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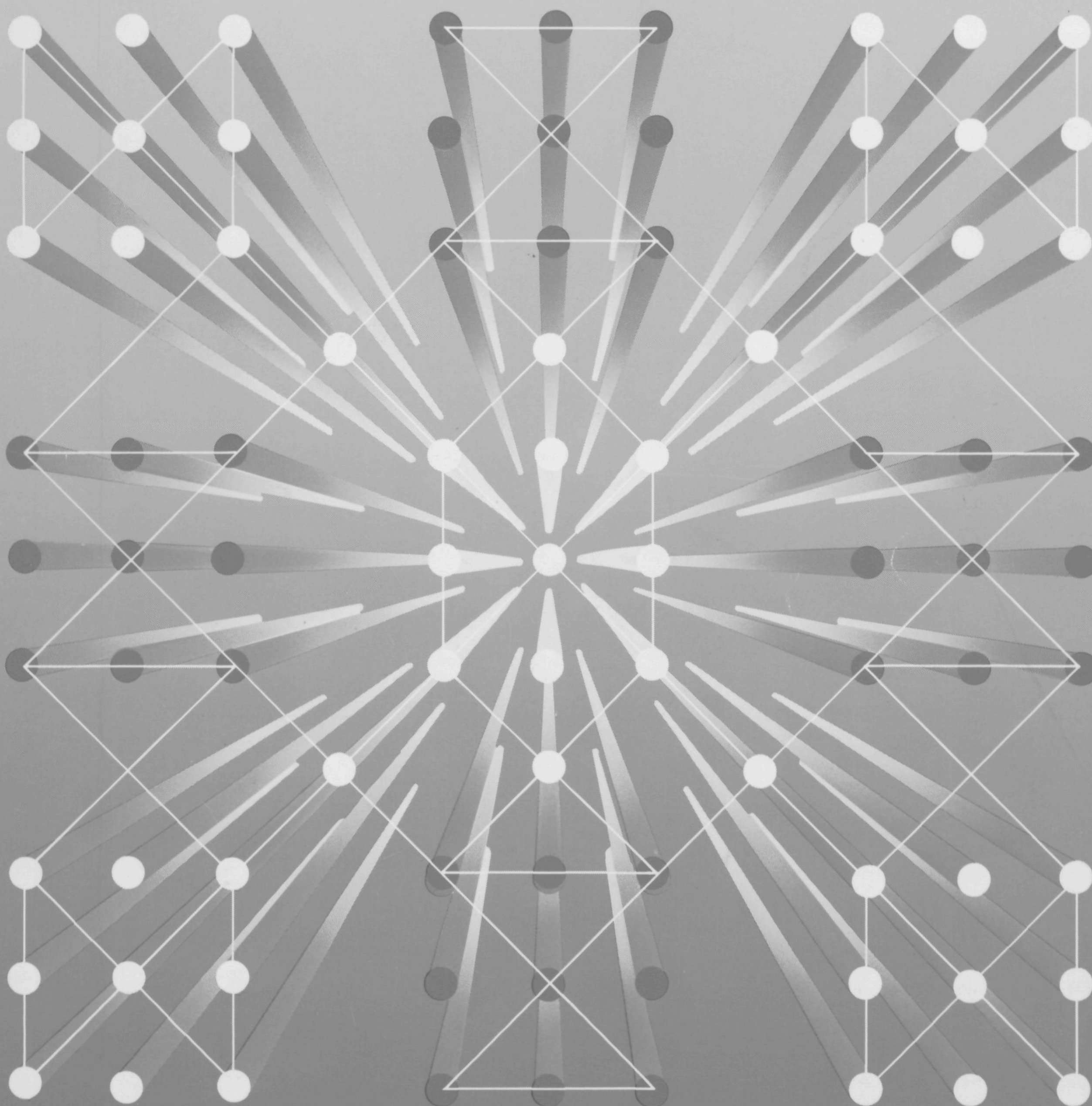

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PREFACE

This paper examines the use of patent statistics as science and technology indicators for Canada. It describes the current status of patent statistics and analyzes their advantages and limitations; reviews the various types of indicators constructed on the basis of patent statistics; and presents recommendations for the development of science and technology indicators.

Science and technology indicators may be defined as statistics which measure quantifiable aspects of the creation, dissemination and application of science and technology. As indicators, they should help to describe the science and technology system, enabling better understanding of its structure, of the impact of policies and programs on it, and the impact of science and technology on society and the economy.

Patents As Indicators of Invention is one of a series of background papers on science and technology indicators to be published by Statistics Canada. The purpose of the series is to describe the theoretical development, limitations and application of various statistics suggested as indicators of science and technology.

Current indicators of Canada's scientific and technological activities include:

- expenditures on research and development;
- federal government scientific activities;
- personnel working in science and technology;
- Canadian research output (citations);
- Canadian patented inventions;
- international payments and receipts for technology;
- trade in selected commodities.

Statistical tabulations of the indicators will be released in **Science and Technology Indicators,** Catalogue No. 88-201, an annual summary; **Industrial Research and Development Statistics,** Catalogue No. 88-202 (annual); **Resources for Research and Development in Canada,** Catalogue No. 88-203 (annual); **Federal Scientific Activities,** Catalogue No. 88-204E (annual); and in a monthly service bulletin, **Science Statistics,** Catalogue No. 88-001.

A list of the proposed background papers is included at the end of this publication. These papers represent the opinions of the authors and do not necessarily represent those of Statistics Canada. Comments are invited and should be addressed to Humphrey Stead of the Science and Technology Statistics Division.

This paper has been prepared by Professors Louise Séguin Dulude and Fernand Amesse of the École des Hautes Études Commerciales.

Martin B. Wilk
Chief Statistician of Canada

TABLE OF CONTENTS

INTRODUCTION

Society has always sought to improve comprehension of the activities on which its vitality and material well-being are based. An improved understanding of the nature, scope, evolution and comparative vigour of these activities opens the way to a clearer perception of their impact and the optimum conditions for conducting them. Twentieth century science and technology are no exception. Their impact on our way of life is obvious.

However, our comprehension of science and technology remains extremely limited, largely because of the problems involved in accurately defining and measuring them.

Progress in science and technology is part of a complex process involving a constant flow of information between scientific research, development, production and marketing, all aimed at a specific useful result and conducted within equally specific economic constraints. Measuring the process necessarily entails observation of all its aspects.

Over the past few decades great importance has been assigned to the human and financial resources formally engaged in the process. More recently emphasis has shifted to other aspects, e.g., references to scientific articles and patents.

A patent is an interesting gauge of science and technology. By definition it provides formal recognition of a new and useful scientific result. This does not mean, however, that a patent provides an unreservedly valid indicator of scientific and technological activity.

The purpose of this study is to report on current use of Canadian patent statistics. By way of introduction to the subject and to provide greater familiarity with its scope, we will briefly touch on patent statistics in general, including the definition of a patent and a discussion of the strengths and limitations of patent statistics. This will be followed by an examination of the various types of science and technology indicators that can be derived from patent statistics, with a view to determining the indicators most useful in the analysis of Canadian science and technology. Finally, the recommendations provided, are intended as guidelines for the development of science and technology indicators based on patent statistics in the light of their quality and usefulness in the Canadian context.

Despite the proliferation of literature on using patent statistics to measure science and technology effort, many of the studies on how such measurement would apply in Canada are very limited, and further work is needed to elucidate the potential development of such indicators. This is particularly true for the measurement of individual inventiveness in Canada.

The authors wish to give special thanks to Messrs. H. Stead, L. McCabe, P. Hanel and Y. Fabian, for their invaluable and highly pertinent comments on the final version of the report.

Chapter 1

PATENT STATISTICS AS SCIENCE AND TECHNOLOGY INDICATORS

Reasons for Renewal of Interest in Patent Statistics

Gone are the days when patent statistics were the only available indicators of the state of science and technology. Today there is a broad range of such indicators, most of them of recent development.

Government and research interest in the measurement and analysis of science and technology is relatively recent. The first national surveys of R&D (research and development) expenditure and personnel date from the mid-fifties. The efforts of the Organization for Economic Co-operation and Development (OECD) to standardize the measurements and make them comparable began in the mid-sixties.

Publications of statistical series on R&D resources almost entirely superseded patent statistics as a yardstick for science and technology. Patent statistics were used circumspectly, and expressly, as the only source of data in cases where company policy explicitly forbade publication of R&D budget information. Over a long period of time the most effective way to measure progress in science and technology was to measure R&D input. Patent statistics played a minor role.

Over the past few years opinion has changed; patent statistics are now seen as a valid indicator of some aspects of science and technology. Some applications are considered highly acceptable, and even unique. Among the main reasons for the change in viewpoint are:

. increase in importance assigned to the analysis of various aspects of science and technology;
. change in attitude to ward measurement in the field of science and technology;
. development of various data banks, making more information more readily available;
. incentives provided by various countries (e.g., the United States) and organizations (e.g., the OECD) for use of patent statistics as a science and technology indicator.

Individual discussion of each point should provide better understanding of the conditions under which patent statistics are most useful.

There is no doubt whatsever that all levels of government currently give increased importance to the analysis of various aspects of science and technology. There is overwhelming evidence that science and technology are the basis of any economy's productivity and competitive position. The sheer volume of resources poured into these fields is constantly rising, and allocating them effectively is a matter of increasing concern. The traditional measurement of science and technology input now appears insufficient. There is an urgent need for measurements that provide assessments and comparisons of science and technology results.

The need for more complete information on science and technology has led to a change in thinking on measurement. While there was a time when there was great discussion of the relative merits of the various measurement methods, it is now generally agreed that no one method can be complete or totally satisfactory. Indeed the word "indicator" is increasingly substituted for the word "measurement", reflecting a realization that measurement of scientific and technological phenomena is necessarily indirect and partial, reflecting only one aspect.

In 1978, Pavitt stated this view in a report for the National Science Foundation:

> The basic assumption of this paper is that both R&D and patent statistics show different aspects of the same process of industrial innovation. This is somewhat different from the normal assumption that since patents by definition involve novelty, and since invention is defined by novelty, patents capture and measure the earlier stages of a process that leads from novelty/invention through development, testing, engineering, to full scale innovation. [Pavitt (1978) p. 64]

The report given by workshop IV of the 1980 OECD Science and Technology Indicators Conference follows the same line of thought:

> Indicators usually have to be examined in groups or bunches which taken together may throw light on the phenomenon under review of which, taken individually, they could give only a very partial picture. [OECD (1980d) p. 2]

The very complexity of a scientific or technological phenomenon precludes direct, one-step measurement. The current analytical tendency is toward a broad spectrum of indicators that reflect the phenomenon's various aspects. A single series of figures, even several, is no longer sufficient. In some cases the various indicators point in the same direction, confirming structural features and trends of the science or technology in question. Conversely, indicators sometimes contradict one another. When this happens the analyst is obliged to examine the peculiarities of the science or technology or, at the very least, re-examine his conclusions.

The current interest in patent statistics and the accompanying search for new indicators has been fueled in part by the development of data banks and the work of organizations such as the OECD and the National Science Foundation. For years patent statistics were merely an adjunct of administrative data issued by national patent offices, and included no more than global figures on patents applied for and issued. Patent documents were long and verbose. Anyone trying to obtain a clearer understanding of a given science or technology by studying relevant patent documents was in for a long, tedious search. Jacob Schmookler's(1) historical series of patents grouped by industry are a good example of the patience such a task involves.

On completion of his study, Firestone was able to define some of the traditional limitations of patent statistics:

> Canadian patent statistics are not collected on the standard industry and product classification as is the case for statistics by the Dominion Bureau of Statistics. The data obtained by the patent office serve satisfactorily its administrative needs.
>
> But the statistics cannot be related to the host of other economic data collected by the Dominion Bureau of Statistics on a comparable industry and product basis, an essential requirement for economic analysis. [Firestone (1971) p. 311]

Three major developments in patent data and data processing have removed the traditional limitations on the preparation of patent statistics:

- privately-operated science and technology data banks established for the use of patent agents, companies and patent offices have provided access to all the information previously only available in patent documents; among the most important data banks are Derwent Publication Ltd., Search Check Inc. and IFI Plenum Data Co. (Claims Citation, Claims U.S. Patent Abstracts); related software provides a variety of methods for searching aggregate patent related information, especially that pertaining to scientific and technological content; the software was designed to be used by professionals involved in taking out patents, to facilitate anticipation search and assessment of patent strategy in cases involving competition; some researchers are now using it to develop indicators for specific technologies [Campbell (1982)]; others have used patent references or numbers of claims made in a patent to develop indicators of patent quality [Narin (1982b)].

- data banks containing patent-related economic information have also been established to meet the needs of experts who are interested in the economic impact of intellectual property or of scientific and technological activity and are attempting to establish a link between patents and other economic parameters; the banks are generally set up by government agencies, e.g., the Office of Technology Assessment and Forecast (OTAF), the Canadian Intellectual Property Office;(2) both these data banks consist of a series of relationships between patents and various aspects of the economy, in particular industrial classifications; since 1974 the National Science Foundation has published a concordance relating American industrial and patent classifications, providing statistics that can be used to analyze patents (issue and/or application) by product or industry; the Economic Analysis Section of the Canadian Patent Office has followed virtually the same procedure with the establishment of PATDAT;(3) this data bank contains traditional patent information plus additional economic data, e.g., possible manufacturer or user of patented invention; because of the data banks' purpose, the latter development currently offers the greater potential for the establishment of new patent based science and technology indicators.

- the third development is international in scope; it involves publication of international statistics on patents applied for and granted in a variety of countries; statistics are published annually by the World Intellectual Property Organization (WIPO); a further innovation is the establishment of INPADOC [International Patent Documentation Centre]; in both cases statistics and other data are

(1) An example of these series may be found in a collection of J. Schmookler's works edited by Z. Griliches and entitled **Patents, Invention and Economic Change.**
(2) Other national government agencies have developed or plan to develop similar data banks.
(3) The reader who wishes further details on the various data banks, more specifically on PATDAT, may refer to the Appendix at the end of this paper.

the fruit of efforts by national patent offices to provide reliable and comparable information through a system of international classification, which offers a potential source of science and technology indicators, especially those related to foreign patents applied for or issued.

The developments in patent information, especially the last two, have greatly benefited the National Science Foundation which has already added series derived from its patent statistics to its statistics on science and technology input; in addition, the OECD has held conferences on science and technology indicators, stressing science and technology output indicators.(4) The impetus provided by these two organizations has been an important factor in the renewal of interest in patent statistics.

Current interest in patent statistics and science and technology indicators may seem surprising, considering the almost total lack of interest in patent data when the first statistical series on R&D personnel and expenditures were released. The profound change is understandable in terms of the sheer volume of data required by today's science and technology analysts, coupled with their conviction that the varied aspects of science and technology can be most effectively assessed by the use of a plurality of specific indicators. In the words of an expert in the field:

> Even with their limitations, patent data represent one of the best output indicators of technological activity and indeed any "first level" assessment of the state of science and technology would include an analysis of patent statistics. [Bond (1979) p. 2]

Patent statistics are undoubtedly valuable science and technology indicators. Like any other scientific or technological data, they do have limitations. To understand how to use them one must understand their strengths and weaknesses.

Patent Statistics - Strengths and Weaknesses

Assessment of the strengths and weaknesses of patent statistics must be done in light of the use to be made of the data. All the characteristics attributed to patent statistics stem from the nature of the patent itself and its role in scientific and technological production. We will begin by defining a patent and then proceed to an analysis of the characteristics peculiar to it. This procedure is aimed at providing a better understanding of the limitations of patent statistics in specific situations and an appreciation of their scope as science and technology indicators.

The Patent's Peculiar Nature

A patent is a statement of ownership of an invention. It is governed by national legislation on intellectual property (which varies from one country to another). Patents are subject to the Union Convention for the Protection of Industrial Property, which ensures every patentee who is a citizen of a member country the uncontested right to that patent in all member countries and priority of foreign patent application. The priority essentially consists of a one-year exclusive right beginning on the date of the first patent application submitted in any member country. During this time the patentee may apply in the other member countries; the time limit is always calculated from the date of first application.

The grant of a patent requires:

- formal or informal invention (resulting from structured research and development carried out within an organization, or individual effort and ingenuity) that produces a result;

- that the result be a "patentable" invention, i.e., meet the "patentability" standards set out in the legislation of the various countries; two of the most important criteria are usually novelty and utility;

- that the inventor or the person who has control of the invention decide to take advantage of intellectual property legislation to protect the invention and comply with established procedure for issue of a patent; the inventor submits a patent application and may apply to intellectual property bureau in foreign countries; a patent application is in fact an application for exclusivity of manufacture, sale and use of a new and useful technical process or product, within the limits set out in the claims included with the application, and on the condition that full disclosure of the invention is provided;

(4) Other government agencies have shown an interest in this type of indicator. Two of these are INPI (**Institut national de la propriété industrielle,** France) and Statistics Canada (See **Science and Technology Indicators,** Catalogue No. 88-201).

. that the examiner (where there is a system for the examination of applications) accept the application; this involves a review of prior art to check that every claim made in the application meets "patentability" standards; the time taken for the examination will vary according to the complexity of the application and the efficiency of the intellectual property bureau involved; from one to six years may elapse between application for and issue of a patent; the overall North American average is approximately two to three years; the Office of Technology Assessment and Forecast (OTAF) gives an average of 19 months for the United States.

A count of patents applied for or granted is in reality a count of letters patent (applied for or granted). The resulting figure is not a complete measure of invention since it depends on a number of other factors. These include patentability standards as defined by the laws of different countries; the decision by the inventor or owner of an invention to have recourse to the intellectual property system or not; the strictness of examiners; and administrative delays encountered in the various patent offices.

The number that represents the aggregate of letters patent refers to a collection of items of varying importance. Letters patent attest to an invention's novelty and industrial usefulness. They in no way guarantee its marketability, from either a technical or economic standpoint. Not all patented inventions are produced industrially. In some cases, there are problems in transferring the technology to a large scale operation; in others there are marketing problems.

Kronz defines a patent as an expectation:

> The very nature of a patent count is, in my opinion, the manifesto of an expectation. The expectation or belief of the applicant is that, there is a technological and/or economical chance for progress and/or profit, obtained either by active or by passive action. [Kronz (1980) pp. 3 and 4]

A patent is an unusual item because of what it almost is; its strengths and weaknesses stem from this.

Patent Statistics - Strengths

Comanor and Scherer clearly summarize one of the greatest advantages of patent statistics:

> Patent statistics have one compelling advantage over alternative indexes of technical activity: availability in great abundance. Yearly counts are readily obtained for a span of more than a century, either in aggregated form or broken down by class of invention or sponsoring firm. [Comanor and Scherer (1969) p. 392]

The wealth of data contained in patent statistics can be used to establish time series that cover long periods. Figures on specific aspects can be obtained by breaking down the data according to a variety of technical and economic parameters. Patent statistics are no longer the exclusive source of long time series. Their significance is being challenged by expansion of other indicators (e.g., R&D expenditures and personnel). However, statistics on specific aspects of patents have retained their importance. They provide access to material that is cross-classified on the basis of a multitude of criteria related to inventors, patentees, and invention type. Some of the more important classifications are:

. country of residence of inventor and patentee;

. category of economic agent (individual, government, company);

. characteristics of economic agents, especially with reference to patent holding companies (R&D, sales, labour force, profit, industry, etc.);

. type of patented invention, by process/product type and technological content;

. industries that may benefit from the invention, as manufacturer or user.

Patent statistics are conducive to a more in-depth study of science and technology than any other relevant data because they allow for examination of the subject from many standpoints and approaches. They are extremely flexible, an important point because available science and technology indicators are narrow in scope, each one providing a picture of one specific aspect. Bond's (1979) analysis of the drop in patents granted to American inventors is a good example of analytical flexibility. Taking a drop in patenting by American residents as a starting point, she moves on to a comparison by industry, a comparison with patents granted to non-residents, and breakdown of foreign patents by country of origin. The overall picture emerges from the aggregated data. Adler (1980) provides a further example of the flexibility of patent statistics in his analysis of the decline in the number of patents granted within the chemical industry over the past 25 years. His figures even include a breakdown by major companies operating in the industry.

The examination process and the patentability standards applied to patent applications ensure that results in the fields of science and technology remain high. Many authors are of the opinion that this fact is a further advantage of patent statistics.

> The primary attractiveness of patent data is that: (1) there are annual time series available on the number (and composition) of patents issued, and (2) the grant of a patent reflects an initial judgment that a new idea beyond the prior art has been reduced to practice, i.e., a measure of technical inventiveness. [Schiffel and Kitti (1978) p. 327]

> The standards of patentability enforced by the examiner during the examination process create a "leading" indicator of scientific and technological effort. [Campbell and Nieves (1980) p. 6]

A patent is a formal statement that a new and useful technical result has been obtained. Because of this unique quality, patent statistics may be used as an indicator of science and technology results. The only other indicators available are related to resources earmarked for research. It would seem that patent statistics can provide at the very least a partial measurement of some scientific and technological results. There are problems involved. These will be discussed later in the section on the shortcomings of patent statistics.

The patent as an indicator of technological innovation is also useful in forecasting. In some fields, qualitative and quantitative analyses of patent applications indicate the emphasis and scope of current technical effort and development trends for the future.

> When a technology finally arrives at the market, it seems to the lay public, and sometimes to the competition, that it sprang from nowhere. In fact, it may have taken 10 or 15 years of feeding and probing to get from lab bench to loading dock. Of course, it is during this development period that technologies are least visible from the outside. Often, the only way we can tell that something is going on during this period is from patents. [Campbell (1979) p. 4]

In this context, the fact that a patent indicates only certain aspects of current technological development is of lesser importance than the fact that it indicates future development trends. Examination of the number and composition of patents in a specific class of patented inventions offers interesting opportunities to a company desirous of assessing its technological position, or to a planning agency in search of a definition and direction for a country's technology.

Pavitt (1983) sees a good future for this type of patent statistics usage, on the basis of several pertinent articles by Campbell and Nieves (1980), Campbell (1982) and Narin (1982a and 1982b). He emphasizes the importance of analyzing the increase in number of patents granted within specific technologies, and the number of references to patents. The purpose of the latter analysis is to determine which patented inventions are most cited.

Despite these positive aspects, Pavitt (1983, pp. 22-23) has two serious reservations that are worth mentioning. The first concerns the validity of the classification by technology used in patent analysis. Classification is in fact one of the more complex and frequently modified areas of patent records. There is no guarantee that detailed analysis of a class of patents is capable of reflecting rapid technological change. His second reservation is related to interpretation of the evolution of patent applications in a given technology. A higher than average increase in the rate of patent applications from within a given technological field is not necessarily indicative of a high level of inventiveness. For a relationship to be proven, it must be demonstrated that the fields of high innovation can normally be characterized by a period of intense activity involving an increase in patent applications. The use of patents in technological forecasting remains largely experimental.

Finally, patent statistics are potentially a major force because of their intrinsic international character. Most of the data involved must be obtained nationally before they can be compared. Because patents are part of a system of internationally integrated intellectual property, patent data are especially useful in uncovering aspects of science and technology that transcend national borders. This is especially true in the case of large multinational firms. These companies are said to play such a large part in the affairs of some countries that claims to domestic control of certain economic policies, specifically as concerns science and technology, are often unfounded. Information related to patent families, inventor's country of origin, patentee's country of origin and multinational control networks is probably the most easily obtainable, and most revealing of the multinationals' technological dynamics. In fact, patent related data are the only type of science and technology data that can transcend national borders and provide information on technology control networks.

The study carried out by OTAF analysts on patents taken out by the largest foreign multinational corporations [Lawson (1982)] is a good example of patent statistics use. In this case the patent statistics demonstrated the concentration of patented inventions in the hands of the multinationals and the relative position of American companies in the country's science and technology. Patent family data are especially useful to the study of multinationals: the technology and market strategy most beneficial to the corporation can be determined by analyzing the state of science and technology in a variety of countries.

To recapitulate, patent data have four unique, or virtually unique, features:

. they are available in long time series;

. they may be broken down into individual units and arranged according to a large number of parameters related to inventions or the owners of inventions;

. they provide results of, at the very least, the technical aspects of invention;

. they are international inasmuch as they are governed by current intellectual property legislation.

These features (especially the last three) make patent statistics an ideal tool for analysis of scientific and technological activity from various aspects and on various levels. They provide a picture of research productivity, and of future technological development and its international implications.

Patent Statistics - Major Shortcomings

The earlier definition of a patent and the reservations mentioned in the discussion of the advantages of patent statistics have also hinted at some of their shortcomings. The simplest way to describe these is by repeating the terms used by S. Kuznets (1962) in his incisive article on the problems encountered in the measurement of science and technology. Simply stated, patent statistics have limitations related to identification and evaluation. All the reservations expressed on the subject of patent statistics come down to the following two factors:

1. Identification

In the measurement of any phenomenon, the yardstick used should theoretically be capable of measuring the overall phenomenon at any time and in any place; patent statistics provide only partial or incomplete measurement; two common criticisms are expressed:

. not all inventions are patentable;

. not all patentable inventions are in fact patented.

Patent statistics do not include those inventions for which no patent application is filed because, under existing patent legislation, they are not industrially useful or innovative. Neither do they include patentable inventions for which no application is filed simply because the inventor decides against taking advantage of intellectual property legislation.

2. Evaluation

If a phenomenon is to be measured, each one of its units should be comparable or, at the very least, convertible to a common scale; patent statistics are made up of a wide variety of factors; a compilation or comparison of letters patent that cover a broad range of inventions produce figures that are not necessarily valid indicators of anything at all; such a procedure is much like adding containers with no regard to size or content; arranging the containers according to size and then counting them would be a step in the right direction; a further improvement would be to subdivide them by size and content; better still would be to convert each unit on the basis of a common scale of measurement (e.g., monetary value).

Evaluation problems are at the root of many of the criticisms that have been made:

- some patented products or processes are in fact major inventions; others are minor improvements to existing ones [Comanor and Scherer (1969), Demonts (1971), Bosworth (1973), Baker (1976), Pavitt (1979), Greif (1980) and Kronz (1980)].
- some patented inventions are potentially highly innovative, others are not [de Bresson (1980) and Greif (1980)].
- some patented inventions play a merely defensive role in company patent strategy, others are related to marketable commodities [Scherer (1965) and Greif (1980)].
- some patented inventions have a high economic potential, others do not [Schmookler (1957), Kuznets (1962) and Greif (1980)].

Evaluation problems are obviously very serious in themselves. However, like identification problems, they should be considered "relatively". This can be done by examining the way in which analysts have reacted to patent statistics shortcomings.

Reaction to Shortcomings of Patent Statistics

Reactions to patent statistics shortcomings are of three types, each of which can shed a little light on the shortcoming in question.

The first reaction to identification and evaluation problems related to patent statistics is the realization that the problems are common to all measurements of science and technology efforts, whatever the type of indicator.

Measuring R&D expenditure or personnel provides a picture that is no more complete. It takes no account of resources devoted to the upgrading of inventions by individuals, or small and medium-sized companies that have no R&D departments as such. Another shortcoming of the measurement of R&D expenditure or R&D personnel is the lack of information on input productivity. What is the use of adding up numbers of researchers and technicians with no regard to the quality of the work produced? The same is true of figures on dollars spent on R&D with no regard to the productivity of the money. These examples merely go to show that no actual measurement of science or technology effort ever attains the accuracy theoretically possible.

The second reaction to the shortcomings of patent statistics has more interesting possibilities. It is related to the calculation of probabilities and consists of considering each one of the limitations and inherent features of patent statistics as a random variable. If we admit that a number of factors (patentability of results, technical quality, market value, etc.) are the source of inaccuracy and lack of homogeneity in measurement, it follows that the measurement will vary according to these factors. If the distribution of the factors or features is held constant, the measurement will be significant to a certain degree, i.e., indicate a central trend. This argument has been stated repeatedly, in particular by Comanor and Scherer (1969) and Greif (1980).

The argument may be stated in more concrete terms. If, among all inventions, there is a constant probability of finding a patentable invention; if, among all patentable inventions, there is a constant probability of finding a patented invention; and if, among all patented inventions, there is a constant probability of finding an invention of a given quality, then patent statistics are a valuable indicator.

The above argument may satisfy the human search for logical explanation and so justify in a general way the use of imperfect yardsticks. It provides nothing in the way of explanation of the nature of the imperfections, and is valueless unless the distribution of the various factors is completely random.

The most satisfactory reaction to the problems involved in the use of patent statistics is undoubtedly that of the analysts who have attempted to measure the effect of the numerous factors that produce biased patent statistics. Three main questions arise:

- What is the relationship between patent statistics and other science and technology indicators, more especially input indicators (R&D personnel and expenditure)?
- What is the relationship between patent statistics and innovation?
- Are the relationships influenced by the fact that the firms being compared are of different sizes, belong to different industry groups and are located in different countries?

CHART 1. Authors Who Have Examined Basic Questions on the Subject of Patent Statistics

	R&D expenditure/ patent relationship	R&D personnel/ patent relationship	Bibliometric indicator/ patent relationship	Innovation/R&D/ patents relationship	Industrial patent use	Firm size/ patents issued	Industry of origin/ patents issued	Country of origin/ patents issued	Impact of industrial concentration	Impact of industrial and geographic diversification
Sanders (1964)					X					
Scherer (1965)	X					X	X		X	X
Mueller (1966)	X	X					X			
Sandor (1967)	X					X	X			
Harris and Finn (1968)					X					
Comanor and Scherer (1969)	X	X		X						
Firestone (1971a)					X					
Firestone (1971b)					X					
Johannisson and Lindström (1971) .						X	X		X	X
Schiffel and Kitti (1978)								X		
Soffer (1978)								X		
Pavitt (1979)	X	X				X	X	X		
de Bresson (1980)				X						
De Melto **et al.** (1980)				X						
Greif (1980)	X									
Macioti (1980)			X							
Hanel (1982)	X						X	X		
Narin (1982)			X							
Soete and Wyatt (1982)							X	X		
Scherer (1983)	X					X	X		X	X

We will answer the above questions in a systematic manner. Chart 1 presents the results in a different form for the reader's further information.

There is consensus among authors on the first question. They all find a significant statistical relationship between science and technology input indicators and patent statistics.

> An economically meaningful relationship does exist between what goes into the inventive process as measured by R&D and what comes out as measured by "patents". [Mueller (1966) p. 34]

> One strong result is that patenting, although not barred to part-time corporate inventors is closely associated with formally organized R&D activity. [Scherer (1983) p. 4]

This fact is interesting in itself; it also justifies the use of patent statistics as a science and technology indicator. However, all the authors do have reservations. They feel the relationship is significantly influenced by differences in firm size and industry group. More on that later. The first thing to do is examine the implications of the first question.

If there is in fact a statistically significant input/patent correlation, the two types of indicators must have something in common. In principle, and despite the reservations expressed, they relate to the same reality. It is logical to use patent statistics to analyze aspects of science and technology not easily examined by input indicators. However, the relationship is not straightforward enough for patent statistics to be a valid indicator of R&D output and productivity. Patent data must first be made comparable, taking into account the intrinsic differences in quality of patented inventions. Comparability has been the goal of a number of attempts to develop a quality index based on number of claims or patent references made, or number of foreign patents granted.

Examination of the possible relationship between patent statistics and innovation has so far been approached from two directions. The first considers the extent to which a patent identifies an innovator, and the extent to which innovation leads to patent application. The second approach examines eventual use or marketing of patented inventions. Both approaches deal with the patent/innovation relationship, i.e., the value of a patent as an indicator of innovation. One of the reasons for the complexity of the relationship is the difficulty involved in defining the word "innovation".

C. de Bresson (1980) and de Melto **et al.** (1980) have taken the first approach in their examination of the question. de Bresson attempts to pinpoint a relationship between firms that have structured R&D, firms that hold patents and firms identified as innovators by business reviews and industry experts. His results show that 36% of innovative firms do in fact engage in R&D, and that 21% of them hold patents. de Melto **et al.** examined 283 innovations introduced in five Canadian industries. They found that 32% of the innovations were patented, or that a patent was pending. This percentage may vary, however, with firm size, cost of the innovation and the extent to which it is truly revolutionary. At first glance it would appear that the patent is a poor indicator of innovation, but it must be remembered that innovation is extremely difficult to measure accurately.

Innovation may be the most elusive concept involved in measuring the economic impact of science and technology. It is also one of the most relevant. What exactly is an innovation? Basically it is a useful break with past practice, usually involving organizational or technical change. The scope of the word is far broader than that of the expression "patented technical invention". An innovation can be predominantly commercial or technical. Neither is necessarily more economically valuable than the other. Commercial innovation stems from in-depth market know-how rather than technical expertise. Technical innovation is but one aspect of innovation. Patented inventions are an even smaller aspect, which is not to deny their importance.

The second approach probably does a better job of defining the relationship between patent statistics and innovation. The basic premise is to determine the extent to which patented inventions are in fact used. The work done to date has produced some interesting results.

It would seem that between 50% and 60% of patented inventions are used during the lifetime of the patent. Sanders (1964) reports that rate-of-use figures for American companies vary from 49% to 71% depending on firm size. A study of the British system gives a use rate of 30% for Great Britain.(5) Firestone (1971b) reports that 51.4% of patents held by Canadian residents are used in Canada, compared to only 15.7% of patents held in Canada by Americans, and a mere 5.6% of those held by residents of other countries. Harris and Finn (1968) did a study of foreign holders of American patents. Only 20% of these were being used in the United States, although 40% were being used in the inventor's country of origin.

(5) Information taken from page 148 of Firestone's study (1971b), which gives the results of the **Report of the Committee on the British Patent System.**

These data have so far been largely ignored, despite their obvious interest. If a patent is to be appreciated as an indicator of "a particular type of innovation", it must first be seen as of intrinsic interest. It would seem that approximately half of patented inventions are used, most often in the inventor's country of origin. Some people view this result as disappointing. However, it is in line with other figures on the success and failure of new products and processes. There is a vast difference between invention and innovation; the failure rate is bound to be high. Regrettably, available data on patent use are fragmentary and based on studies of limited scope. If we are to gain insight into the innovative capabilities of economic agents (i.e., individuals or organizations) within various industry groups, we must have access to more accurate and complete data.

When taken in its larger sense, the fact of innovation goes so far beyond strict industrial application that patent statistics can never hope to measure the phenomenon. And, in concrete terms, innovation often involves secondary non-patentable modifications of existing processes and products. But, to the extent that patented inventions form an important reservoir of future innovations (especially of technical stripe), patent statistics might constitute an invaluable indicator if they are used with better knowledge of rates for success, failure or use of patents.

A third research approach is concerned not just with observing the relation between patent statistics and other indicators but with verifying that relation's stability. The major concern has been to find whether, regardless of differences in firm size, industrial sector, economic agents, type of invention and country of origin, the correlation between patent statistics and input indicators remains constant. The finding is that it does not. This means that the usefulness of patent statistics as indicators is limited by biases arising from the characteristics inherent in a given population. The nature of these biases must at least be stated clearly.

A common observation on the effect of firm size has been stated clearly and succinctly by Pavitt:

> As the size of firm increases, the ratio of R&D expenditures to sales increases, but the number of patents per unit R&D expenditure decreases. [Pavitt (1979) p. 67]

Why is the number of patents issued to a firm affected by firm size? The most common explanation is that research performance decreases with volume, i.e., the larger the firm, the lower the R&D productivity. The problems involved in using patent statistics as an output indicator are all too familiar. Simply stated, their usefulness is limited by their heterogeneity.

There are other explanations, some of which appear to be more satisfactory. Some authors see invention in a large firm as quite different from invention in a small firm. In a large firm, invention is complex and systemic, and risks can be taken. Small firms tend toward less technically ambitious development. This would explain the fact that the R&D/patents ratio is inversely proportional to firm size. Other writers believe that large firms tend to apply for fewer patents, either because patents offer little protection for their inventions, which are often related to processes, or because these firms believe they can better control the market through secrecy or technical superiority.

Nothing that has been suggested to date justifies outright rejection of any of the above explanations. Firm size has only recently been recognized as a factor. Any theory that takes quality or complexity of patented inventions into account will help explain the observed differences between small and large firms.

The important work of Scherer (1965) confirmed that the patents/input ratio is affected by industry group. The greatest effect is observed in industries that engage in work related to military defence, and industries that receive the lion's share of research contracts. In these industries, according to Mueller (1966), Pavitt (1979) and Scherer (1983), the ratio between patent statistics and input is generally small. The relatively smali number of patents can be explained by the secrecy surrounding most defence work, company patent strategy with regard to government contracts, and the fact that the type of work involved (prototype development, testing, monitoring), is not very likely to produce patentable inventions. Pavitt (1979) and Scherer (1983) claim that the same holds true for the automotive industry, essentially because of the nature of the science and technology involved. With such an overwhelming concern for product modification (design, etc.), few patentable inventions are to be expected.

Industry differences point to the need for an industry classification based on the type of science and technology engaged in, and for identification of modifying factors.

The differences attached to type of economic agent are simply the usual differences between individual and government. Individual inventions are generally considered less complex than company inventions; the percentage of inventions patented by individuals in a given industry is thought to indicate ease of entry into the industry. Pavitt (1979) disagrees. Lack of consensus is probably due to our lack of knowledge concerning individual inventiveness. It is generally agreed that government inventions have a low rate of use [Holman (1963) and National Science Board (1981)].

It is common knowledge that fewer applications are made for processes than for products. There are two probable explanations. A new process is often easier to protect by secrecy than by patenting. Furthermore, its potential economic value is often lower than that of a new product.

All the factors mentioned can be interrelated. A given industry may be less technically active in terms of patent statistics simply because the firms involved are relatively small, or because industry technology stresses process development. Emphasis on process development in the seventies is the most common explanation given for the slowdown in scientific and technological progress (at least in terms of patent statistics) during the period. The energy crisis, coming at the same time as increased interest in environmental protection, led firms to concentrate on improving existing science and technology, leaving no time for new product development.

Differences due to inventor's country of origin are easier to monitor than those discussed above simply because they are generally not directly related to invention as such. There are obviously differences between the various intellectual property protection systems and the effectiveness of their administration. There is also a significant difference between the propensity to patent in one's country of residence and the propensity to patent abroad. Furthermore, the propensity to foreign patenting is linked to both invention origin and projected market, on the basis of historical and economic links between countries (trade, investment, etc.).

Thus there are three reasons why it is decidedly risky to compare directly the inventiveness of a country's residents to that of non-residents. Basing any such comparison solely on a country's domestic patent statistics is no more reliable.

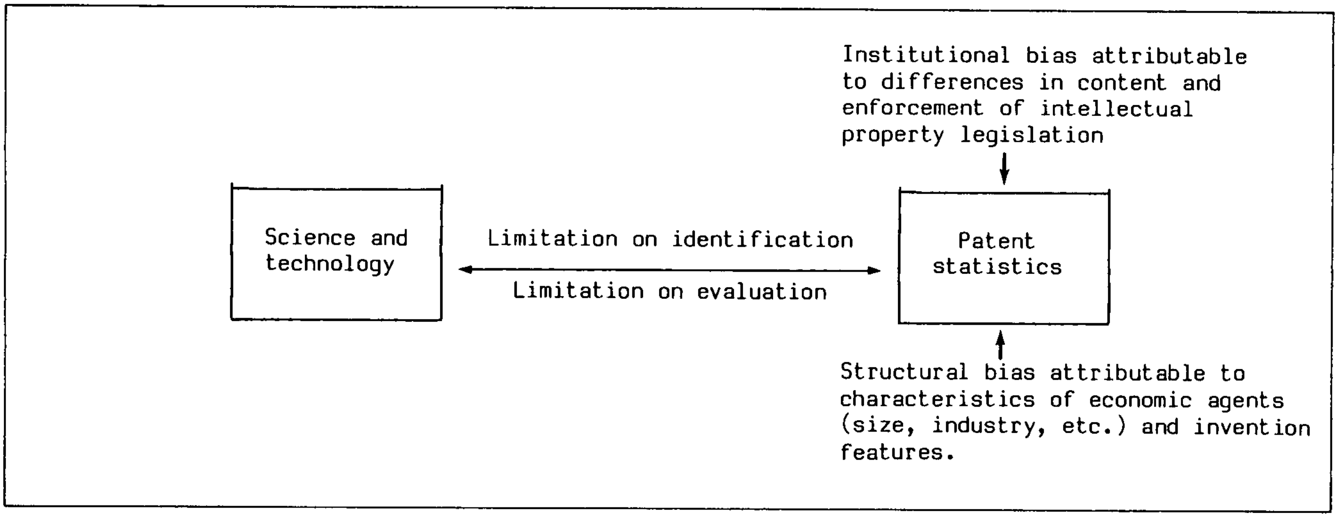
Figures on patent applications are often a more reliable source of information. They are less affected by legal and administrative disparities in intellectual property legislation. The information bias caused by the higher propensity to patent domestically can be avoided by selecting for comparison only patent applications made in a large foreign market. The figures will be even more reliable (and avoid the effects of historical and economic links and privilege) if the comparison covers the entire foreign market.

Conclusion

The complexity of science and technology and the increasing volume of resources being poured into the field have led many to express a need for indicators other than traditional input indicators. The growing use of computerized data banks in compiling patent statistics provides a wealth of pertinent information. Patent statistics have a number of advantages: the figures apply to the results of science and technology; they may be broken down and cross-classified in a variety of ways; and their scope is international.

It must be kept in mind that, strictly speaking, patent statistics are statistics on letters patent issued. They suffer from limitations inherent in this situation, and from the information bias resulting from a number of institutional and structural differences as depicted in Chart 2. Use of patent statistics to establish science and technology indicators must take these factors into account.

CHART 2. Facters Affecting Patent Statistics



Limitations on identification and evaluation are inherent to patent statistics. If they are to provide valid science and technology indicators, they must be used with great care. Current work aimed at increasing comparability of results shows promise.

Definite progress has been made in understanding the institutional bias of patent statistics. The newer indicators provide useful comparisons and minimize the impact of recognized causes of bias.

Structural bias is a more difficult problem to resolve. Although its most obvious aspects have been recognized, limiting their impact is another matter. Familiarity with the problem at least makes analysts more cautious in their interpretation of results.

In a recent discussion of the various types of science and technology indicators, Freeman drew essentially the same conclusions:

> Progress depends on using these indicators whilst taking full account of the genuine difficulties and taking appropriate steps in each specific case to minimize these difficulties. [Freeman (1982) p. 5.7]

To define useful indicators (i.e., indicators for all aspects of science and technology) requires consideration of all aspects of patent statistics. It remains to decide which of the various indicators available are the most useful for Canada.

Chapter 2

EVALUATION OF THE USEFULNESS OF PATENT STATISTICS IN CANADA

How to Derive Benefits from the Strengths of Patent Statistics in the Canadian Context

As shown in Chapter 1, interest in patent statistics is partly the result of the need for analysts to gain a better understanding of the various aspects of scientific and technological activity, and partly due to the unique strengths of patent statistics. There are therefore, despite the need for taking precautions in interpreting the data, clear benefits to using patent statistics as indicators.

Making use of the strengths of patent statistics means making the most of the fact that they represent public domain data which are not restricted by confidentiality requirements. Thus, analyzing Canadian industrial invention on the basis of patent statistics makes it possible to focus on unexplored aspects of invention. Another strength of patent statistics, which are becoming increasingly accessible as a result of computerized data banks, is that they make it possible to derive a great many national and international links for both aggregate and detailed data.

Any proposals to develop statistical series for patents must take both of these aspects into account to ensure that the knowledge concerning science and technology to be provided by such series would be difficult to obtain otherwise.

The specificity of Canada must also be part of such series. As the reports of workshops I and IV of the OECD Science and Technology Indicators Conference emphasized (1980a, 1980b), the development of statistical series must take into account the status of patent data in Canada as well as economic features specific to Canada until standard statistical series for patents have been developed.

That is why we will give special attention, in our consideration of possible statistical series, to the availability of data on Canadian patents and especially to the possibilities of the PATDAT data base.

For each statistical series for patents considered, we will examine the interest and usefulness for Canada. We will then describe how best to compile the series to ensure thay they will be worthwhile indicators. It is nevertheless worth pointing out here that although it is possible to construct a number of statistical series that will be of great general interest, the current status of work on invention in Canada will not always permit a clear statement of what interpretation they are to be given in Canada. In such cases, we would have to conclude that additional analyses would be useful for improved understanding of these series in the Canadian context.

Some Comments Prior to Our Consideration of Statistical Series for Patents in Canada

Before proceeding to our consideration of the various possible types of statistical series for patents in Canada, two underlying questions should be reviewed. They are of special importance for Canada because of the peculiarities of its patent situation. These two questions are:

- How does one define, in the Canadian context, the practice of science and technology by residents, as indicated by patent statistics?

- What are the limitations placed on the use of statistical series for patents by the small number of inventions patented by Canadian residents?

The Problem of Defining the Level of Canadian Science and Technology Activity

Most studies that use patent statistics to measure the level of a country's science and technology activity use as a criterion the patentee's country of residence, the inventor's country of residence, or the country where the original application was filed and used as a basis for establishing priority. These three criteria do not give the same results, although many data banks make use of only one of them, which must therefore necessarily be followed. For example, OTAF and WIPO use only the criterion of inventor's country of residence. The Derwent Corporation and INPADOC data bases use only the priority country where the original application was filed. PATDAT uses both inventor's country of residence, patentee's country of residence, as well as country of original application when the original application was not filed in Canada.

The results of applying these three different criteria are particularly significant in Canada, where the differences could well be very marked.

We have reservations about the use in Canada of the criterion of the patentee's country of residence and the criterion of priority based on country of original application.

The criterion of patentee's country of residence subjects the measurement of inventiveness to the uncertainties of assigning patents within the multinational network present in Canada. Many patented inventions invented by a foreign inventor are assigned to firms (usually subsidiaries) residing in Canada. A smaller number of patented inventions invented by Canadian residents are no doubt assigned to non-resident firms. Statistics Canada (1982) has previously pointed out that "one-quarter of the products and processes patented by Canadian residents were invented abroad" (p. 45).

The criterion of priority based on country of original application is not normally used to define a country's inventiveness when there is information about the inventor's or the patentee's country of residence. However, a number of data banks do not provide this information, which means that the priority country must be used as the best approximation for inventor's or patentee's country of residence. If it were to be used for Canada, this criterion could seriously underestimate Canadian inventiveness because many Canadian inventors and patentees first patent their inventions in other countries, especially the United States.

Thus the criterion of inventor's country of residence, or PATDAT's use of both inventor's and patentee's country of residence as criteria, are much better measures of Canadian inventiveness. Nevertheless, providing a count of Canadian inventiveness remains a complex matter that merits further study.

Many inventions by Canadian inventors are patented in Canada alone, while others are patented abroad without subsequent filing for a patent in Canada, and still others are patented in Canada and in other countries on the basis of Canadian priority or another country's priority. It should be recalled that Canadian residents apply for more patents in the United States than in Canada, a fact reported first by Schiffel and Kitti (1978) p. 330, Ellis (1980) p. 19 and Statistics Canada (1982) p. 43.

Greater knowledge of this phenomenon would no doubt help in understanding the effects of large markets and particularly of North American integration on Canadian invention. Additional knowledge would also perhaps make it possible to develop special indicators to measure the quality of Canadian inventiveness. Some authors [Harris (1979) p. 24, Faust and Schedi (1982) p. 4 and Savignon **et al.** (1982) p. 1] see a measure of invention quality in patents filed abroad and in the size of the country in which patents are filed.

Limitations Due to the Small Number of Patents of Canadian Origin and/or Ownership

The final issue of the **Annual Review of Science Statistics** (1982) listed various statistics on Canadian invention. From 1978 to 1980, Canadian residents filed an average of 1,753 patents each year in Canada, 2,027 in the United States, 428 in the United Kingdom, 245 in Japan and smaller numbers in various other countries.

This small number of patents filed or obtained by Canadian residents reflects the even smaller number of economic agents responsible for the phenomenon. It certainly sets limits on the level of detail that can be achieved in analysis or statistical series for patents. The number of observations for various categories would be nil or so small as to restrict interpretation of the data to commenting on the general behaviour of certain economic agents. The data could also be unstable from one year to the next, revealing no significant trends. Thus the small number of patents for Canadian inventors limits the possibilities for producing detailed series, at least for Canadian invention.

Using an average or aggregating the data for several years could provide a partial solution to these problems. One would have to check, however, that the data observed in the statistical series do not reflect only one or two economic agents. If this were the case, the phenomenon in question would have to be clearly linked to these few agents and not attributed to Canadian agents as a whole.

Various Classes of Science and Technology Indicators Based on Patent Statistics

Now that these reservations have been stated, it is time to look into the various classes of indicators that have already been used for various purposes or that could be so used. We will examine in turn the following specific indicators:

- aggregate indicators of invention;
- economic agent indicators;
- corporate indicators;
- technology-specific indicators.

For each of these types of indicators, our approach attempts to describe why they are of interest, to analyze their significance in the Canadian context, and to specify ways of implementing them.

Aggregate Science and Technology Indicators

Aggregate science and technology indicators based on patent statistics are the indicators encountered most commonly, both because of their convenience (using a single figure or ratio as a science and technology indicator) and the availability of data for such indicators. In general, they attempt to make various types of comparison possible, either in terms of time or space (national vs foreign) at a given time. In short, an aggregate indicator is a figure or ratio which, when used in various comparisons, may indicate a relative trend or weighting of science and technology effort for a given country.

Comparisons of various time periods are used much less than comparisons between residents and non-residents at a specific time. However, the change in the number of patents applied for or obtained by the residents of a country, or the change in the percentage of total patents applied for or obtained by the residents of a country, have elicited a great deal of interest in recent years. American findings based on decreasing trends signified by this figure or this percentage underlie this interest [Bond (1979)]. In Canada, even though the figure and the percentage are low (averaging between 5.8% and 7.8% from 1978 to 1980 depending on which criterion of Canadian inventiveness is used), an historical series would be of interest, if only to identify the direction of the trend. It is also of interest in view of the great emphasis placed by the Canadian government for the past few years on increasing corporate R&D effort. Constructing such series in Canada is not problematic when Canadian invention is defined using the criterion of inventor's country of residence. If the criterion of patentee's country of residence is used or if both criteria are used together, then only PATDAT can provide the required data, and it provides complete data only from 1978.

Comparisons of the position of nationals compared to non-nationals in patent statistics is the basic feature of aggregate indicators. There are in fact four main types of "international" comparison:

- comparison of the relative contributions of residents and non-residents to the total number of patents filed for or obtained in various countries;
- comparison of the percentage of patents filed for or obtained by non-residents in a specific country;
- comparison of percentage of patents filed for or obtained by residents in their country of origin and abroad;
- comparison of number of patents filed for or obtained by residents of two different countries in the other country.

This is commonly called the balance of patents.

These four types of comparison may be made on the basis of statistics on patent applications or patents granted. They may also be expressed in absolute, relative or weighted terms. However, before discussing the merits of each of these types of comparison and their interest for Canada, one must specify preferences between patent applications and approved patents on the one hand, and absolute and relative indices on the other.

(a) Patents Applied or Granted?

In general, most international comparisons are based on patent application statistics rather than statistics on patents issued. When patent statistics come from different patent offices, it is desirable to limit bias due to differences in intellectual property legislation and the efficiency of the various offices. Keeping to statistics on applications filed therefore makes it possible to reduce the problems caused by differences in procedures for examining patents, in patentability criteria, in the stringency with which criteria are applied, and finally, in the time required for a patent to be issued. From this point of view, the number of applications filed is a better reflection of the R&D effort of the various economic agents and their inventiveness [Comanor and Scherer (1969) p. 395, Schiffel and Kitti (1978) p. 328, Harris (1979) pp. 12-13, OECD (1983a) pp. 3 and 10]. It must be admitted, however, that application statistics are not as accurate a reflection of the actual number of inventions and are more indicative of the time of an invention's appearance [Kitch (1979) p. 59], while statistics on patents issued are more indicative of the moment of innovation [Comanor and Scherer (1969) p. 394].

In theory, any use of patent statistics from several countries should ideally use patent applications, while any use of patent statistics from the same country should use statistics on patents issued. However, statistics on applications are not as widely available as statistics on patents issued, and the latter sometimes suffer from inconsistencies due to various administrative circumstances. The National Science Board (1981) and Lawson (1982) refer to this in connection with American statistics on patents approved in 1979:

> Patent counts for 1979 are unreliable because the Patent and Trademark Office did not have enough money in that year to print and issue all approved patents [National Science Board (1981) p. 111].

(b) Indices Expressed in Absolute or Relative Terms?

Many of the indicators that can be derived from application or patent counts can be presented in absolute or relative terms.

- In absolute terms, one usually considers either the number of patents filed for or held by residents and non-residents, or the contribution of the latter to the total number of patents.

- In relative terms, the number of patents is weighted using either the Gross Domestic Product (GDP) or the total population or labour force.

An indicator expressed in absolute terms expresses for a group of countries the effort or weight of each in the international supply of inventions from these countries.

An indicator expressed in relative terms refers instead to the technological strength or weakness of the various countries, i.e., their competitive position. The purpose of the GDP weighting is to cancel the effect of national differences in gross potential demand for patented inventions. Some researchers [Schiffel and Kitti (1978) p. 348, Séguin Dulude (1981) p. 65 and Soete and Wyatt (1982) p. 8] use the GDP in this fashion. The purpose of using total population or labour force is to cancel the effects of national differences in the hypothetical supply of inventions, assuming that there are no national differences in technological performance. Others use total population [Soffer (1978) p. 35, Macioti (1980) p. 108 and Pinson (1980) p. 7] or total labour force [Stead (1983)]. To summarize, the indicator expressed in relative terms makes it possible to confirm the assumption of equal inventiveness once the differences in potential invention supply and demand have been eliminated.

Whether expressed in absolute or relative terms, these indicators are interesting and contribute toward providing a description of various phenomena.

(c) Contribution of Residents and Non-residents in Various Countries

Comparing the relative contribution of residents and non-residents to the total number of patents filed for or obtained in each country is a method used often. It is used by Schiffel and Kitti (1978), Soffer (1978), Statistics Canada (1978), Macioti (1980), the National Science Board (1981), and Soete and Wyatt (1982). We also know what is the result of applying this indicator to Canada: Canada is a country where the residents' contribution to total invention is weakest. This result and its possible interpretation call for further comment, however.

Let us begin by pointing out that the phenomenal growth in international trade in manufactured goods and in direct foreign investment over the past 30 years have strongly stimulated foreign demand for patents. Bosworth (1980) found a significant link between the number of American applications filed in 50 countries and the number of American subsidiaries located in these countries. Schiffel and Kitti (1978) found that there was a significant relationship between the number of patent applications filed by various industrialized countries in the United States and Japan and total export sales of these countries to the U.S. and Japan. Others [Holman (1979) pp. 50 and 51 and the OECD Secretariat and Pinson (1982) p. 5] basically argue that growth in the number of foreign applications is related to the internationalization of national corporations, which leads to a decrease in the residents' percentage of total applications or patents in the various countries, even in countries where there is a large number of firms with strong technological leadership.

In short, the more a country is a large market for export, investment or assigning licences, the greater is the interest of non-residents in obtaining its letters patent. Moreover, the larger the population, the higher the volume of production and the greater the number of technologically advanced companies, the higher will be the number of residents being issued patents.

In fact the combined action of these two forces determines the status of residents and non-residents in any given country. In countries with a small domestic market (e.g., Finland, Austria, Spain), the potential for residents is clearly low compared to the potential for non-residents, but then there is very little interest in such markets by non-residents. In countries with medium-sized markets (e.g., Canada, Belgium, Australia and Italy), the result of the action of the same forces will likely be very different: the potential of residents is clearly stronger compared to non-residents, but the markets are large enough to attract a great deal of interest from non-residents. The major industrial countries (United States, West Germany, Japan, United Kingdom, France), where both the potential of residents and the attraction of the markets for non-residents are very high, show much greater variations in the relative contributions of residents and non-residents.

Thus, comparing the percentage of patents filed for or issued in various countries by residency of applicant may well be somewhat of an indicator of a country's technological strength, but it is probably much more of an indicator of the attraction of the various markets for non-residents. Comparing countries in terms of the relative contribution of residents and non-residents to the total number of patents filed or issued clearly works strongly against countries with medium-sized markets, and it is therefore not a very good indicator of their technological vitality.

(d) Percentage of Patents to Non-residents in a Single Country

In view of the bias inherent in the first type of comparison (market attraction), many analysts have preferred a second type of indicator to offset the bias. In general, what was proposed was a comparison within a single country that is a major market for all the other countries. Most analysts chose the United States, including the National Science Board (1977, 1979 and 1981), Pavitt (1979 and 1982), Macioti (1980), Séguin Dulude (1981) and the OECD (1983). Others, including Schiffel and Kitti (1978) and Soete and Wyatt (1982), chose to use two or more major industrial countries.

It is clear that this type of comparison must exclude the residents of the one or more countries used for the basis of the comparison because, in such a market, nationals are those primarily concerned and have more ready access to their own country's intellectual property system. Notwithstanding these precautions, and no matter what country is selected for the comparison, its market never has the same level of attraction for all countries. Thus the countries with the highest levels of trade, investment, and cultural and political affinity should be favoured in such comparisons. The attraction of the major markets should also favour nationals of small countries whose domestic markets offer fewer opportunities for export, investment or patenting.

This type of comparison within the United States or another major market will therefore likely be biased in favour of residents of small countries and countries with priority links with the major country. Thus Canada should have a positive bias with the United States and a negative one with the EEC. Japan would likely be relatively neutral for comparison purposes, but for Canada, as for other countries as well, the number of patents filed for or granted would probably be so low that it could only be the result of the behaviour of a very few economic agents. Such problems have led to the development of other approaches.

Soete and Wyatt (1982), rather than using a single large market, chose to use several in order to be able to compare foreign application and patent statistics. One could similarly consider comparing several or even many countries by attempting to control bias by weighting. The number of foreign applications filed in a market could then be weighted by the total export sales of manufactured goods and sales by subsidiaries whose parent companies are in countries used in the comparison.

Finally, it is worth pointing out that a value could be determined for the change over time of such an index. In fact diverging trends of the index from one country to another could reveal the technological competitiveness of these countries. The index would, however, probably have a general upward trend because of the internationalization of national firms and its impact on the number of foreign patent applications. Holman (1979) went so far as to suggest that patents filed by or granted to multinationals be identified separately in such comparisons to better isolate their effect on the evolution of foreign patent applications.

(e) Percentage of Patents Filed for or Obtained by Residents in Both Their Country of Origin and Abroad

To offset yet again the biases identified in the various international comparisons that are intended to be indicators of each country's technological contribution and competitiveness, analysts like Soffer (1978), Macioti (1980) and Pinson (1980) made use of the number of national and foreign patents filed by a country's residents.

This type of comparison is very difficult to interpret, however, especially for medium-sized countries, because it includes two comparison features, each of which is potentially biased in the opposite direction from the other, without necessarily cancelling each other out. It is likely, however, that countries with a large number of multinationals that control subsidiaries in many foreign countries are favoured in such a comparison. In fact multinationals, which often operate in high technology industries, which centralize R&D effort in the country where the head office is located or in a few large countries, and which file for or obtain patents in many different countries, should weigh heavily in this type of comparison. Japan, on the other hand, should be underestimated because of the late internationalization of Japanese corporations.

It is in fact easier to understand this type of comparison if it is broken down into two stages. In the first stage, countries are compared on the basis of residents' contribution to the total number of patents filed for or obtained in each of the different countries. In the second stage, they are compared on the basis of the contribution of the residents of the various countries to the total number of international patents filed for or obtained. The comparison of international patents filed for or obtained by country could be specified further by distinguishing the number of inventions for which patents were requested abroad from the number of foreign applications to which each of these inventions gave rise. Using patent family data could make it possible to distinguish between the number of families and the number of family members.(6)

(f) Balance of Patents

The balance of patents makes it possible to compare the number of applications (filed) or patents (obtained) by residents of one country in a second country to the number of applications filed or patents obtained by residents of the second country in the first country. The indicator could then take the form of a difference or quotient for each pair of countries or for a country in comparison to the rest of the world or to a sub-group of other countries.

It has already been used by the National Science Board (1972, 1974 and 1976), Pinson (1980) and Statistics Canada (1980 and 1982), among others. This international comparison is intended to include only the foreign applications of the countries being considered in order to avoid bias caused by national applications.

It goes without saying that the positive or negative nature of this balance for countries of varying economic scales does not truly indicate the technological strength or weakness of a given country. Similarly, the comparison is clearly also affected by the trade and investment balance, which often derives from a technological advantage.

The evolution of the patents balance over time may, to a degree, reveal trends in the technological competitiveness of two countries. However, where a country's production moves toward internationalism, the trend of this balance may simply be an indication of a stronger propensity to patent in the other country, without really indicating a change in the country's level of technological effort. In fact, a constant or even declining number of inventions by a country's residents could give rise to an increasing number of foreign applications in the second country.

(6) Faust and Schedl (1982) suggested using only the number of patents establishing a priority. We believe that the number of countries in which a patent is filed provides additional information, i.e., as an index of the economic value of the invention.

(g) Recommendations on Aggregate Indicators

As we have seen, the four types of international comparison most commonly accepted as aggregate indicators of a country's technological status and competitiveness all involve interpretation problems due to bias in varying degrees.

The basic reason for these biases is that the comparisons take into account three aspects of the phenomenon at the same time: the different technological capacities of various countries, the different attraction of various countries in terms of patent applications and finally, the relative ease with which the various economic agents can file patent applications in one or more countries.

The interplay of these three forces varies for various specific indicators, although theoretically one would wish to measure only the first aspect. There are not, to our knowledge, any indicators that can neutralize the effects of the attraction and ease of patenting. At most, such effects can be somewhat offset. Their net effect, however, is sometimes to overestimate and sometimes to underestimate the technological contribution and position of a given country. Thus, analyzing a given country's position on the basis of the four types of indicator at a specified time could give different results without necessarily being nonsensical. It is therefore important to first evaluate the size and direction of the biases and to then compare the results for Canada using the four types of indicator before adopting one or more of them.

To evaluate the size of the biases, we recommend constructing a specialization index for various countries applying for patents in countries that issue patents. The index could be compiled using a matrix of applications filed by country of origin and by country receiving the applications. It is important to use a large enough number of patenting countries of varying size if Canada's (a medium-sized country) status is to be understood in comparison with the others.

The index could take the following form:

$$\frac{P_{ij}\Big/\sum_j P_{ij}}{\sum_i P_{ij}\Big/\sum_i\sum_j P_{ij}} = \frac{P_{ij}\Big/\sum_i P_{ij}}{\sum_j P_{ij}\Big/\sum_i\sum_j P_{ij}}$$

where P = number of patents applied for
i = by residents of country i
j = in country j.

Compiled using WIPO application statistics.

The index obviously represents the ratio of the percentage of total foreign patent applications by residents of country i that are filed in country j, to the corresponding percentage for residents of all other patenting countries. The index also shows the ratio of the percentage of applications filed by country i out of the total number of applications filed in country j, and the corresponding percentage for all countries issuing patents.

The entropy of this index is 1. In fact, when the ratio is 1 it means that the percentage of all of country i's (Canada's, for example) applications which are filed in country j (the United States, for example) is identical to the corresponding percentage for the other patenting countries. If the ratio is greater than 1, there is an emphasis on this country and no doubt a favourable bias due to the attraction for the residents of country i or to the ease with which they can patent there. If the ratio is less than 1, there is an under-emphasis and no doubt an unfavourable bias.

This study would therefore identify both the types of comparison and the countries that are likely to be subject to the most bias in order to make subsequent choices possible. To provide a better assessment of the relative value of these international comparisons in terms of stability and consistency, each of the four above-mentioned types of indicator should be compiled and studied for Canada over a specified period of time.

We believe that carrying out such a two-stage study would be highly desirable before selecting one or more aggregate indicators to measure the status of Canada's technology.

Science and Technology Indicators for Economic Agents

Immediately following the concern to develop good indicators to allow Canada to be compared to other countries in terms of technology indicators based on patent statistics comes the use of patent statistics to identify certain structural features of technological effort. The development of such series is more recent than for aggregate indicators, and there are fewer of them. One such development gave rise to a statistic designed to isolate the contribution of various types of economic agents to inventions patented by residents. The main interest is in individuals, government and business.

On average, from 1978 to 1980, 31.6% of patents issued by Canada to Canadian patentees and 41.6% of patents issued to Canadian inventors were granted to individuals. It is difficult to compare this to the figures for other countries because data on patents issued to individual residents are rarely included in international statistics. It is possible to do a comparison with the United States, however, using OTAF data. Statistics Canada (1982) reported that the contribution of individual residents is much lower in the United States than in Canada, with respective figures of 24% and 37% for 1976-1979. Bertin and Pinson (1979) reported a figure of 38.7% for France and were surprised about how large the figure was. Sirilli (1982) reported that the percentage of total patents issued in Italy that went to individuals was over 50%. For foreign applications, 39% of patents filed in the United States by Canadian residents were filed by individuals [Stead (1983) p. 43]. Thus both resident individuals and resident firms in Canada are filing the same number of applications in the United States. PATDAT data also make it possible to establish that individuals file initial applications in the United States as often as do companies resident in Canada. In fact 22% of Canadian patents issued to individuals and firms have American priority. Finally, the list of the 20 to 25 major domestic patentees of Canadian patents for Canadian inventions includes a number of individuals who hold as many patents as some major Canadian foreign subsidiaries.

All of the above indicates that the process of applying for and issuing patents in Canada is strongly linked to individuals. If the government(7) contribution to patenting were to be added to the individual contribution, 40% to 45% of scientific and technological effort, as measured by statistics on patents issued to residents, would be attributable to non-business sectors. This is significant in view of what has been said about individuals and government as participants in the inventive process.

A number of studies have nonetheless pointed out that the importance of individuals as participants in invention was decreasing. Kronz and Grevink (1982) confirmed this in their study of the patterns of the contribution of individuals to patent applications in England, West Germany, France and the United States from 1910 to 1980. The trend would indeed be a sign that in industrialized societies, science and technology is becoming increasingly institutionalized. This is the age of private and public research laboratories and professional researchers. All of which leads to at least two questions: how does Canada compare to other countries in terms of patents to individuals on the one hand and governments on the other; and what is the current trend in Canada?

According to Holman [(1979) p. 45], the number of foreign applications from a given country is inversely proportional to the percentage of domestic applications filed by individuals, because individuals do not have the same opportunity to file patents abroad and their inventions are not generally as good. How does this apply to Canada? A high percentage of total domestic applications is filed by individuals and yet we have observed, at least in the United States, that the individual propensity to file patent applications is at least as high as the propensity of firms to do so. Is this a strictly North American phenomenon?

In general, little is known of the inventiveness of individuals as displayed by patenting. Very little is known about who such individuals are and the degree to which they are independent of institutional research structures. It would appear that their inventions are primarily products rather than processes [Séguin Dulude (1981) p. 66], that they have little to do with complex and advanced technology industries [National Science Board (1981) p. 114 and Pavitt (1982) p. 38] and that inventions patented by individuals are concentrated in a few industries. As for the use of these inventions by individuals, all we can do is underline the fact that no information is available. Are these inventions dead ends because there is no demand or because the inventors don't have the resources to manufacture and market them? Are the patents primarily assigned to businesses under licence and, if so, to what types of firms?

All these observations lead to three main topics of interest. The first simply has to do with the role of the economic agents in patent applications filed by residents. An indicator that would make it possible to compare Canada to other countries and to follow trends would be worth considering here. Such a comparison would require similar data from other countries. Data of this sort on the contribution of individuals and governments to the total number of patents issued to nationals are not generally available in the standard statistical sources, although they are usually compiled by the various patent offices.

The second topic of interest concerns the behaviour of individuals as patent holders. This is more of a survey of individual Canadian patentees which could provide information about who they are and what happens to their patented inventions. All this report can do is note that there is no available information on such matters.

(7) One must be careful here in view of the dubious definition used by PATDAT to define this economic agent. (See Appendix)

The final topic of interest concerns the economic links between the inventive activity of the various agents and the Canadian industry structure, in order to provide information about how the various agents fit together.

One statistic that would be of interest in this connection would be the agent's contribution to patented inventions that could be manufactured or used in Canada's various industries, according to the PATDAT data bank. Of course this sort of statistic would have to be compiled over more than one year to avoid the problems inherent in the fact that there is only a small number of inventions patented each year by Canadian residents.

The National Science Board [(1979) p. 220 and (1981) p. 291] has already published such information for the United States. It involves statistics reporting the relative percentages of patents obtained by business, government and individuals for all patents issued to American residents for 55 classes of products. These statistics would appear to reveal significant differences between the three agents. It would also be possible, by using OTAF data(8) to break down data in a similar fashion for the various Canadian agents over a specified period for comparison purposes.

Business Sector Science and Technology Indicators

The number of patents issued yearly by Canada to all resident firms for Canadian inventions is a small one. The average from 1978 to 1980 was 668. The number of firms holding these patents is even smaller, because a small group of companies (Bell-Northern Telecom Ltd., Canadian General Electric, Inco Ltd., Du Pont of Canada, etc.) is very active, accounting for a high percentage of patents granted in Canada to resident firms. The issuing of patents by Canada to non-resident firms is, on the other hand, done on an impressive scale, with the big multinationals dominating the scene.

The statistic that would be most revealing of this state of affairs would, without doubt, be a table comparing the 25 largest patentee companies in Canada over a recent period (three years). The table would have to distinguish three classes of firms.

- Firms resident in Canada would be the first class. For the 25 with the most patents obtained, the total number of patents from Canadian inventors held by these firms would be given.

- Non-resident firms would be the second class. For the 25 with the most patents, the total number of Canadian patents and the number, or percentage of the total, constituting patents from Canadian inventors would be given. The difference would be an indirect indicator of how much of these firms' scientific and technological effort originates in Canada.

- Multinationals (parent company and subsidiaries, including the Canadian subsidiary) would be the third class. For the 25 major patentee companies, the total number of Canadian patents that they control and the number, or percentage of the total, constituting patents from Canadian inventors issued to their Canadian subsidiaries would be given, as well as the number or percentage of the total constituting patents on inventions by non-resident inventors owned by their Canadian subsidiaries.

The PATDAT data bank has all the data needed to construct this sort of comparative table, including the information on ties between firms for over 3,000 multinationals. These ties make it possible to determine whether a multinational's Canadian subsidiaries hold patents as well as their importance within the group.

We feel that, more than anything else, a table such as the one we have just described would tell us about the scientific and technological effort of the major companies and their degree of control over science and technology in Canada. The multinationals class should be particularly revealing concerning the level of participation by Canadian subsidiaries in the scientific and technological work of the groups to which they belong. There is quite likely a great deal of variation from one multinational group to another. Theories on the multinationalization of corporations generally show that corporations become international primarily to develop a comparative advantage that is often of a technological variety. Multinationals tend to concentrate their research and to locate research facilities on the basis of market size and differences in R&D costs and efficiency. Research and development facilities are often located close to the corporation's head office, where most of the multinationals' strategic activity takes place.

If one went beyond the table to data on the patent families, the international control of the multinationals over patents could be shown, as well as the role performed by the group's Canadian subsidiaries and Canadian inventors. This would be of great interest, but it would first require some experimentation.

(8) The characteristics of the PATDAT and OTAF data banks are compared in the Appendix.

In addition to the technological control demonstrated by patent ownership, an interesting area is the potential technological contribution of non-resident firms. The PATDAT data on potential manufacturing and user industries are of key importance here.

For the total number of Canadian patents issued to non-resident companies, a table giving a breakdown by industries that are potential manufacturers or users of patented inventions would be an indicator of the foreign contribution. It would be useful to further breakdown this contribution by firms whose head offices are in the United States, Japan or West Germany. For some industries, it would also be useful to be able to state the Canadian contribution of Canadian firms holding inventions patented in Canada, where this contribution is significant.

Ideally, the table should include an indicator of trends by industry. This type of indicator would give information both about science and technology trends in various industries and about changing patterns of competition among the major countries. In short, it would make it possible to indicate which industries are growing and which are declining, as well as the evolution of the competitiveness of the major firms of the major countries and of Canada. This type of indicator is, however, limited for the moment by the availability of data, because PATDAT has complete information only from 1978 on. It would be necessary to check the period for which such a trend index would likely be a useful indicator.

In short, a statistic on the technological contribution of firms would highlight the potential economic links between the inventions patented and the Canadian economy. Ideally, it should provide information about current competitiveness and trends.

It would, therefore, have to include a breakdown of inventions patented by firms by Canadian industry groups, information about the contribution of non-resident firms by major countries and finally, where apport is significant, the Canadian firms. For trends, it should indicate each industry's contribution trend as well as the general trend in the pattern of contributions for non-resident firms, major countries, and Canada.

Because of the small number of patentee firms in Canada, many other interesting statistics lose their meaning. It is nevertheless worth mentioning a few of them here, even though one has to be careful to assess the possibility of using them according to the context in which they are introduced.

In view of what we have already said on the subject in Chapter One, it would be most interesting to have a statistic for Canadian resident firms which compares R&D effort, patents, the size of firms and the major industry. Any integration, even partial, of these variables in a statistical table would be most revealing.

How many Canadian companies carry out formal R&D without holding any patents and, inversely, how many hold patents without carrying out any formal R&D? How does the link between the patent and the R&D effort vary from one size group to another? How does the link vary from one industry group to another?

All these questions bring us closer to problems concerning the links between various science and technology indicators on the one hand and, on the other hand, the determining factors for science and technology in Canada. A recently published study by Lacroix and Séguin Dulude (1983) considers these questions and confirms their significance.

Science and Technology Indicators by Family of Technology

One of the most original features of patents data is that they lend themselves to detailed breakdown into technological classes and sub-classes or, in other words, provide information about the content of inventions. The use of technological classes makes it possible to study specific areas of technology, either to describe what has taken place in the past or to determine what is likely to come about in the near future.

Data breakdowns of this sort have thus far been used primarily for technological forecasting purposes. In addition to identifying the major areas of intense technological effort and the most active companies, newcomers to the field are noted as well as those who are getting out, and new leaders are identified. Questions of this sort have been considered in various works, including OTAF (1977), Campbell and Nieves (1980), Campbell (1982) and Lawson (1982).

Of course this sort of detailed data analysis is of less interest in the context of technology indicator research based on patent statistics. One might, however, wish to have a statistic that indicates the status of developments in various areas of interest to Canada, such as fields requiring technological adaptation. For example, the National Science Board [(1981) pp. 115 and 116] is interested in energy-related developments. One might also be interested in developments relevant to environmental protection. In short, this family of technology approach could well be the key to development useful indicators for following up on State priorities, for example. It is not our role to identify such priorities, but we believe that they should include fields where developments foster the safeguarding of Canadian economic interests. The same is true for questions related to energy, environment and resources on the one hand, and new technology (robotics, office automation, biotechnology) on the other.

Once the fields of interest have been determined, there is the problem of selecting from among the various classes and sub-classes of patents those that contain the statistics relevant to the developments in question. The help of patent examiners and other patent experts would be essential here in defining the classes properly. Some data banks, including those of Derwent Corporation and IFI Plenum (U.S. Patent Claims), give access to technological data by means of a system of keywords which are used to define the families of technology. A discussion of the relative merits of accessing data through patent classes or key words would be far too technical for our purposes. It is worth pointing out, however, that using key words allows a greater degree of precision than classes, as well as greater flexibility in defining the technology field of interest.

In addition to the above questions pertaining to the collection of statistics on technology fields, a number of methodological questions must also be examined carefully and evaluated in terms of the objectives of the chosen statistic. One such question concerns the use of application statistics versus the use of statistics on patents issued. Another relates to the scope of statistics to be compiled, i.e., whether domestic or international data should be used.

Insofar as the main concern with this type of indicator is to produce a current and even future index of selected fields of technology, then theoretically at least, statistics on patent applications filed should be used. Application statistics tell more about the current state of development because they do not involve any delays between the invention date and the information provided. However, the various data banks that contain the most suitable data for the development of families of technology indicators are not based on applications but on patents issued. The only exception we are aware of is the WIPO industrial property statistics on applications and patents issued. These, however, are presented in an aggregated form that is of little use to us. In practice, then, statistics on patents issued will have to be used, and it will be necessary to search for current indices in information that is three or four years old, depending on the administrative delays involved. If this delay effect is to be kept to a minimum, data from countries where such delays are known to be as short as possible should be used.

Insofar as our concern is the status of a technology or a technological field, world information should be used as much as possible. Otherwise our indicators would reveal the status of the technology only for the countries covered by the patent statistics. We therefore believe that it is essential to collect data from one or more countries for which we are certain that most economic agents are covered by the data, and also that it will be possible to compare the relative strengths of the contributions.

The use of Canadian data on patents issued to construct indicators of activity in selected areas of technology could be of interest. It is clear that statistics that are to be used to construct indicators of aspects of technology very specific to the Canadian context, should be based on Canadian data.

Canadian data could also be of interest for other more international areas of technology. In fact, insofar as the economic agents responsible for developments are primarily non-residents from the major industrial countries, the use of statistics on their patenting in a medium-sized foreign country (Canada, in this instance) might well be expected to keep bias in comparing their performance and relative strengths to a minimum. Moreover it is far from obvious, despite the attractions of the Canadian market (size, per capita income, reliance on imports, etc.), that all the technological developments found in emerging technologies are patented in Canada. The international life cycle of technologies generally runs its first phase in the biggest markets.

However, the use of patent statistics for a major market, whether the United States, West Germany, Japan, France or the United Kingdom, would involve a clear-cut bias in favour of nationals of these countries and non-residents who have preferential links with these countries.

Ideally then, data from international patent data banks such as the Derwent Corporation or INPADOC should be used, because patent families are available from them and it is possible to make a distinction between the basic inventions patented and the many patents stemming from the basic invention.

Such international data makes it possible to more readily identify those involved in a given area of technology and to analyze their relative strengths. For Canada, however, serious limitations arise from using such data sources. The main problem is that there is no indication in these data of the inventor's or patentee's country of residence. To evaluate the relative strengths of the various countries, one must look to priority countries. Thus for the smaller industrial countries, the use of priority country as equivalent to inventor's country of residence is likely to weigh against them.

All of which shows that there is no ideal data base with which to construct an indicator for Canada. The data base should therefore be selected on the basis of the indicators of greatest interest.

We believe that this type of indicator should be based on two concerns: the significant presence of Canada in priority areas and the vitality of the areas of technology.

For the former, the bias should be as favourable as possible for the participation of Canadian inventors, because it is clearly more in our interest to prevent the introduction of a bias that would underestimate their contribution than one that would overestimate their contribution. Because the objective is less to evaluate the relative strength than it is to identify a significant presence, the PATDAT data bank and eventually the OTAF data bank could be used. The presence indicator could be a statistic of the percentage of patents held by Canadians in a specified number of areas of technology in Canada and the United States. If the indicator is close to zero, then this means there are virtually no Canadian inventors because these are the two markets most biased in their favour. If the percentage is close to the average for patents issued to Canadian inventors, then there is a significant presence.

For the second concern, our interest lies in the vitality of the areas of technology and the relative strengths of the various countries. It mainly involves identifying an international trend and evaluating the strength of the various countries in an emergent area of technology in order to determine which of the major industrial countries are involved in keeping the field active and healthy. This type of endeavour calls for international patent data of the kind produced by the Derwent Corporation or INPADOC. The vitality indicator could be a statistic on the growth rate of patents issued in certain fields of technology and on the percentage of patents issued to the major industrial countries.

Chapter 3

SUMMARY OF RECOMMENDATIONS

The first goal set for this study was to present an overview of the usefulness, strengths and weaknesses of patent statistics as science and technology indicators.

In general, we agree wholly with the views of those who claim that we do not currently have a satisfactory method of directly measuring science and technology effort, but rather a number of indirect and partial measures which are really indicators. We also believe that better analysis and understanding of science and technology are achieved by using a variety of indicators than by the extensive use of only a few. Different indicators describe various aspects of the phenomenon, and serve to confirm findings when they agree, or to call them into question and look into them in greater depth when they disagree.

We found that patent statistics have unique characteristics which make them a useful tool for analysis in spite of their limitations. The three characteristics which appear to us to be most useful are the following: first of all, patent statistics are evidence of the appearance of inventions; secondly, they are both national and international in character; finally, they are very flexible in their capacity for being used in all sorts of combinations and cross-classifications.

We also noted that in Canada, there is an abundance of patent data on the basis of which indicators could be developed. Specifically, Canada already has a computer data bank for patents which also contains economic data. In spite of a few shortcomings, this data bank compares favourably with the OTAF data base used to develop patent indicators in the United States.

We therefore recommend that patent statistics be used to develop a number of science and technology indicators that could be added to other indicators to facilitate analysis of science and technology in Canada.

The second goal set for this study was to examine the various possible indicators that could be based on patent statistics and make recommendations concerning them.

We examined four ways of using patent statistics to construct indicators: aggregate indicators, indicators for economic agents, business sector indicators and family of technology indicators.

Aggregate Indicators

Aggregate indicators are the most common and the most frequently used. Their purpose is essentially to make it possible to compare countries in terms of science and technology. We described four types of such indicators:

- contribution of residents or non-residents in the country under consideration;
- contribution of non-residents in a major market;
- contribution of residents to the total of domestic and foreign patents;
- the bilateral balance of patents.

Despite the various current uses of aggregate indicators, we discussed primarily the first type.

There is bias built into each of these indicators and none of them, on the strictly theoretical level, is more satisfactory than the others. Only experimentation will make it possible to determine which is best. We recommend:

- constructing a specialization index for a large number of countries of various sizes that are active in issuing patents, to make it possible to estimate the direction and scale of inherent bias for the four types of aggregate indicators;
- using each of the indicators over a series of years to check trend and stability;

- using the above-mentioned method to determine which type of indicator has the least bias and the greatest stability, and then keeping to only this type of aggregate indicator;
- using the information acquired in the evaluation process to comment on the meaning of this indicator;
- using this aggregate indicator for comparison with other countries; the comparison should include a substantial number of small and medium-sized countries as well as the major industrial countries;
- eventually aggregating the data for these countries in the same manner as the OECD aggregates its statistics on R&D effort (high, medium and low intensity countries).

Indicators for Economic Agents

Patent statistics are used to construct sectoral indicators primarily to determine the contribution of three agents to a country's science and technology.

Nearly 40% of Canadian patents issued to Canadian inventors go to individuals, which appears to be a very high figure insofar as comparisons with other countries are possible. This is the key finding that guides the recommendations that follow.

We recommend that an in-depth study of individual patenting activity be carried out in order to establish meaningful relations. It is imperative to determine what exactly is covered by the word "individual" and what are the links, if any, between them and the formal sectors of the economy. It is also imperative to learn more about the uses to which they put their patented inventions. In fact we feel it is necessary to assign meaning to the scientific and technological activity of individuals, because if it involves inventors searching for financial gain, then their contribution to inventions patented in Canada is already a useful indicator for science and technology policy.

Despite a current shortage of data, we recommend using patent statistics to construct an agent-related indicator that would make it possible to compare the science and technology contribution of the various economic agents in a substantial number of countries.

We recommend using the economic data from PATDAT to prepare a table linking patents issued to the three types of agents (individuals, government, business) to Canadian industry groups. The table would provide information about the relationships between technological effort and the various Canadian economic agents. A new definition of "government" should be worked out with the Patent Office because the current definition is suspect.

In some instances, agent statistics (for the table by industry) would have to be produced by adding data for more than one year because of the small number of patents issued each year.

Business Sector Indicators

Patent statistics show remarkably clearly a major fact of Canadian life: the strong presence of the multinationals and the limited weight carried by Canadian firms. Our recommendations concerning firms are primarily intended to demonstrate where control over science and technology in Canada rests.

We suggest first of all establishing a list of the 25 largest patentees in Canada for three categories of firms:

- resident firms;
- non-resident firms;
- multinationals.

Let us define these classes:

The first class includes all firms (whether Canadian or foreign controlled) with operations in Canada. The second includes all firms with no operations in Canada, which primarily consists of parent companies of multinationals. Thus far, we have the only list published to date. The third class consists of multinational networks, i.e., all firms holding Canadian patents which are controlled by the same parent company. For example, Canadian General Electric would in all likelihood appear in the first class, while General Electric Corp. would no doubt appear in the second class and General

Electric Corp. and all its Canadian and foreign subsidiaries that hold Canadian patents would count as one unit in the third class. This type of breakdown is made possible by the fact that PATDAT reconstructs ownership links between patent holders.

For the listing of the first class, we suggest including the number of patents from Canadian inventors held by the firm. For the listing of the second class, we suggest including the number of patents held by the firm and the number of patents from Canadian inventors held. For the listing of the third class, we suggest including the total number of patents held by the group and the percentage of these which are patents from Canadian inventors.

To be able to specify the impact of the scientific and technological effort of resident and non-resident firms on Canadian industry, we recommend using PATDAT data to construct a table which would take the following form:

Column 1: Breakdown of patents held by non-resident firms by industry.

Columns 2-3-4: Percentage of patents in each class held by major countries (United States, Japan, West Germany).

Column 5: Upward or downward trend in each category.

Column 6: Breakdown of patents from Canadian inventors held by resident firms (compile over several years where required).

Column 7: Percentage of total industry patents held by resident firms.

Indicators for Families of Technology

The use of patent statistics to construct indicators of effort by technology field is probably the most recent and the most promising development. We make two recommendations here, but first we wish to emphasize the importance of working together with those involved in science and technology policy to define the fields of interest and to work with specialists in these various fields to establish classes of relevant patents.

We recommend preparing a statistical table to serve as an indicator of the presence of Canadian inventors in a number of selected fields of technology. Using PATDAT for Canadian data and OTAF for American data, it would specify the percentage of Canadian inventors' patents in the total number of patents for a given field.

We also recommend a second statistical table to serve as an indicator of international technological vitality for selected technology fields. This table, which would be based on data from an international data base, should include the number of patents for each field, the percentage held by major industrial countries and the growth rate for the number of patents.

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Appendix

DATA BANKS

Access to patent data banks is essential to the development of science and technology indicators from patent statistics. In Canada these include PATDAT, the WIPO Intellectual Property Statistics Annual and, where required, the OTAF data bank, DERWENT, INPADOC, CLAIMS U.S. Patents Abstracts and CLAIMS U.S. Citation. Further details on PATDAT and the various other data banks follow.

PATDAT

PATDAT is a data bank that consists of patent data specially processed for economic analysis of patents. It is in many ways similar to the American OTAF data bank. Some of its main features are:

. it contains all the basic information for every patent granted by the Patent Office;

. it contains a wealth of additional economic information entered by analysts for the specific purpose of comparing patents to other economic variables.

The following is a list of basic patent data, followed by brief comments.

. Inventor's name
. Patentee's name
. Inventor's country of residence
. Patentee's country of residence
. Patent number
. Application number
. Issue date
. Application date
. Priority country (where applicable)
. Priority date, i.e., date of original application
. Priority number
. Canadian patent classification number
. Version of IPC (international patent classification) used
. IPC classification number
. Patent agent's code
. Type of patentee: individual, company, government.

The above is a list of all the information required for administrative and statistical analysis of patents.

The data bank can provide patent statistics according to country on the basis of a number of parameters (inventor's country of residence, patentee's country of residence, or both). It can also provide figures by industry (optionally by country) according to type of patentee. There is one reservation. The classification assigned to some patentees is questionable. For example, universities are classified as companies, while some government-controlled companies are classified as government.

PATDAT's data base supports statistics by invention classification, based on both the Canadian patent classification and the IPC classification. It also supports all types of compilation related to number of patents by patentee or by inventor.

The data base is excellent. The only additional information that might be useful is the province of residence of Canadian inventors. Regional implications of science and technology are increasingly seen as an important factor. The most important feature of PATDAT is the additional economic data it contains for each patent. The subject warrants further discussion.

Additional economic data may be summarized as follows:

- each patent is assigned an SIC (standard industrial classification) code that indicates the invention's probable industry of manufacture and probable industry of use;

- there are two other classifications: "consumer use", for an invention not aimed at a manufacturing industry, and "general use", for an invention not aimed at any specific user category;

- each patent is assigned a classification based on invention type; there are four main classifications: process, product, process-product, and process-apparatus. This replaces an earlier classification that claimed to have economic implications. It was abandoned because it required too much user discretion. The current classification is an almost perfect match for patent application contents, and a good example of a useful classification.

A summary of the objectives and difficulties of the task, and of the procedure followed, can provide insight into the nature and value of the economic data added to the patent data.

Intellectual property analysts have long stressed the importance of including other economic data with patent data as the only method available for improving analysis of the economic impact of invention. J. Schmookler (1972) pioneered the compilation of statistical series of patents for this purpose. It is nonetheless still difficult to establish a link between a patented invention and other economic parameters. To our knowledge, the American and Canadian patent offices have each developed a method that relates patent statistics to industrial classifications. The best way to understand the Canadian approach and its merits is to describe both and compare them.

As demonstrated in the comparative table shown on the following page, the objectives are the same, the method and application not entirely so. The greatest difference in method is that the U.S. Patent and Trademark Office uses a concordance based on a consensus of many analysts' decisions on patent classifications while Canadian patent analysts assess each patent individually. (See next page for further details.)

The American approach is cheaper and, once a concordance has been developed, its application to any patent in a given category or sub-group is automatic. Ongoing revision is required because of frequent changes to patent categories and sub-groups, unlike more stable classifications. Automatic assignment to a category or group requires thorough familiarity with the category or group, without any explicit reference to content. Schmookler (1972) has shown the shortcomings involved in assigning a patent to an industry category or sub-group without first conducting a detailed study. The Canadian method offers a better guarantee against errors of classification by lot, because each case is treated individually and content is a factor. Human error is, of course, a possibility. The consistency attainable by analysts who must make similar decisions repeatedly is difficult to assess.

OTAF Data Bank	**PATDAT Data Bank**
Objective	
To relate patents to classification of American industries.	To relate patents to classification of Canadian industries.
Method	
Development of a detailed concordance relating patent categories and groups to industrial classifications.	Training analysts in patent assessment; the analyst must be able to assess each individual patent as to the industry most likely to manufacture the invention and the industry most likely to use it.
Application	
"...the basic questions asked in relating patent classifications to SIC categories were: 'What type of establishment would be engaged in **producing** the **products** or **apparatus** having the structural or functional features encompassed by that patent classification?' or 'What type of establishment, in producing products or apparatus, would be carrying out the **process steps** included in the patent classification?'" (p. 92)	The analysts ask the following questions regarding each patented invention: (a) What industry is most likely to **manufacture** the invention? The question applies to all inventions other than those for pure processes; for pure processes, it is irrelevant. (b) What industry is most likely to **use** the invention? The question applies equally to processes and products; consumer products may be classified as such.
"...where those questions could not be clearly answered and ambiguity existed as to which of several possible SIC groups to assign a patent classification, it was placed in all of the possible groups." (p. 92)	To provide the best identification possible, inventions may be assigned to a maximum of three industries of manufacture and three industries of use, listed in decreasing order of importance. Inventions of general use may be classified as such.
"To provide a more accurate picture of patent activity by product field a computerized duplicate elimination procedure was used to eliminate the distorting effect of multiple counting of patents within a single field." (p. 93)	

Note: Detailed information on the application of the American method is quoted from:

The Office of Technology Assessment and Forecast, **Indicators of the Patent Output of U.S. Industry,** U.S. Patent and Trademark Office, U.S. Department of Commerce (undated).

There are also important differences in the way the methods are applied. The systems provide answers to virtually the same questions, but the Canadian approach is far more exhaustive and detailed; each user has the option of developing a specific personal approach from the general PATDAT approach. The American Patent Office automatically classifies a product or apparatus according to the industry most likely to manufacture it; by the same token it classifies a process according to the industry most likely to use it.

A Canadian Patent Office analyst follows the same procedure for a product or apparatus. In addition, he decides on which industry is most likely to use the product or apparatus described in the patent documents, or classifies it "general use" or "consumer use". The Canadian analyst decides on the industry most likely to use a process for which a patent application is made.

A PATDAT user who wants to use the American approach may do so by calling up a complete list of product patents, a complete list of product-process patents, and a complete list of process-apparatus patents by industrial classification of the principal manufacturer, and a complete list of process patents by industrial classification of primary user. This procedure can provide accurate answers to the key questions used in developing an American type of concordance; i.e., it outputs the manufacturing industry most likely to make a product or apparatus or use a process. The American approach has no provision for product or apparatus use, although, economically speaking, this link is as interesting as the link to production. The Canadian approach does consider the use aspect.

The most complex aspect of any attempt to relate a patent to a specific industry rests in the fact that while some inventions are very specific in their use and application, others cover a broad range. Patent classification does take this into account in that it allows for a patent to be listed under more than one technical category or sub-group. Here again the American and Canadian approaches differ. The American approach provides for a category or sub-group to be listed under more than one industry. A patent is listed as many times as it has potential uses. The American system also has an automatic system for correcting errors resulting from the inclusion of a patent in several categories. We are not familiar with the details of the system. The Canadian approach is far more straightforward. Assuming that no invention can be considered to be related to a single industry, the analyst has four options:

- assign a single industry code;
- assign two industry codes;
- assign three industry codes; or
- classify the invention (as to use) as "general".

The foregoing is another example of PATDAT's user flexibility. If the user wants to work on the basis of an invention's lack of specificity, and explore the possibility of manufacture or use by a secondary industry, he has access to the data provided by the analyst in the secondary and tertiary industry codes, and can list the same invention several times if he believes it is non-specific and broad in scope.

In-depth comparison of the American and Canadian data banks on patents and industry facilitates understanding of their respective features and appreciation of the strengths and weaknesses of the Canadian Patent Office.

Some of the main features of the Canadian data bank are depth of approach, clarity of information and user flexibility. These features demand individual classification of every patented invention and excellent judgement by the analysts. The main distinction between the approaches is philosophical. The American approach minimizes human error by using a summary, automatic procedure. Lack of detailed observation may result in classification errors. The Canadian approach minimizes classification errors by the depth of its analysis; individual judgement leaves room for human error.

Scherer (1982b) examined the relative merits of linking patents to industry on the basis of a detailed examination and the rigid classification approach taken by the American Patent Office. He concluded that the approach based on detailed examination is clearly superior, but very expensive.

PATDAT has another unique feature. The data bank includes a file of patentee firms that shows their corporate relationship. Lifting the corporate veil reveals the actual power structures, so necessary to any statistical study of patent concentration.

Familiarity with PATDAT's basic method and approach is essential to its use. The rest is incidental. It would be helpful to have one or more additional SIC codes for all Canadian patent holding firms. These could be provided by linkage with another data bank, or by direct input. This would relate patent statistics to other economic data on patentee industry. It would be useful in statistical studies and any other type of study aimed at comparing R&D effort and patents issued within a given industry.

Greater detail could be provided on the economic meaning of patent use. When a patent analyst specifies an invention's probable industry of use, he is not necessarily referring to a final user. This is especially true of machinery components or parts that have two types of users, one at the level of intermediate demand and one at the level of final demand.

WIPO Intellectual Property Patent Statistics

There is little to add on the subject. The data consist of standard data on patents applied for and granted in various countries. They are indispensable to comparative statistical studies. One important point is that the statistics are compiled on the basis of the issuing country and of the inventor's country of residence.

OTAF - American Data Bank

The essential economic features of this data bank are given in the comparison with PATDAT. The bank also contains exhaustive information on inventor's country of origin and patentee's country of origin, and on priority countries specified by applicants for American patents.

Once the similarities and differences of PATDAT and the American data bank are clearly understood and, because of the importance of the United States to Canadian patent applications abroad, the American data bank can be the source of interesting studies on American patents applied for and issued to Canadian residents. Cautious comparison of the two systems can also prove interesting.

DERWENT and INPADOC Data Banks

These data banks have one feature the others do not. They are based on legal patent families, i.e., they list the original patent application by country and all patents issued in all other countries on the basis of the priority specified in the original application. They are the only data banks that provide for examination of foreign patenting and analysis of business sector patenting strategy.

The two data banks suffer from a common limitation in that they do not provide any direct means of identifying patented inventions by the citizens of a given country. Neither contains information on inventor's or patentee's country of residence.

A user who wishes to compile statistics on, for example, foreign patenting by Canadian inventors must use an indirect analysis method. The information is retrieved from the data banks successively for each Canadian inventor or patentee by name, or (adapting the time-saving method of some users) by priority country as an indirect indicator of the inventor's nationality, assuming that an inventor normally applies first in his country of residence.

CLAIMS U.S. Patent Abstracts and CLAIMS U.S. Citation

The Claims U.S. Patent Abstracts data bank is a bibliographical bank, as is the previously mentioned DERWENT bank. This type of data bank features information on patent title and summary of content. A glossary of key words related to the various technologies provides access to the desired information.

Claims U.S. Patent Abstracts lists all patents issued in the United States with the standard patent information and content summaries. It is used mainly by persons looking for information or statistics on specific technologies that require key words for their definition.

It could be used in conjunction with the Claims U.S. Citation data bank, the purpose of which is to list all citations of American and foreign patents to which reference is made in a patent issued in the United States. There is growing interest in analysis of patent references as an indicator of patent quality.

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