISIC classes has been developed at MERIT (Verspagen *et al.*, 1994) and a concordance between IPC and SITC has been developed for 46 high-technology product groups by ENEA, Cespri and Politecnico di Milano and is reported in Annex IV of the OECD Patent Manual (see Breschi, 1994). Other work has been carried out at FhG-ISI in Germany and at the Finnish Central Statistical Office.

3. FIRM-LEVEL ANALYSIS

After spelling out the key concepts and the methodological problems for the use of technology indicators, three major dimensions of analysis have to be addressed: the company level, the industry level, and the country level. These will be discussed in sequence, in terms of three major research topics: the sources, the structure, and the impact of innovations.

3.1 The sources of innovation for firms

3.1.1 Evidence from innovation surveys

The innovation surveys carried out so far (see, in particular, ISTAT, 1989, 1995; Ministère de l'Industrie, 1994; and, for a comparison, Kaminski, 1993) have already highlighted several aspects of the sources, inputs and outputs of industrial innovation. One key piece of information provided by innovation surveys is the number of firms actually involved in innovation. Large firms or firms active in technologically dynamic sectors tend to innovate on a regular basis, while most companies, especially smaller ones, introduce innovations irregularly. On such a critical question, however, the different designs of surveys have so far prevented meaningful comparisons across countries. The framework provided by the OECD Oslo Manual and the Community Innovation Survey now makes possible the development of comparable evidence.

The CIS-based survey for Italy (ISTAT, 1995) covered close to 23 000 firms, one-third of which (7500) have declared that they introduced innovations in the 1990–92 period. The share of innovating firms ranges from 84% for firms with more than 1000 employees to 26% for firms with 20–49 employees. The CIS-based survey for France shows that in the same period close to 40% of firms (using a sample of 4500 firms) have declared that they introduced innovations, with similar differences across size groups (see Lhuillery, 1995). The CIS-based survey for Germany covers a sample of 2900 firms; 65% reported that they have introduced new or improved products or processes in the last three years or intend to do so in the coming years (Licht, 1994).

Innovation surveys have also produced new evidence on factors hampering innovation. Lack of funds, the excessive cost of innovation, and high risk are generally indicated as major obstacles (ISTAT, 1995). Such information can be useful in order to design specific policy measures aiming at increasing the rate of innovation in firms that already introduce innovations or to overcome the barriers to innovation in those that have failed to do so.

Innovation surveys have also identified the sources used by firms to sustain innovation. According to the CIS-based surveys for Italy and France (ISTAT, 1995; Lhuillery, 1995), sources internal to the firm (R&D and other departments), suppliers of equipment and materials, customers, exhibitions and trade fairs are (in that order) the main sources of innovation. Customers, technical journals, trade fairs and suppliers (in that order) emerge from the EPO survey as the main sources of information on technical developments for both patenting and non-patenting firms in Europe.

Another important finding on the sources of innovation is the remarkable inter-industry difference of patterns. While traditional industries tend to use sources external to the firm and often acquire innovations embodied in capital goods, science-based industries use internal sources such as R&D and design (see Pavitt, 1984; von Hippel, 1988; Archibugi *et al.*, 1991).

A major contribution of innovation surveys is the information they provide on the various expenditures related to innovation. The CIS-based survey for Italy shows that R&D accounted for only 36% of total innovation costs, with 14% due to design and trial production, and 47% devoted to innovation-related investment. The share of R&D grows with the size of firms, while the importance of investment falls (for firms with more than 1000 employees, it is about 40%) (ISTAT, 1995; the question was not included in the French survey). These findings confirm previous evidence for the importance of non-R&D costs of innovation (see Evangelista, 1995). However, each industry is characterized by a specific combination of embodied and disembodied, tangible and intangible sources of innovation.

Arvanitis and Hollenstein (1995) present an attempt to explain firms' innovative activities. Using data from the Swiss innovation survey, the authors find that the degree of appropriability and technological opportunities affect firms' innovations more than demand or market conditions. Crepon and Duguet (1994) examine how market effects and externalities affect innovation in French firms and find a close relationship between R&D and patenting.

3.1.2 The multi-technology firm

Industrial economists and management analysts often need to identify the technological nature of the innovations developed within a firm (Brockhoff, 1992). The majority of firms, and above all the large ones, are highly diversified, and this is reflected in their innovations. Their technological activities often cover a larger number of fields than their product lines. However, innovation surveys are not able to provide a satisfactory description of the technological nature of the innovations introduced.

Patents, instead, provide much more detailed information. The high level of disaggregation offered by patent data and the number of patents registered by large firms make it possible to investigate the distribution of a firm's innovative projects. Several studies have considered firms' patent portfolios either to study their technological diversification (Kodama, 1986; Niwa, 1992; Patel and Pavitt, 1994) or to identify to what extent firms benefit from innovations carried out by firms engaged in similar technological areas (Jaffe, 1986). These studies have shown that:

- the majority of companies have a wider distribution of technological activities than product lines and that they often produce their own equipment and machinery, or the intermediate components of their products;
- patents can help to identify company strategies, often before they are implemented in the market;
- patents are also a valuable tool for identifying the combination of different branches of knowledge into a new technological advance (technology fusion).

3.2 The structure of innovation: firm size and concentration

A current important topic in industrial economics concerns how industrial concentration and market structure relate to innovation. What is the relative innovation performance of small and large firms? Is there a specific market structure (such as monopoly, oligopoly or perfect competition) that can maximize the rate of innovation? This extensive literature is reviewed, among others, by Kamien and Schwartz (1982), Baldwin and Scott (1987) and Cohen and Levin (1989).

Several indicators, in particular R&D and patenting, have been used to test these hypotheses. These indicators are particularly valuable for describing the technological activities carried out in large firms. In fact, both R&D and patenting are concentrated in large firms: less than 700 world companies are responsible for nearly 60% of the world patents, a share slightly higher than their share of world business-funded R&D (see Patel and Pavitt, 1991b; Casson, 1991). Similar levels of concentration also emerge at the level of individual countries.

Neither R&D nor patents provide an accurate account of the distribution of innovative activities across firms of different size (see Ministère de l'Industrie, 1994). It has been shown that standard R&D surveys underestimate the amount of R&D carried out in small firms (Kleinknecht, 1987; Kleinknecht and Reijnen, 1991; Archibugi *et al.*, 1995).

However, beyond the question of the accuracy of the measurement of R&D activities, it appears that significant non-R&D innovative activities are carried out to a greater extent in smaller firms and in traditional industrial sectors. Innovation surveys have been used to assess the relative contribution of large and small firms to innovation (Pavitt *et al.*, 1987; Acs and Audretsch, 1990, 1992; Archibugi *et al.*, 1995; Malerba and Orsenigo, 1995). The results of these studies have confirmed the existence of significant inter-industry differences in concentration ratios. They have also shown that small firms in selected fields are not disadvantaged in terms of innovation when compared to their larger competitors.

Other attempts have recently been made to identify innovation flows in specific industrial districts. It has been suggested that small firms tend to create their own networks for acquiring and transferring technical information. The specific role of very small firms in the innovation process and as part of supplier networks of large firms is discussed by Kaminski (1995).

3.3 The impact on firms' performance

Patents and technological indicators also highlight the dynamics of the innovation process and its impact on the performance of firms. Technology is expected to influence firms' economic performance in a variety of ways, including productivity, growth and competitiveness. A major research project on these issues has been developed by the US National Bureau of Economic Research; it focuses on the relationship between technological factors (measured by R&D and patents) and economic indicators such as productivity and stock market value (see Griliches, 1984, 1990; Griliches *et al.*, 1991; Hall, 1993). It has shown that the technological performance of the firm is positively associated with its market value.

Using innovation counts, Acs and Audretsch (1990) have also studied the role of technology in the growth of firms. Simonetti (1994) has used patent indicators combined with other variables for US firms; Schwitalla and Grupp (1994) have undertaken a similar study for German firms. Geroski *et al.* (1993) have considered how innovation affects firms' profitability. While these studies have confirmed that performance and technology are associated, they have also suggested that it is not easy to identify a general pattern of causality going from the latter variable to the former.

4. INDUSTRY-LEVEL ANALYSIS

The characteristics of an industry play a key role in shaping firms' technological activities and performance. The intensity and scope of a firm's innovative efforts are strongly constrained by industry-specific aspects, including technological opportunities and market structure. Detailed information on the similarities and differences among industrial sectors and on flows of know-how is needed in order to understand the boundaries of firms' innovative activities. As for firms, the role of industrial structure is here considered in terms of the sources, structure and impact of innovative activities.

4.1 Technological interdependence

Technology systems are characterized by strong interdependence. Some innovations might be produced and used within the same firm, but most significant innovations move among firms and sectors. Some innovations have a single user industry; others have a more pervasive impact across industries. Much progress has been made in understanding and measuring economic interdependence, using techniques such as input–output tables (for a review, see Archibugi, 1988; De Bresson, 1990). Acquiring information on technological interdependence requires the availability of data on innovations classified according to both sector of production and sector of use. The study of technological interdependence has first a descriptive value. It makes possible, among other things, the identification of industries with strong interactions. It may also lead to important policy implications: identifying upstream suppliers of innovations for a specific industry may help design appropriate innovation policies.

4.1.1 Innovation flows across sectors

A variety of innovation surveys have also recorded and classified the industries that use innovations (see Robson *et al.*, 1988; Marengo and Sterlacchini, 1990; De Bresson *et al.*, 1994). Most studies have been carried out at the country level and identify the specific characteristics of user–producer interactions. Some key intersectoral links have emerged as persistent patterns. De Bresson (1995) finds important differences in the industry clusters according to intensity of innovation flows in Italy, France and China, thereby confirming the different innovative and industrial structures of the three countries.

4.1.2 Patent flows across sectors

Information from user sectors can also be obtained from patent data. Each patent document is assigned to a sector according to its technical nature, but since the invention involved should also be 'useful', a patent may also include a reference to its prospective use. The latter information, unfortunately, is not systematically collected in patent documents and databases.

Schmookler (1966) and Scherer (1982b) have identified the sector of use of individual patents, thereby making it possible to produce matrixes of technological interdependence, with each cell containing the number of patents that share the same industry of production and industry of use. From 1972, the Canadian patent office has also provided information on the industry likely to use patents (Séguin-Dulude, 1982; Hanel, 1994). A method to estimate patents by industry of use for all countries on the basis of the Canadian data has been developed by Robert Evenson and his colleagues at the University of Yale (see Englander *et al.*, 1988; Evenson *et al.*, 1988). Using Canadian data for the 1986–89 period, Hanel (1994) has produced a matrix for the production and use of inventions by 29 industries (the matrix is reported in the OECD Patent Manual, Annex IV–B; OECD, 1994).

4.2 The industrial structure of innovation

At the industrial level, it is possible to identify several common aspects of the structure of the innovative process. These have been summarized in various taxonomies based on different R&D intensities, on sources of innovations, on mechanisms of technical change, and on firms' strategies. Pavitt (1984) proposed a most successful taxonomy identifying four broad groups: industries where the introduction of innovations is generally based on R&D (science-based); industries where innovations largely come from suppliers of inputs and machinery (supplier-dominated); industries which emerge as specialized suppliers of innovative goods; industries where innovation and process technology are closely linked to scale factors (scale-intensive). This taxonomy has been widely applied to technological data, such as innovation counts and patents, either at industry level (Archibugi *et al.*, 1991; Kristensen, 1993) or at firm level (Cesaratto and Mangano, 1992; Molero and Buesa, 1994), as well as to economic data on production and trade.

Evangelista (1995) develops further qualifications of industrial patterns using data from the first Italian innovation survey and considering firm size and the nature of innovative activities (disembodied know-how such as R&D and design and engineering on the one hand, and technology embodied in tangible innovative investment on the other). Four groups are identified: technology users that introduce innovations developed by other industries; small-scale innovators that emphasize innovative design and engineering; industries dominated by large-scale firms, which rely on investment in innovative machinery; sectors combining both high R&D and high tangible investment efforts.

4.3 The impact on the performance of industries

The distribution of a firm's sales according to the type of innovation introduced is an important indicator of the economic impact of innovations. Such data are now included in the CIS-based innovation surveys; data for Italy show that 27% of firms' sales were due to products with (radical or incremental) innovations; 28% were affected by process innovations; and 45% had no innovative content. While little change is found in groups of firms of different sizes, large differences emerge among sectors; 75% of sales in the office machinery industry include product innovations, and shares of around 50% are found for most machinery and electrical sectors, while values below 20% are found in some traditional industries (ISTAT, 1995). In the French CIS-based survey, 41% of firms reported a share of innovative sales between 0 and 10% of total sales and less than 20% of firms reported that more than 30% of their turnover was related to product innovations (see Lhuillery, 1995).

This indicator of the market impact of innovations, as measured by the shares of sales of innovative products, offers a rather different picture from that of other technology indicators. In a preliminary analysis of the findings of the German CIS-based survey, the shares of innovative sales appeared largely unrelated to R&D and patent indicators (Licht, 1994). This confirms the results of the first Italian innovation survey (Cesaratto and Mangano, 1992).

This evidence can be related to EPO survey findings showing that, among European firms applying for patents, 47% of sales were unaffected by innovation, while 26% were due to new or substantially changed products and processes and 27% to improved products and processes. Among non-patenting firms, the share of sales with no innovation stood at 52%. No differences by firm size have emerged in these patterns (EPO, 1994, p. 74).

In assessing the impact of innovation on industry performance, it should be borne in mind that the most innovative sectors are also those whose weight in the economy is increasing. However, as pointed out above (Section 4.1), a major result of innovations is a reduction in the (relative) costs of new products and activities and, therefore, generalized productivity gains in several user sectors. In order to account for such increases in productivity, innovative activities, measured either by patent or innovation surveys, should be available for both sector of production and sector of use (see Scherer, 1982a; Englander *et al.*, 1988; Sterlacchini, 1989; Geroski, 1991).

Electronics is a major example of an industry that is an important producer of innovations. The dramatic reduction in the cost of many electronic products makes a comparison between high technological activity (as measured by patents) and the value of production in the industry (with growing volumes, but falling prices) potentially misleading, as the benefits of the innovations are actually distributed to user industries.

An industry's ability to exploit the benefits of the innovations it has produced is strictly related to the degree of appropriability. If appropriability and market power are strong, all benefits can remain with the innovating firm, and its performance may show strong productivity gains. Conversely, when appropriability is low and diffusion mechanisms and competition are strong, the benefits can quickly spread to users and consumers in the form of lower prices and/or better products or processes. In this case, productivity gains are expected to be found economy-wide. It may be pointed out that this is one of the implicit assumptions underlying research on innovation and 'total factor productivity' in neo-classical models (see Griliches, 1984; Englander *et al.*, 1988).

Innovation surveys provide additional information on the impact on performance expected or experienced by the innovating firms. While most of this evidence is likely to be qualitative and difficult to relate in a systematic way to quantitative variables, new light can be shed, especially at the sectoral level, on the link between innovation and performance.

The impact innovations introduced by firms have had on employment and capital intensities offers a relevant example. In the first Italian innovation survey, carried out on 8220 firms (see ISTAT, 1989), it was asked whether the innovations introduced had led to an increase, decrease or no change in the use of labour and capital. A study at industry level by Vivarelli *et al.* (1995) shows the labour-substituting effects of innovations (in most sectors and sizes of firms) and their capital-deepening nature (in practically all cases). The overall negative impact of innovation on employment in Italian industry is found to be caused by the dominant role of process innovations and embodied technical change. A labour-increasing ties that emerges from country data. Indeed, the characteristics of countries and their national systems of innovation, namely their industrial strengths and fields of excellence, remain important for shaping the direction taken by the international flows of innovative activities and the strategies of multinational firms. Barré (1995) argues, however, that international innovative networks organized by multinational firms and national systems of innovation affect each other in a broader way, with a variety of country and sectoral specificities.

These results, however, hold mainly for the group of more advanced OECD countries that are active participants in the globalization of technology. The perspective is different for the less advanced countries, which are mainly recipients of technology flows from abroad and which are more dependent on the activity of multinational firms. In terms of international flows of technology, the strategies of multinational firms and the policies of individual countries often follow divergent paths.

5.2 The structure of innovative activities across countries

When technological efforts are investigated at the country level, it is relevant to identify the structure of national innovative activities across industries. Many studies have compared industrial patterns of innovation across countries in order to describe a country's relative technological position and its relative specializations. While the lack of internationally comparable innovation data has prevented cross-country analyses, patent data have been extensively used to investigate national strengths and weaknesses in technological fields, at different levels of aggregation (see Soete and Wyatt, 1983; Patel and Pavitt, 1991a; Archibugi and Pianta, 1992).

A large number of patent-based studies have provided a detailed description of countries' innovative activities and comparative performances, and their changes over time. They include Narin and Olivastro (1987b), Slama (1987), Patel and Pavitt (1989a) for Germany; Patel and Pavitt (1989b), Narin and Olivastro (1987a), Cantwell and Hodson (1991) for the United Kingdom; Pavitt and Patel (1990) and Barré *et al.* (1994) for France; Narin and Olivastro (1988a) for Japan; Paci (1991), Boitani and Ciciotti (1992) and Breschi (1994) for Italy; Engelsman and Van Raan (1993) for the Netherlands.

This is a rather straightforward application of patent data; however, attention should be paid to the nature of the databases and indicators used when making comparisons across countries, industries and over time (these issues are reviewed in detail in the OECD Patent Manual). The use of different databases (patents in individual countries, in the United States, at the European Patent Office, in all triad countries, etc.) has made it possible to compare different pictures and to assess the value and limitations of patents as a technology indicator.

This evidence has shown that countries differ in their sectors of strengths and weaknesses in technology. Moreover, some countries concentrate their activity in selected fields, while others distribute their efforts more uniformly across technological areas. As expected, small countries show higher levels of specialization in technological activities as well as in industrial production and trade. In spite of the relative convergence of aggregated technological efforts in advanced countries, the differences in their sectoral specialization have generally increased (see Archibugi and Pianta, 1992).

5.3 Innovation and national performance

In order to investigate the impact technology has on the performance of countries and industries, several studies have related patent data to economic indicators, either at national level or when investigating industrial patterns. Aggregate studies of the role of technology as a source of countries' competitiveness have shown that a higher intensity of technological activities has a generally positive impact on national growth. A large body of literature on technology and growth has investigated this relationship, using all the available indicators.

Patent data, disaggregated by product/industry, have been used to explore the relationship between technology and trade. Several studies have shown that sectoral specialization resulting from patents is generally associated with the industrial pattern of countries' exports (Soete, 1987; Fagerberg, 1987, 1988; Cantwell, 1989; Dosi *et al.*, 1990; Amendola *et al.*, 1993; Verspagen, 1993; Eto and Lee, 1993). Other studies have explicitly addressed the problem of the concordance between different classifications discussed above (Section 2.4), developing a more accurate correspondence between patent classes and international trade categories (Soete, 1981; Dosi *et al.*, 1990; Amendola *et al.*, 1992). Grupp *et al.* (1995) link patent data and export performance of most OECD countries using a product-based classification of high technology.

Research on the patterns defined by the relationship between industries' innovative activity and national performance has provided a better understanding of the differentiated impact technology has on the growth of individual industries and has highlighted important specificities of national systems of innovation. This is a field where the availability of improved—more significant and more comparable—databases will open new opportunities for research and policy studies.

6. CONCLUSIONS

Patents and innovation surveys offer two important means of acquiring information about technological change in firms. They have advantages and disadvanimpact is only found in a few sectors characterized by higher expenditures for design and engineering and higher shares of product innovations.

5. COUNTRY-LEVEL ANALYSIS

Recent research has emphasized the importance of national systems of innovation and their differences across OECD countries in terms of institutions, relationships among actors, size of resources, sectors of specialization, and type of performance. In parallel, a growing literature has addressed the globalization of technology, which mainly results from the activity of multinational firms. This section discusses the national patterns emerging from innovation and patent data and the impact of cross-border flows of technology on countries' positions.

5.1 The global sources of innovation

The innovation process is increasingly taking place on a global scale. Archibugi and Michie (1995) have identified three major forms of globalization of technology (Table 3).

First, the *global exploitation of technology* includes the use by firms of patents and other intellectual property rights to protect their inventions and block competitors as they prepare their entrance into foreign markets or license their technology to local producers. This large and growing phenomenon (6% growth rate a year) is due both to the practice of extending protection to more countries (three to four countries on average) and to the actual growth in the number of patented inventions. Evidence on this trend is also provided by the joint report of the patent offices of Europe, the United States and Japan (EPO, JPO and USPTO, 1993) and by a study by Schmoch and Kirsch (1993).

Second, the *international collaboration* in firms' innovative efforts represents a pooling of resources from different countries, due to the search for complementarities in firms' technological and marketing strategies. It may involve not only the generation of innovations, but also their application, diffusion and adaptation to local markets. According to the database on inter-firm cooperation agreements developed at MERIT by Hagedoorn and Schankeraad (1993), there has been an average annual increase of 6% in the number of international technology agreements between the first and the second half of the 1980s. International collaborations are also revealed in the rapid growth of patents with inventors from more than one country. Brown and Hirabayashi (1995) examine this aspect and show that the number of US patents with at least one American and one foreign inventor grew from 90 in 1983 to 1500 in 1993. An analysis of EPO patents with inventors from France and other countries is carried out in Duguet (1994).

Third, a *global generation of technology* is found within single multinational firms when innovation is the result of efforts undertaken in laboratories and plants situated in several countries (Pearce and Singh, 1992). An indicator of this tendency is provided by the share of patents granted to the foreign subsidiaries of multinational firms. Recent studies (Patel and Pavitt, 1991b; Patel, 1995) have shown that these accounted for less than 4% of total patents in the period 1981–86, with 1% annual growth between the early and late 1980s. Schmoch (1995) presents similar results for multinational firms in the telecommunications sector.

These results suggest that the degree of globalization in the generation of technology by large firms is lower than it is for production and investment, and that it is confined to specific industries, countries and firms. The production of technology remains largely in (or in the vicinity of) the home country of the innovating firm.

While the globalization process is important for selected firms and industries, it appears to have little influence on the overall picture of innovative activi-

TABLE 3. Three meanings of 'Techno-globalism'

	Economic equivalent	Measure(s)	Results: Stock	Results: Flow
(a) Global exploitation of technology	International trade flows (as opposed to foreign direct investment)	Patents extended in foreign markets. Technological balance of payments	Patents were on average extended in 3–4 foreign markets in 1990	6% average annual growth rate for the OECD countries during the 1980s
(b) Global technological collaboration	International joint ventures	Inter-firm technical agreements. Patent licensing	Not available	6% annual growth comparing the period 1985–89 to the 1980–84 period
(c) Global generation of technology	Foreign direct investment (as opposed to trade flows)	Patents and R&D of firms from outside their home country	3.8% of US patents in 1981–86	1% growth between 1981–85 and 1986–90

Source: Archibugi and Michie (1995).

tages that complement other widely-used indicators such as R&D, trade in high-technology products, bibliometric indicators, etc., and provide in-depth information on certain aspects which cannot be obtained from other indicators.

6.1 New developments for patent-based indicators

The use of patenting as an indicator of technological innovation has grown steadily over the past decade. Patent data are available at low cost and in large numbers; this makes it easier for international organizations, government agencies, research centres, and individual scholars to use them. Several of their shortcomings can now be dealt with either by statistical elaborations or by refinement of the data. The most relevant research areas and problems are the following:

- The need for improved estimates, more reliable and more comparable across countries, of the extent to which patents account for all inventions and are actually used for introducing innovations or carrying out production at the firm, industry and country levels.
- Refinement of the quality of patent data in order to understand the value of individual patents. As mentioned above (Section 2.2), patent citations, renewal fees, number of claims and number of extensions are used to account for the individual value of each patent. Over the last decade, the cost and effort required by this type of research have been considerably reduced by the availability of computerized databases. So far, individual research teams have invested their own resources and efforts to produce these data sources. It would be desirable to obtain data on the quality of individual patents at the source, i.e. from the national patent offices.
- Patents are also used to study technological interdependence. At present, only the Canadian patent office provides information on the sector of use of the patented invention. This information enlarges considerably the usefulness of patent indicators, and Canadian patents have been used by a growing number of scholars. It is to be hoped that other patent offices will follow this example.
- As indicated in Table 2, one of the main advantages of patents is to provide internationally comparable information on detailed technological fields. Recent research has further improved the accuracy of patent-based international comparisons by examining the extension of patents to the most significant markets (see Schmoch and Kirsch, 1993).
- Patents are also increasingly used to monitor innovations occurring within the firm. Large firms have considerable innovative activities that are confidential in nature, but detailed descriptions of some of the most important innovative activities are reported in patent documents. Patents can be used to chart the direction and content of current innovative activities carried out by firms.
- Finally, a large body of literature has used patent-based indicators either at country or industry level in order to link technology to patterns in science, R&D, production and exports. Patents should be related to other data, including technology, bibliometric and economic indicators, in a more systematic approach.

6.2 New developments for innovation surveys

Innovation surveys are one of the main new developments in the measurement of technological change. Until very recently, they faced some basic limitations, notably the lack of harmonization and standardization over time and across countries. The OECD Oslo Manual and the EU-sponsored Community Innovation Survey (CIS) have made available a large body of evidence, with internationally comparable and standardized data, for the countries of the European Union. The main research areas and problems in this field are:

- Besides the core questions of the OECD–EU harmonized questionnaire used in the CIS-based innovation surveys, the surveys could gather information on a wide variety of themes of potential interest to researchers and policy makers. Agreement on which aspects deserve priority is important in order to make more effective the process of revising the Oslo Manual and preparing for the next round of the Community Innovation Survey.
- Innovation surveys carried out so far have indicated that, to obtain comparable results, a common questionnaire is a necessary but by no means sufficient condition. Survey results can be compared only if the statistical methodology used, including implementation and sampling, is harmonized. Efforts should be made to establish a common statistical methodology for the basic analysis of innovation data.
- Innovation surveys do not yet provide for carrying out time-series comparisons. It is now feasible and useful to start collecting data on innovation at regular intervals; it has been recommended that innovation surveys should be carried out every three years.
- Out of the large amount of information emerging from the CIS surveys, it would be important to identify new key variables that summarize effectively the evidence provided by the survey. In particular, variables such as the total cost of innovation, the share of sales due to innovative products, and the specific role of investment emerge as new major indicators derived from the CIS surveys. For each, it is necessary to validate their relevance and compare the evidence they provide with that provided by other indicators.
- Besides the specific quantitative indicators obtained, innovation surveys offer an important opportunity to investigate the deeper mechanisms of the innovation process, including the objectives

pursued, the sources used, the obstacles encountered. In particular, evidence on the objective of innovative efforts may shed new light on the process by which firms select innovations, on their quality and nature, and on their relation to organizational changes and to major current problems, such as the diffusion of information technology, technological unemployment, and environmental protection.

Finally, the results of the parallel developments in the fields of patent and innovation indicators should be compared in order to provide a more integrated picture of innovative activities at the firm and industry level. This would make it possible to give a more adequate quantitative description of the current technological strategies in OECD countries and thus provide support for policy decisions of firms and governments.

6.3 The 'next' innovation indicators

The field of innovation indicators requires close interaction between concepts and measures, between method and theory. It is expanding rapidly, and new developments are emerging in the context of different studies and disciplines. Researchers in various disciplines are increasingly using technology indicators in different conceptual contexts; they range from technologists and business specialists to economists (who study firms, industries or the macroeconomy), and from legal experts concerned with the appropriability of inventions to policy makers in science, technology and industry. They all make different assumptions and ask different questions. While the wide use of technology indicators should be encouraged, it is important to ensure interaction among the different disciplines, so as to stimulate continuing discussion and progress in the basic understanding of how technology indicators relate to changes in science, technology, economy and society. The range of innovative activities examined by technology indicators needs to be expanded.

6.3.1 Services

While most efforts so far have been confined to the manufacturing industry, the CIS survey is now being tested for the inclusion of service industries, which are major users of innovations, namely information technology. Here, the very concept of technological innovation has to be clarified, and progress must also be made on the criteria for the classification of service activities.

6.3.2 Software

Software, which represents a major area of innovation across manufacturing and service industries, presents a particular problem, since it is covered by copyright rather than patent protection.

6.3.3 Organizational innovations

Interest in the nature and relevance of organizational innovations within firms and in business networks is increasing. Important research questions include how to define and quantify them and how they relate to technological innovations.

6.3.4 Use of innovation

So far, emphasis has been on the production of innovations; however, more data is now becoming available on the use to which they are put, particularly in the case of information technology goods and services. More attention should also be devoted to the information that can be gathered on the objectives and priorities of innovative efforts, and, in particular, on their impact on employment, the environment and society.

6.3.5 The changing boundaries of the firm

While it is often assumed that the entire innovative process is carried out within a single firm, innovating firms in fact draw from a much broader range of knowledge and activities. The boundaries of innovating firms are in fact changing. The importance of large in-house R&D laboratories is declining, while inter-firm R&D cooperation, the role of small innovating firms affiliated to larger companies, the network structure of innovators, the closer links to university research, and the growing international dimension of the innovation process are increasing. More generally, the rapid pace of organizational innovations within business groups is also reshaping the scope and nature of innovation within firms.

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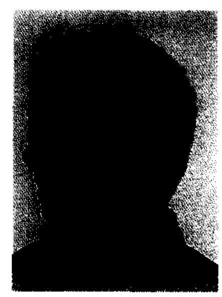

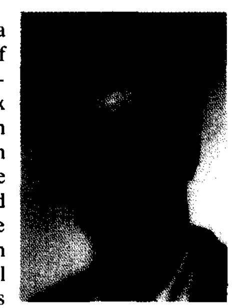

Daniele Archibugi (Rome, 1958) holds a degree in Economics from the University of Rome and a DPhil in Science and Technology Policy from the University of Sussex (UK). He was a stagiaire at the Commission of European Communities in Brussels in 1981–82 and a Junior Consultant of the Organization for Economic Cooperation and Development in Paris in 1983. He joined the Institute for Studies on Scientific Research and Documentation of the Italian National Research Council in 1985, where he has worked on theory and measurement of technical change. He has led research on the technological specialization of advanced countries promoted by the Commission of the EC. He has co-authored a few books on the economics of innovation and has published extensively in academic journals. He has been a consultant for the EC, the OECD and for other national and international organizations. He has been a visiting fellow of the University of Sussex, the Roskilde University Centre and the University of Cambridge.

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Translations of abstracts

Measuring technological change through patents and innovation surveys

Daniele Archibugi and Mario Pianta

Technovation 16(9) (1996), 451–468

Mesurer les changements technologiques grâce à des brevets et des études sur l'innovation

Résumé

Cet article offre une vue d'ensemble des recherches récentes qui utilisent des études sur l'innovation et les brevets comme autant d'indicateurs d'activité technologique. Nous débattrons des problèmes méthodologiques et conceptuels pour mesurer les changements technologiques. Nous avons classifié les différents types d'informations qui peuvent être tirées des bases de données concernant les brevets et les études sur l'innovation, ainsi que des études sur les efforts des entreprises innovantes. Ensuite nous passerons en revue les conclusions, les faiblesses et les forces méthodologiques de telles études, en prenant considération en tout premier lieu certains facteurs au niveau de l'entreprise elle-même. Ensuite nous ferons l'analyse de la structure industrielle, de nos observations au niveau du pays même et du processus de mondialisation. Un regard global montre que des conclusion très riches et importantes sur l'activité technologique des entreprises peuvent être tirées de ces indicateurs. Un résumé des nouveaux départs pour la recherche sur l'innovation ainsi que des données sur les brevets constitueront la conclusion de cet article. Copyright © 1996 Elsevier Science Ltd

Das Messen technologischer Veränderungen durch Patente und Innovationsumfragen

ABRISS

Dieser Aufsatz bietet einen Überblick über neue Forschung mittels des Gebrauchs von Innovationsumfragen und Patentdaten als Indikatoren technologischer Aktivität. Die konzeptuellen und methodologischen Probleme des "Messens" von Technologie werden diskutiert, mit einer Klassifikation der Arten von Information, die von Patentdatenbanken und von Umfragen zu Innovationen und den Innovatonsbemühungen von Firmen abgeleitet werden können. Die Ergebnisse und die methodologischen Stärken und Schwächen solcher Studien werden betrachtet; zuerst betrachten wir die Beweise auf Firmenebene, dann die Analyse der industriellen Struktur und zuletzt die Beweise auf nationaler Ebene und den Prozeβ der globalen Verbreitung. Der Überblick zeigt, daβ diese Indikatoren reichhaltige und wichtige Beweise für die technologischen Aktivitäten von Firmen beiten. Eine Zusammenfassung von neuen Ansätzen zur Forschung auf der Grundlage von Innovations- und Patentdaten schlieβt die Arbeit ab. Copyright © 1996 Elsevier Science Ltd

Medir el cambio tecnológico por medio de los patentes y sondeos acerca de la innovación

Resumen

En este artículo se ofrece un panorama general de la investigación reciente tomando los sondeos acerca de la innovación y los datos de patentes como indicadores de la actividad tecnológica. Se comentan los problemas conceptuales y metodológicos de "medir" la tecnología y se clasifica en distintas categorías la información que se puede sacar de los bases de datos de patentes y de los sondeos en lo que a las innovaciones y los esfuerzos innovadores de las empresas se refiere. Los resultados y las ventajas y desventajas metodológicas de estos estudios se revisan, tomando en consideración primero lo comprobado a nivel de empresa, en segundo lugar el análisis de la estructura industrial y por último la evidencia a nivel de pais y el proceso de globalización. En la vista general se demuestra que estos indicadores proporcionan evidencia rica e importante acerca de las actividades tecnológicos de las empresas. Se termina con un resumen de los nuevos puntos de partida para la investigación basada en la innovación y en los datos de patentes. Copyright © 1996 Elsevier Science Ltd

The indirect economic effects of Ecopetrol's contracting strategy for informatics development