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The emergence of S&T indicators: why did governments supplement statistics with indicators?

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Abstract

Science and technology (S&T) indicators are widely used in policy documents as well as in science and technology studies. This paper traces their origins and shows that it was the Organization for Economic Co-operation and Development (OECD) that first imagined and developed science and technology indicators. In the 1960s, the debate on technological gaps between the United States and Europe gave the OECD the opportunity to develop the first world-wide indicators on science and technology. The National Science Foundation (NSF) followed in the 1970s and improved the methodology of indicators on science and technology with its publication entitled *Science Indicators*. Science and technology indicators remain contested however, because centered on inputs rather than outputs, and because preoccupied mainly with the economic dimension of science and technology.

Keywords: S&T indicators; OECD; NSF

1. Introduction

Governments and researchers from industrial countries have been measuring science and technology (S&T) for over 50 years. The indicators in use today are derived from two sources. Firstly, quantitative information on science and technology is in great part due to the groundwork of governmental organizations such as the National Science Foundation (NSF) in the 1950s and intergovernmental organizations like the Organization for Economic Co-operation and Development (OECD) in the 1960s. There have doubtless been highly systematic attempts at measuring science and technology before the 1950s, but these were confined to eastern Europe.

Secondly, a large debt is owed to the work of J. Schmookler and Derek J. De Solla Price during the 1950s and 1960s for directing the attention of university researchers to the measurement of science and technology. Following this work, the fields of scientometrics and, more particularly, bibliometrics have united several dozen researchers world-wide and yielded a variety of data for countless users (sociologists, historians, political scientists).

Given the centrality of science and technology statistics in science studies (economics, policy, sociology) and government policies, the absence of any socio-historical examination of the measurement is surprising. Many manuals summarize the field, and a voluminous literature consists of articles discussing or criticizing science and technology indicators, but there is nothing approaching a history of the field. This article aims to fill such a gap by

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looking at the emergence of science and technology indicators.

The US government was one of the first to get involved in the measurement of science and technology. After preliminary experiments in the 1930s and 1940s, the NSF took the lead in the early 1950s (Godin, 2002). Beyond the regular survey on R&D, the NSF innovated again 20 years later. In 1973, it published *Science Indicators* (hereafter SI), the "first effort to develop indicators of the state of the science enterprise in the United States" (National Science Board, 1973a, p. iii):

> The ultimate goal of this report is a set of indices which would reveal the strengths and weaknesses of US science and technology, in terms of the capacity and performance of the enterprise in contributing to national objectives.

The publication had a large impact. Indeed, SI was, according to a recent National Science Board (NSB) publication, the organization's bestseller (National Science Board, 2001, p. 20). It was widely acclaimed, discussed world-wide and served as a model for several countries and organizations: in 1984, the OECD started a series entitled *Science and Technology Indicators*, which in 1988 was replaced by *Main Science and Technology Indicators*. Eurostat followed in 1994 with its *European Report on Science and Technology Indicators*. France also started its own series *Science et Technologie: Indicateurs* in 1992, and Latin American countries followed suit in 1996 (*Principales Indicatores de Ciencia y Tecnologia*).

The present paper is a brief history on the origins of science and technology indicators (1965–1978). Where does the idea of indicators come from? How has it evolved over time? What did it mean for governments? It is generally forgotten that science and technology indicators did not originate in the United States but were first imagined at the OECD. Certainly, the NSF considerably influenced the methodology of data collection on science and technology in OECD countries in the early 1960s, but it was the OECD itself that inspired SI. Indeed, the debate of the 1960s on gaps between the United States and Europe gave the OECD the opportunity to develop the first world-wide indicators on science and technology. These indicators, among others, were later included in SI and gave the NSF the idea to develop indicators to assess the state of science and technology in the United States.

The first part of the paper defines and clarifies the notions of statistic and indicator in order to distinguish them. The second traces the main factors that lead to SI and the third discusses the impact it had, particularly on OECD. The fourth relates SI to previous OECD reflections in order to show that the data produced during the debate on "Technological Gaps" in 1968 served as a model for the NSF.

2. Indicators as policy tools

Statistics are mathematical tools for the treatment of numerical data (MacKenzie, 1981, p. 2). Prior to Quetelet's work (1796–1874) however, statistics was the compilation of numerical information (Porter, 1986). It was "untouched by the application of mathematical tools (aside from simple rules for computing rates and averages)" (Camic and Xie, 1992, p. 779). After Quetelet, more sophisticated statistics (based on measures of variation) began to replace averages, at least in the works of mathematicians and statisticians.

Most government statistics are of the first kind. They are totals calculated for a number of dimensions and published as such. These statistics are simple numbers produced by additions, not by complex mathematical tools (such as regressions and correlations). They refer not to the methodology for the treatment of data but to the data themselves (Woolf, 1989). Science and technology statistics follow the same pattern.

This is not to say that government statistics have not evolved since Quetelet's time. Indeed, it was government together with social scientists who invented the notion of indicators. Indicators began to appear in economics in the 1930s: growth, productivity, employment and inflation. The first social indicators were developed during the same period (President's Research Committee on Social Trends, 1933), but the term itself became widespread only in the 1960s (Bauer, 1966; Sheldon and Moore, 1968).

The "movement" for social indicators considerably influenced the development of similar statistics in science and technology. Indeed, early editions of SI benefited from regular exchanges with the Social Science Research Council (SSRC) Committee on Social Indicators (USGPO, 1976, pp. 33, 41–42). Among other things, SSRC organized two conferences, one in 1974 (Elkana et al., 1978) and another in 1976 (Scientometrics, 1980), sponsored by the NSF, and devoted to improving the quality of science indicators, and to better defining output indicators.

How did people distinguish an indicator from a regular statistic? A glance at definitions should help answer this question. In 1969, US President L. Johnson asked the Department of Health, Education and Welfare to develop the necessary social statistics and indicators to chart social progress. The report, issued in 1970, defined an indicator as "a statistics of direct normative interest which facilitates concise, comprehensive and balanced judgements about the condition of major aspects of a society. It is in all cases a direct measure of welfare and is subject to the interpretation that, if it changes in the "right" direction, while other things remain equal, things have gotten better, or people better off" (Department of Health, Education and Welfare, 1970, p. 97). Similarly, Parke, then director of the Center for Coordination of Research on Social Indicators of the SSRC, defined indicators as "statistical time series that measure changes in significant aspects of society" (Parke, 1976, p. 48). Elsewhere, he specified (Sheldon and Parke, 1975, p. 696):

> To comprehend what the main features of the society are, how they interrelate, and how these features and their relationships change is, in our view, the chief purpose of work on social indicators.

An important element of these definitions is that of warning about changes. A social indicator measures dimensions of a phenomenon in order to follow the state of society. A second feature of indicators is that they are statistics that must be recurrent, otherwise they would not meet the aforementioned requirement—measuring change. Thirdly, indicators usually appear as a collection of statistics: a lone statistic can rarely be a reliable indicator. Finally an indicator rest on a model: "an indicator is properly reserved for a measure that explicitly tests some assumption, hypothesis, or theory; for mere data, these underlying assumptions, hypotheses, or theories usually remain implicit" (Holton, 1978, p. 53). Price formulated the same requirement the following way: "To be meaningful, a statistic must be somehow anticipatable from its internal structure or its relation to other data (. . .). It means the establishment of a set of relatively simple and fundamental laws" (De Solla, 1978, p. 72).

All these features are present in the OECD's 1976 definition, according to which an indicator is "a series of data which measures and reflects the science and technology endeavor of a country, demonstrates its strengths and weaknesses and follows its changing character notably with the aim of providing early warning of events and trends which might impair its capability to meet the country's needs" (OECD, 1976b, p. 6). Similarly, the NSB of the NSF suggested that: "indicators are intended to measure and to reflect US science, to demonstrate its strengths and weaknesses and to follow its changing character. Indicators such as these, updated regularly, can provide early warnings of events and trends which might impair the capability of science—and its related technology—to meet the needs of the Nations" (National Science Board, 1975, p. vii).

3. Indicators under pressure

US Congress passed the law creating the NSF in 1950. Under this law, the NSF was charged with funding basic research, but was also given, under the influence of the Bureau of Budget (England, 1982, p. 82), a role in policy advice and in the evaluation of research. The NSF was asked to "maintain a current register of scientific and technical personnel, and in other ways provide a central clearinghouse for the collection, interpretation, and analysis of data on scientific and technical resources in the United States".[1] In 1968, Congress explicitly mandated the NSF to report on the status and health of science and technology.[2]

During the first year of its existence, the NSF mainly understood its role in evaluation as one of collecting and disseminating statistical information and issuing

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[1] Public Law 507 (1950) and Executive Order 10521 (1954).

[2] Public Law 90-407 (1968).

statements concerning conditions that are desirable for the advancement of science (Wolfe, 1957, p. 340). As early as 1953, with its first survey on R&D, the NSF stated (NSF, 1953, p. vi):

> No attempt has been made in this report to present any conclusions as to general policies (. . .). However, factual information of the kind developed by the study does provide an initial basis for policy (. . .)".

Rapidly, people outside the NSF became uncomfortable with such an understanding of its mandate. Too few policy analyses and assessments were said to accompany the numbers. A.T. Waterman, the first director of the NSF, always defended the organization against these criticisms. His main argument was that "it (was) unrealistic to expect one federal agency to render judgement on the overall performance of another agency or department" (Waterman, 1960, p. 1643).

Nevertheless, SI was the result of these criticisms, as well as being the response to new and explicit instructions from the government. In September 1970, President R. Nixon asked the Office of Science and Technology (OST) and the President's Science Advisory Committee (PSAC) to "submit each May a report on the status and health of science and technology" (USGPO, 1983, p. 183). The request was, in fact, a reminder to the Board that it had not fully met its obligations (indeed, Congress will made a similar request again in 1976). The NSB met with the two organizations and reconsidered the nature of its annual report. It studied two options (National Science Board Minutes, 1970). One was to issue an occasional white paper on policy, which was to be independent of the annual reports. The other was to produce an annual report that "would provide baseline data for each year with a series of chapters providing an assessment of the health of science" (USGPO, 1983, p. 183). The latter option prevailed.

In February 1971, the NSB began discussions on the possibility of a SI report (National Science Board Minutes, 1971a) and approved the "systematic development of data and information on the health of science indicators and the preparation of an annual report based thereon" (National Science Board Minutes, 1971b). To that end, an ad hoc committee on science indicators was formed, chaired by Roger W. Heyns, member of the Board, Chancellor of the University of California at Berkeley and President of the American Council on Education (National Science Board Minutes, 1971c). The committee first conceived a long list of 57 possible measures, divided into seven categories,[3] and then rated the indicators on a scale of importance and feasibility (see Appendix A; Heyns, 1971). By January 1972, the work was so advanced that the Board decided that its 5th annual report and subsequent ones would be based on science indicators (National Science Board Minutes, 1972a).[4] The Board reviewed the proposed indicators in March (National Science Board Minutes, 1972b) and a first draft of the report was circulated for comments in September (National Science Board Minutes, 1972c). The final report was approved in November and, as requested by law, transmitted for review to the OST, the Office of Management and Budget (OMB) and other agencies (National Science Board Minutes, 1972d). In September 1973, SI was officially sent to Congress (National Science Board Minutes, 1973b).

One month later, the Board estimated that, approximately 11 000 copies had been distributed so far and was pleased with the favorable press coverage (National Science Board Minutes, 1973c). The recognition of the reputed quality of SI would be confirmed again in 1982 when Congress amended the law of NSF and asked, among other things, for a biennial report on science indicators.[5]

According to Falk, the main person behind SI, the document was a success because of five characteristics.[6] Firstly, it collected dispersed statistics all in only one book. Secondly, it discussed science mainly by way of charts rather than numbers. Tables appeared primarily in the appendix. Thirdly, it included brief highlights for policy makers. Fourthly, there

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[3] Scientific output, activity, science education, attitudes toward and interest in science, manpower, extent of new thrusts, international.

[4] In fact, since May 1971, the 5th annual report was planned to be on undergraduate science education. In October however, the Board took notice of the lack of unanimity on the scope of the report and reconsidered the subject. Fortunately, a draft report on science indicators was ready to take its place.

[5] Public Law 97-375 (1982).

[6] Falk, personal conversation (24 May 2000).

was small analysis.[7] Finally, each edition always contained something new in terms of information and indicators.

SI was planned and considered by the NSB to respond directly to the mandate Congress gave it from the start, that is to provide a regular assessment of science in the country (USGPO, 1976, p. 7). In 1976, for example, Heyns highlighted the six purposes and functions SI was intended to serve (USGPO, 1976, p. 10):

- to detect and monitor significant developments and trends in the scientific enterprise, including international comparisons;
- to evaluate their implications for the present and future health of science;
- to provide continuing and comprehensive appraisal of US science;
- to establish a new mechanism for guiding the nation's science policy;
- to encourage quantifications of the common dimensions of science policy, leading to improvements in R&D policy setting within federal agencies and other organizations;
- to stimulate social scientists' interest in the methodology of science indicators as well as their interest in this important area of public policy.

Not all people agreed, however, with such a positive view of SI. Government officials as well as academics critically discussed the document at length in several forums (GAO, 1979; USGPO, 1976; Elkana et al., 1978; Cozzens, 1991; McGinnis, 1979; MacAulay, 1978; Holmfeld, 1978; Scientometrics, 1980). The main criticisms centered on the following:

- The "operationalism" of SI (as General Accounting Office (GAO) called it), that is the tendency to use data because it is there rather than develop an explicit model of science and technology that would underlie the measurement. During the 1976 hearings on SI in Congress, R. Ayres, Vice-President, International Research and Technology, summarized this view in the following terms: "(. . .) the number of Nobel prizes is easy to count and that is why you are collecting them, not because it means anything" (USGPO, 1976, p. 72). Indeed, Heyns himself admitted, during the hearings before Congress, that: "the priority emphasis on input indicators was predicted on the general availability of a number of accepted conventional measures" (USGPO, 1976, p. 10). This was one of the central criticisms of GAO: "At the time these measures were selected, most of the data already existed in hand for NSB (. . .) particularly in NSF's Division of Science Resources Studies" (GAO, 1979, p. 19). "It was natural that the initial SI reports would be based largely on an operational approach, deriving indicators from the readily available data on the basis of suspected importance. This approach, however, incorporated a limited view of science and technology, and led to the construction of a number of indicators whose underlying assumptions are tenuous or invalid" (GAO, 1979, pp. 50–51). S. Cozzens attributed this tendency to pressures of having to add new indicators in each edition (Cozzens, 1991, p. 5).
- The input/output model, where links between inputs and outputs are badly demonstrated: SI "lacks any overall unifying model that makes sense of the connections between science, technology, economy and society" (Cozzens, 1991, p. 10). It is "too constricted by an input/output model framework. In this approach, science and technology are seen as resources which go into, and tangible results which come out of, a black box" (GAO, 1979, p. 19).

  The emphasis on inputs (expenditures and personnel; GAO, 1979) to the detriment of outputs and impacts, as a consequence of an implicit model of science as autonomous (Elkana et al., 1978, pp. 5–6). "The more inputs, the healthier the system" (Cozzens, 1991, p. 11).
- The implicit assumptions and objectives inspired by the 1945 rationale to justify the federal funding of science (Holmfeld, 1978, pp. 40–41).
- The relative absence of analysis of long-term trends and the politically neutral discourse: "It is the Board policy that the data should speak for

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[7] I would add, moreover, that this analysis was non-controversial. Indeed, NSF personnel confessed to the GAO that: "the reports were meant to emphasize quantitative data and not venture at all into evaluations or assessment" (GAO, 1979, p. 55). This philosophy is still prevalent today: at the end of the 1990s, the President of the NSB claimed, again, that the Board should discuss policy matters more directly. See *Science* (1997a) and *Science* (1997b).

themselves" (Cozzens, 1991, p. 6). "While *SEI* is an excellent statistical reference tool, its politically neutral text keeps it out of the business of assessment, and its encyclopedic size and organization transmit segmented information rather than a synthetic overview" (Cozzens, 1991, p. iv).

The NSF view of the world: "Matters of interest to NSF get high priority for inclusion, and matter of interest to other agencies get lower priorities" (Cozzens, 1991, p. 10). This is manifested by "extensive treatment of academic research, a bit of information on industrial basic research, and a smattering of input data on government research" (Cozzens, 1991, p. 11).

- The highly aggregated level of data: there was a "tendency throughout most of SI-72 and SI-74 to opt for bulk measures (. . .), even when more details spectroscopy of data was available in the literature" (Holton, 1978, p. 46).
- The absence of details on methodology: "A widespread problem in the analysis of data is lack of attention to how the data were generated, to their limitations, and in general to the error structure of sampling, selection, measurement, and subsequent handling" (Holton, 1978, p. 17).

Over the years, SI (SEI since 1987)[8] has grown considerably in content. While SI contained 93 pages and 112 tables in the 1972 edition, these numbers, respectively increased to 177 and 258 in 1989. With the 2000 edition, SEI published two volumes for the first time. Over the same period, the indicators also grew in number and covered more and more dimensions of science and technology: resources, workforce, economic performance, impacts and assessments, enrollment in science and graduation, scientific literacy, publications, citations, technology and international collaboration information and communication technologies (see Appendix A).

4. Following SI through OECD

SI had a huge impact on OECD. In December 1976, the OECD Committee for Scientific and Technological Policy (CSTP) organized a meeting of national experts on R&D statistics in order to prepare the work of the second users group on OECD work on R&D statistics.[9] The OECD Secretariat submitted the question of indicators to the group: "Science indicators are a relatively new concept following in the wake of the long-established economic indicators and the more recent social indicators. So far, the main work on this topic has been done in the United States where the National Science Board has published two reports: *Science Indicators* 1972 (issued 1973) and *Science Indicators* 1974 (issued 1975)" (OECD, 1976b, p. 3). The background document to the meeting analyzed in depth the indicators appearing in SI and compared them to the statistics available, and to those that could be collected and at which cost. The group was asked "to draw some lessons for future work in member countries and possibly at OECD".[10]

The final report of the users group (chaired by J. Mullin) suggested a three-stage program for the development of new indicators (OECD, 1978b, pp. 17–21):

- *Short-term*: input indicators (like industrial R&D by product groups).
- *Medium-term*: manpower indicators (like occupations of scientists and engineers).
- *Long-term*: output (productivity, technological balance of payments, patents) and innovation indicators, as well as indicators on government support to industrial R&D.

A few months later, in November 1978, the OECD Directorate for Science, Technology and Industry (DSTI) responded to the users group report and made proposals to member countries (OECD, 1978a). It suggested to limit indicators to those most frequently requested by users of statistics, i.e. input indicators. The decision was dictated by the need to accelerate the diffusion of data—a limitation first identified by the users group: "(. . .) improvements in the rapidity with which all the *International Statistical Year* (ISY) results are issued cannot be hoped for if the present format of five volumes of data, each containing footnoted figures for the majority of OECD countries

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[8] Science and Engineering Indicators.

[9] Users groups were created in order to better align statistics to the needs of their users.

[10] It is important to remember that, at the time, OECD was collecting information on R&D only (monetary investments and personnel).

and accompanied by country notes, etc. is retained" (OECD, 1976a, p. 4). It was thus proposed to publish data "arranged country by country with only the main indicators in an international format" (OECD, 1976a, pp. 5–6). This was the approach already used elsewhere in OECD (notably for national accounts and labor force data). To that end, it was suggested to create a database from which a report based on indicators would be published every 2 years. The report would replace the fifth volume of the ISY on R&D and "be modeled to some extent on the NSF Science Indicators reports" (OECD, 1978a, p. 8).

The Canadian delegate, H. Stead, judged these proposals too timid. He suggested that the Frascati Manual be revised in order to bring it into an indicator manual (OECD, 1978a, pp. 16–17). The first part would carry more or less the actual content of the manual, while the second would deal with other indicators, namely personnel, related scientific activities, outputs and high technology trade. His suggestions were rejected as premature (OECD, 1979a, p. 4), but the introduction of the manual was rewritten for the 1981 edition in order to put R&D statistics in the larger context of indicators,[11] and an annex on new indicators was added in the 1993 edition.[12]

In the following years, the OECD extended its coverage of indicators beyond input indicators. The first issue of *Main Science and Technology Indicators* (1988) included data on R&D, patents, technological balance of payments, and high technology trade. Overall, the OECD, following the holding of several workshops,[13] produced the following:

1. A series entitled *Science and Technology*: *Indicators Report*. The series was short-lived, however, because it was considered too time-consuming. Only three editions appeared: 1984, 1986 and 1989.
2. A database from which a series of data were, from 1988, published biannually—but without any analytical text:
   (a) *Main Science and Technology Indicators* (1988).
   (b) *Basic Science and Technology Statistics* (1991, 1997, 2000).
   (c) *R&D Expenditures in Industry* (1995, 1996, 1997, 1999).
   (d) *Science, Technology and Industry Scoreboard* (1995, 1997, 1999).
3. A series of new methodological manuals on:
   (a) Technological Balance of Payments (1990).
   (b) Innovation (1992).
   (c) Patents (1994).
   (d) Human Resources (1995).

Despite the number of documents produced, the OECD never went as far as the NSF. Only a relatively small number of indicators appeared in its reports and data series. Despite important reflections and debates on output indicators, for example, the only one present in OECD documents concerns patents.[14] Be it as it may, it was SI that convinced OECD to transform international survey data on R&D into science and technology indicators.

Although the NSF's influence on OECD is evident here, the exchanges between the two organizations were not, however, one-way but bi-directional. I now turn to the way the OECD itself influenced SI.

5. Behind NSF's shoulders

It took only 1 year (from September 1971 to September 1972) for the NSB committee to complete a first draft of SI. In fact, the NSB had the chance to benefit from previous OECD experiences with indicators. As early as 1965, C. Freeman and A. Young

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[11] See Godin (2001).

[12] The question would be discussed again in 1988: "The delegates discussed whether one or more OECD manuals should be developed for measuring scientific and technological activities. They concluded that the revised Frascati manual should continue to deal essentially with R&D activities and that separate manuals in the Measurement of Scientific and Technical Activities series should be developed for S&T output and impact indicators which are derived from entirely different sources from R&D statistics" (OECD, 1988).

[13] Workshops were held on: outputs (1978 and 1979, followed by a conference in 1980), technological balance of payments (1981, 1987), innovation (1982, 1987, 1994), trade (1983), higher education (1985).

[14] Technological balance of payment (TBP) and high technology trade are impacts rather than outputs, contrary to common thinking. In fact, there is an important confusion in the literature, where people usually mix output and impacts. For exceptions, but without any consequences, see OECD (1980) and Falk (1984, pp. 37–39).

compared R&D data and methodology in OECD countries (Freeman and Young, 1965). They analyzed statistics on investments, manpower, technological balance of payments, patents, and migration for seven countries (Belgium, France, Germany, The Netherlands, the United Kingdom, the United States and the USSR). This was the first document in industrialized countries to collect several indicators at once, years before SI did the same.

The report identified a gap between American and European efforts in R&D. Indeed, "gaps" was a buzzword of the time. There has been the missile gap (Levine, 1994, pp. 73–95), the dollar gap (Hogan, 1987, pp. 238–292; Ellwood, 1992, pp. 154–174), and then the technological gap.[15] It was, in fact, a kind of political manifesto published in 1964 by Cognard of the French Délégation Générale de la Recherche, de la Science et de la Technologie (DGRST) that launched the debate on technological gaps. With very preliminary data on R&D, patents and international trade, the article claimed (Cognard, 1964, p. 14):

> On ne voit pas très bien comment une Nation pourrait maintenir son indépendance politique si (elle) était subordonnée à des décisions techniques et économiques de firmes étrangères.

According to Freeman and Young, Europe was lagging behind the United States in terms of both investment and performance. The data on which the conclusion was based, however, were considered insufficient enough to provide a firm basis of comparison. Indeed, OECD member countries only recently approved a standardized methodology for collecting R&D statistics. As a consequence, the second ministerial meeting for science and technology held in 1966 suggested that: "a committee of senior officials responsible for science policy (. . .) be set up, with instructions to carry out the preparatory work for future discussions. Their task included a study on national differences in scientific and technical potential—that is, on what has generally come to be described as technological gaps" (OECD, 1968, p. 5). Ten studies were conducted (nine sector studies plus an analytical report). The material was submitted to the third ministerial meeting on science, held in 1968, under the title *Gaps in Technology*.

The report was the first policy-oriented analysis of data on science and technology. The study confirmed the gap in R&D efforts between America and Europe, but suggested this had no direct effect on economic performance: "the above analysis shows that the United States lead has not had any adverse effects on other countries' growth and trade performance" (OECD, 1968, p. 30). Scientific and technological capability was a prerequisite but not a sufficient basis for success. Besides the size of the US market, important factors were identified as far more important: the role of government support, the educational system, and the management culture.

In order to arrive at this conclusion, *Gaps in Technology* looked at several indicators: R&D, innovation, trade, productivity, technological balance of payments and foreign investments. Some of these indicators were calculated for the first time and would become highly popular in the future (innovation). *Gaps* was the first systematic attempt to measure science and technology on several dimensions using indicators.[16]

A similar exercise followed *Gaps* a few years later. It was, in fact, the third OECD contribution on indicators: *The Conditions for Success in Technological Innovation*, written by K. Pavitt and S. Wald (OECD, 1971). The document followed the third ministerial meeting on science (1968) that asked for a follow-up to *Gaps in Technology*. *Conditions for Success* retained six indicators to measure 10 countries' performance in technological innovation: (1) significant innovation, (2) receipts for patents, licenses and know-how, (3) origin of technology, (4) patents granted, (5) imports and (6) exports in research-intensive industries.

Gaps in Technology had a huge political impact, but the analysis was far more nuanced than it appeared in the media or in some intellectuals' prose (Salomon, 1967). Servan-Schreiber (1967), for example, made a bestseller of his book *Le Défi américain* which "sounded an alarm that America was well on the way to complete domination of the technological industries of Europe and, for the matter, of the

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[15] The question was still on the agenda in the 1980s. See, for example Patel and Pavitt (1987), Fagerberg (1987), and Soete (1987).

[16] The OECD thought, for some time, to produce a gap exercise for third world countries, but never did. However, it documented gaps in fundamental research: Ben-David (1968).

world" (King, in press). As King reminded us, Servan Schreiber based his analysis on OECD data, but without acknowledging it.

Nobody could have missed the ideological discourses on *Gaps* because they were largely diffused in the media (Salomon, 2000, p. 48). *Gaps* had echoes in the United States as well and, for our purposes, in two organizations. First, both the Department of Commerce (DoC) and the NSF began developing their own classification of technologically intensive industries in order to measure international trade (OECD, 1979b, p. 36). The definitions were based on multiple indicators, such as scientific and technical personnel, R&D expenditure as a percentage of sales and manpower competencies. These were the first tentative proposals to measure high technology trade in the United States. The second effect of *Gaps* was that the NSF produced SI, the first comprehensive repertory of science and technology indicators in the world.

6. Conclusion

Science and technology indicators appeared in the mid-1960s, at a time when the term indicator became widely used, particularly in the measurement of social trends. They began to be developed at the OECD, particularly in the influential study *Gaps in Technology* (1968). The exercise was preceded, however, by one published in 1965, that of Freeman and Young, and was followed by one more, this time by Pavitt and Wald (1971). I know of only one more occurrence of the term "indicator" in the OECD literature on science and technology before the NSF. It appears in a chapter title of the results of the first ISY on R&D, published in 1967 (OECD, 1967, p. 12).

While the OECD launched the idea of indicators, it is to the NSF that we owe the development of the field. Before the 1990s, the OECD never really went further than producing only some of the indicators first suggested by Freeman and Young—R&D, patents, technological balance of payments and trade in high-tech industries.[17] The two authors were, in fact, far in advance of everybody. They thought of more indicators than OECD would produce for some time. In contrast, the NSF constructed over 100 indicators in the first editions of SI (OECD, 1976b; Cozzens, 1991), and the publication was imitated by several other organizations world-wide.

Two factors, one internal to the NSF, the other external, played a role in the decision of the NSF to get involved in indicators. Firstly, the 1950 law specifically mandated the NSF to evaluate and assess the state of science and technology in the country. This mandate was far from realized according to bureaucrats. It is probably safer to say that it was the increasing pressures put on the organization rather than the law itself that led the NSF to the decision to do more than to simply collect and publish statistics. Secondly, the OECD study on *Gaps* offered the NSF a model of what could be done and what was to be expected in terms of results when an organization develops indicators.

Because of the quality of SI (and/or because of the volume of indicators), the OECD once proclaimed that: "the main work on this topic has been done in the United States" (see pp. 10–11)[18]—a perfect case of an organization that forgot its own contribution to a field. It was rather the OECD that initiated work on indicators and produced the first analyses of science and technology based on them. But overall, the OECD produced one model—a few indicators to answer policy questions—the NSF another—a large number of data with no real assessment.[19] In fact, the NSF and the OECD were, from the start, in a relative symbiosis, each being a forerunner at a different stage in the history of measurement. A dialectics always existed between the two organizations and it is probably impossible, as usual in social studies, to definitely identify a unique cause to the emergence of indicators. But certainly, the two organizations were at the center of discussions and ideas.

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[17] The selection of these four indicators was the result of the first workshop on output indicators (1978). See OECD (1979b).

[18] This is not an isolated citation. For example, in another document, the OECD wrote: "Prior to this conference, the OECD has not played a very positive role in the development of science and technology indicators": OECD (1980, p. 39).

[19] Indeed, in the same paper where he presented the NSF as the model, Falk (1984) admitted a wide spectrum of alternatives: "At one extreme is the presentation of solely numerical indicators (...). One can go one step further and draw conclusions (...). Or one can go even further and draw the type of conclusions that involve subjective judgments (...). Finally, one can supplement this approach with recommendations for specific actions" (p. 39).

Appendix A

NSF committee’s choice of science indicators

Indicators	Score	Feasibility
(A) Scientific output measure		
(1) Number of papers in top quality, refereed journals	50	(N_1)[a]
(6) Utility of knowledge	45	(D)[b], N_1
(30) Number of referenced articles; citations	38	N_1
(32) Number of refereed publications originating from particular research grants or projects and estimated cost per paper	35	(N_2)[c]
(34) Longitudinal number of patents/population 22–64 years	35	(D)[c]
(B) Activity measures		
(2) Ratio of basic research funds to total investment in R&D	50	D
(3) Federal support of total research by field of science	50	D
(4) Ratio of number of scientific research project support proposals warranting support to number of grants awarded by field of science (NSF and NIH only)	50	D
(7) Ratio of applied research funds to total R&D	45	D
(8) Ratio of development funds to total R&D	45	D
(9) Ratio of federal R&D funds to total federal expenditures for such functions as health, transportation, defence, etc.	45	D
(10) Federal basic research dollars by field	45	D
(11) Total funding of academic R&D (expenditures) and federal funding of academic science (obligations)	45	D
(21) Basic research, applied research, development, and total R&D dollars by source and performer	40	D
(22) Split of federal research support between academic young and senior investigators	40	D
(23) Industrial R&D for R&D performing companies as a percent of sales dollars	40	D
(24) R&D dollars in industry by type of industry	40	D
(33) Federal academic science support by agency	35	D
(35) Non-profit R&D, by source	35	D
(43) Geographic distribution of R&D	30	D
(44) Industrial R&D funding, by source	30	D
(C) Science education measures		
(12) Percent of freshmen selecting science careers	45	D
(13) Distribution of new baccalaureates, masters, and doctorates by field	45	D
(14) Number of science and engineering degrees as a percent of total degrees	45	D
(15) Stipend support of full-time graduate students by: field, type of support	45	D
(31) Ratio of percentage of science and engineering freshmen enrolments and doctorates per geographic origin of students to percentage of total population of that region	38	D
(36) Enrolments in science and math courses in public high schools	35	D
(37) Postdoctoral training plans of doctorates by field	35	D

Appendix A. (*Continued*)

Indicators	Score	Feasibility
(38) Ratio of science faculty to degrees and to graduate enrolments, by field of science	35	D
(42) Distribution of Freshmen science and engineering probable majors by H.S. grades, class standing and test scores	31	D[b]
(D) Attitudes towards and interest in science		
(25) Prestige ratings of scientific occupations versus ratings of other fields of endeavor according to public opinion polls	40	N_1
(26) Poll of views about science on part of students	40	N_1
(39) Poll of views about science on part of public at large	35	N_1
(E) Manpower measures		
(16) Relative and absolute employment of scientists and engineers by sector, degree, and field of science	45	D
(27) Percentage of scientists and engineers unemployed by degree and field of science compared with equivalent ratios for other areas of professional employment	40	N_1
(F) Extent of new thrusts		
(5) Major new frontiers of science opened up during a specific year	50	N_2
(17) Major (frontier) facilities in various areas of science which are feasible and are not being constructed. Comparison with a similar list developed for the rest of the world	45	N_2
(G) International		
(18) Ratio of US scientific publications to world total	45	N_2
(19) Relationship of US R&D/GNP capita among various nations	45	D (67)
(20) R&D scientists and engineers per 10 000 population in different countries	45	D (67)
(28) R&D/GNP in different countries	40	D (67)
(29) Scientific and engineering personnel per 10 000 population in different countries	40	D (67)
(40) Nobel (and other) prizes per capita won by US each year compared with other countries	35	N_2

[a] N_1: new data to be developed—with comparative ease.

[b] Basic data in hand.

[c] N_2: new data to be developed—with comparative difficulty.

Science indicators considered but not recommended

Federal intramural R&D funding, by agency
Percent of science drop-outs during college career
Number of people taking science courses where there are no such requirements
Nationality of invited speakers at large international meetings
R&D expenditures per capita for different countries
Total number of papers produced by US scientists per year
Geographic distribution of academic science dollars for various grouping of institutions (magnitude of federal academic science dollars, number of science and engineering baccalaureates, number of science, Ph.D., etc.)
Increase in number of scientific category jobs in the Department of Labor's Dictionary of Occupational Titles
Relationship of US scientific papers to world papers as compared with US GNP against world's GNP
Technicians/scientist and engineer in different countries
Longitudinal studies of the publication history of a sample of Ph.D. in a variety of fields from a variety of institutions
Number of people who choose to visit science exhibitions or natural science museums
Ratio of number of federally supported articles to federal research funds allocated, by field
Types of instrumentation and techniques cited in the papers
Degrees and graduate enrolments by average GRE score of Masters and Ph.D.
Projections of supply and utilization of all scientists and engineers as well as doctorates by field and activity
Projections by degree and field of science
Balance of payments over time
Growth in cubic footage in university, government, and private research laboratories
Percent of university budgets allocated to scientific departments versus other departments
Annual average percentage of front-page stories in the New York Times that deal with scientific subjects
Salaries commanded by those in "scientific" job categories versus those in non-science categories
Membership in professional societies as percent of total working population
Percent of those listed in Who's Who who have scientific backgrounds
Attendance at scientific symposia, etc.
Subscriptions (per capita) to science magazines and science book purchases
List of such facilities in various areas of science which are feasible and are not being constructed, comparison with a similar list developed for the rest of the world
Percentage of utilization by facility as compared to maximum possible utilization in terms of shifts of operation, number of experiments being performed, etc.

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