**Measuring Output:**

**When Economics Drives Science and Technology Measurements**

Benoît Godin

3465, rue Durocher
Montréal (QUE)
Canada H2X 2C6

**Project on the History and Sociology of S&T Statistics**

**Working Paper No. 14**

**2002**

**Previous papers in the series:**

1. B. Godin, *Outlines for a History of Science Measurement*.
2. B. Godin, *The Measure of Science and the Construction of a Statistical Territory: The Case of the National Capital Region (NCR)*.
3. B. Godin, *Measuring Science: Is There Basic Research Without Statistics?*
4. B. Godin, *Neglected Scientific Activities: The (Non) Measurement of Related Scientific Activities*.
5. H. Stead, *The Development of S&T Statistics in Canada: An Informal Account*.
6. B. Godin, *The Disappearance of Statistics on Basic Research in Canada: A Note*.
7. B. Godin, *Defining R&D: Is Research Always Systematic?*
8. B. Godin, *The Emergence of Science and Technology Indicators: Why Did Governments Supplement Statistics With Indicators?*
9. B. Godin, *The Number Makers: A Short History of Official Science and Technology Statistics*.
10. B. Godin, *Metadata: How Footnotes Make for Doubtful Numbers*.
11. B. Godin, *Innovation and Tradition: The Historical Contingency of R&D Statistical Classifications*.
12. B. Godin, *Taking Demand Seriously: OECD and the Role of Users in Science and Technology Statistics*.
13. B. Godin, *What's So Difficult About International Statistics? UNESCO and the Measurement of Scientific and Technological Activities*.

# Measuring Output:
# When Economics Drives Science and Technology Measurement

Science policy developed over two periods in the second half of the 20th Century. The first was concerned with funding science activities that would help build research infrastructures and develop scientific communities: "science policies concerned themselves with little more than the development of research potential". [1] This period lasted from 1970s. The second period was concerned mainly with allocating scarce resources and, therefore, with choosing from among fields of science on the basis of selected socio-economic objectives: "During the period of contracting budgets, expanding needs, and demands for more oriented research, the necessity for priorities has become abundantly clear". [2] "The increased output of scientists and engineers – in so far as it can be stimulated – is not alone enough of a rationale". [3]

Each of thee science policy periods has a corresponding type of indicator. Until the mid-seventies, most indicators dealt with input, i.e. monetary investments and human resources involved in science and technology. The Frascati manual was emblematic of this early period in that it was exclusively concerned with the measurement of inputs, [4] although it did always include – from the first to the most recent edition – some discussion of output indicators. Nevertheless, it was not until the 1970s before the United States began to systematically develop output indicators, followed by most OECD Member countries in the1980s.

The OECD was an important producer of work on output indicators. There are essentially three types of output indicators in current OECD publications: indicators on patents,

[1] OECD (1974), *The Research System*, Vol. 3: 168.
[2] *Ibid*. p. 190.
[3] *Ibid*. p. 194.
[4] OECD (1962), *The Measurement of Scientific and Technical Activities: Proposed Standard Practice for Surveys of Research and Experimental Development*, Paris.

secondly, indicators on the technological balance of payments (TBP), and indicators on high technology trade. As this short list makes plain, OECD indicators express a particular view of scientific activity. I have argued elsewhere that the NSF based its indicators on the university system. [5] The OECD, in contrast, based its indicators on economics. [6]

This paper deals with the history of output indicators at the OECD. It is concerned with the following questions. Why were certain kinds of output indicators chosen or developed over others? What were the limitations of the selected indicators? What ideas (or ideologies) lay behind the choices? And finally, why was the emphasis placed on economics based indicators as opposed to indicators of university output or of the social impacts of research?

This paper divides into two parts. The first discusses the development of output indicators at the OECD in the 1980s: patents, TPB, and high technology trade. All of these indicators are characterized by a focus on the economic outputs of science and technology. The second part discusses the complete absence of university output indicators. It shows that an important asymmetry exists in the OECD treatment and evaluation of university indicators and other output indicators. It suggests that this asymmetry arose from the desire of national statistical offices to exercise complete control over the measurement of science and technology.

## Economically Speaking

As early as 1963, Yvan Fabian, an ardant promoter of output indicators and a former director of the OECD Statistical Resource Unit (SRU) of the Directorate of Scientific Affairs (DSA), discussed the relevance of output indicators at the meeting that launched work on the Frascati manual. [7] He concentrated on patents, and proposed four indicators that are still published in the OECD biennial publication *Main Science and Technology*

[5] B. Godin (2000), *The Emergence of Science and Technology Indicators: Why Did Governments Supplement Statistics with Indicators*, Montreal: OST.
[6] It is worth noting that the NSF serves academics, whereas the OECD serves governments.
[7] Y. Fabian (1963), *Note on the Measurement of the Output of R&D Activities*, DAS/PD/63.48.

*Indicators* (MSTI). He also showed how patent royalties could be used to measure international transfers of technology.

He was ahead of his time. Although the Committee for Scientific Research (CSR) proposed as early as 1963 to review existing work on the matter [8] and included questions on technological transfers and exports of high technology products in the first ISY, output indicators would not become systematically available before the 1980s. In fact, the first edition of the Frascati manual stated that: "Measures of output have not yet reached the stage of development at which it is possible to advance any proposals for standardization. (…) All these methods of measurement are open to objections". [9] The manual nevertheless presented and discussed the potential of two output indicators: patents and TBP.

By 1981, the manual included an annex specifically devoted to output and discussed a larger number of indicators, namely innovations, patents, TBP, high technology trade, and productivity. The tone of the manual had also changed. While recognizing that there still remained problems of measurement, it stated that: "Problems posed by the use of such data should not lead to their rejection as they are, for the moment, the only data which are available to measure output". [10]

The OECD started using output indicators in the 1960s in two studies with several indicators for assessing the various dimensions of science and technology performance. [11] The success of these studies spurred the DSA, in 1967, to seriously consider using output indicators on a systematic basis: "For an appraisal of research efforts the use of certain indicators such as scientific publications, lists of inventions and innovations or patent statistics can be envisaged". [12]

[8] SR (63) 33, p. 6; SR/M (65) 2, p. 18.
[9] OECD (1962), *op. cit*., p. 37.
[10] OECD (1981), *The Measurement of Scientific and Technical Activities: Proposed Standard Practice for Surveys of Research and Experimental Development*, Paris, p. 131.
[11] C. Freeman and A. Young (1965), *The Research and Development Effort in Western Europe, North America and the Soviet Union: An Experimental International Comparison of Research Expenditures and Manpower in 1962*, Paris: OECD; OECD (1968), *Gaps in Technology: General Report*, Paris.
[12] OECD (1967), *Future Work on R&D Statistics*, SP (67) 16, p. 5.

The real catalyst for OECD work on output however, was the report of the second *ad hoc* review group in 1976, which was itself influenced by the NSF publication *Science Indicators*. [13] The review group suggested that the OECD should get involved in output indicators. Four indicators were proposed – productivity, TBP, international trade, and patents – in addition to innovation indicators. [14]

The OECD's response to the *ad hoc* group was positive. The organization agreed that: "it would be better to push on and begin measuring output than to continue to try and improve input data". [15] However, the Secretariat "is not proposing to launch any special surveys of R&D output but intends to try and work from the existing series of data available, hoping that if the various series are taken in combination their results will be mutually reinforcing. Thus, through no one series is viable taken alone, if the results of several series were to agree this would confer some degree of plausibility on them". [16]

From then on, the OECD developed a whole program of work [17] that proceeded in four steps. Firstly, two workshops (1978 and 1979) [18] and a conference (1980) were held to assess the current state output indicators. [19] Secondly, experimental studies were conducted on three kinds of indicators: patents, [20] TBP, [21] and high technology trade. [22] Thirdly, methodological manuals were published. [23] And finally, databases were constructed and

[13] See : B. Godin (2000), *op. cit*.
[14] OECD (1978), *Report of the Second Ad Hoc Review Group on R&D Statistics*, SPT (78) 6.
[15] OECD (1977), *Responses by the Secretariat to the Questions of the Ad Hoc Group*, DSTI/SPR/77.52, p. 10.
[16] *Ibid*.
[17] OECD (1983), *State of Work on R&D Output Indicators*, SPT (83) 12; OECD (1984), *Secretariat Work on Output Indicators*, SPT (84) 8.
[18] OECD (1979), *The Development of Indicators to Measure the Output of R&D : Some Preliminary Results and Plan for Future Work*, SPT (79) 26.
[19] OECD (1980), *Preliminary Report of the Results of the Conference on Science and Technology Indicators*, SPT (80) 24.
[20] OECD (1983), *Experimental Studies on the Analysis of Output: Patents and the Science and Technology System*, DSTI/SRP/83.13 PART 1.
[21] OECD (1983), *Experimental Studies on the Analysis of Output: The Technological Balance of Payments*, DSTI/SRP/83.13 PART 3.
[22] OECD (1983), *Experimental Studies on the Analysis of Output: International Trade in High Technology Products – An Empirical Approach*, DSTI/SRP/83.13 PART 2.
[23] See below.

data were published on a regular basis – three editions of *Science and Technology Indicators*, plus the biennial publication *Main Science and Technology Indicators* (MSTI).

The following sections deal with each of the three main output indicators that were originally proposed by the *ad hoc* review group and that are currently still available in OECD publications: patents, TBP, and high technology trade. [24]

Patents

Contrary to what D. Archibugi and G. Sirilli have recently argued, [25] the first research indicator to appear in the history of science and technology measurement were patents rather than R&D statistics. We owe much to the pioneering works of the economist Jacob Schmookler, [26] but other economists, [27] and even sociologists, [28] used of patent statistics for studying science and technology in the 1930s and 1940s. As a matter of facts, Simon Kuznets wrote in 1962: "much more data, quantitative and qualitative, are available on output than on input". [29]

When the OECD began working on the methodology of patent statistics in the 1970s, it qualified the indicator as "not particularly favoured by users". [30] But the indicator had one significant advantage over the others: patent data were fairly easy to standardize: [31]

[24] Productivity will be dealt with in another paper.
[25] D. Archibugi and G. Sirilli (2001), *The Direct Measurement of Technological Innovation in Business*, Rome: National Research Council, p.6.
[26] J. Schmookler (1950), The Interpretation of Patent Statistics, *Journal of the Patent Office Society*, 32 (2): 123-146; J. Schmookler (1953), The Utility of Patent Statistics, *Journal of the Patent Office Society*, 34 (6): 407-412; J. Schmookler (1953), Patent Application Statisticsd as an Index of Inventive Activity, *Journal of the Patent Office Society*, 35 (7): 539-550; J. Schmookler (1954), The Level of Inventive Activity, *Review of Economics and Statistics*: 183-190.
[27] E. Graue (1940), Inventions and Production, *The Review of Economic Statistics*, 25 (4) : 221-223.
[28] A.B. Stafford (1952), Is the Rate of Invention Declining?, *The American Journal of Sociology*, 42 (6): 539-545; R.K. Merton (1935), Fluctuations in the Rate of Industrial Invention, *Quaterly Journal of Economics*, 49 (3): 454-474.
[29] S. Kutznets (1962), Inventive Activity: Problems of Definition, in NBER, *The Rate and Direction of Inventive Activity: Economic and Social Factors*, Princeton: Princeton University Press, p. 35.
[30] OECD (1977), Responses by the Secretariat to the Questions of the Ad Hoc Group, *op. cit*, p. 12.
[31] OECD (1982), *Patents, Invention and Innovation*, DSTI/SPR/82.74, p. 21.

> Patents received immediate attention as an output indicator: long time series are immediately available, the data is objective in the sense that it passively reflects an economic decision, and the data is undoubtedly related to an important form of knowledge creation: the invention of economically important new products and processes.

A workshop was held in 1982 to assess the indicator's usefulness. [32] Its main limitations were identified as follows: [33]

- Not all inventions are patented – or patentable.
- Firms and industries vary in their propensities to file patents – and cannot be compared.
- Legal systems and policies vary according to country.
- Patents vary in importance (value).

But these were manageable limitations according to the OECD:

> There has been continuing controversy over the use of patent statistics. (…) But, as J. Schmookler wrote, we have a choice of using patent statistics continuously and learning what we can from them, and not using them and learning nothing. (…) All progress in this field will come ultimately from the reasoned use of this indicator which, while always taking into account the difficulties it presents, works to reduce them. [34]

The OECD consequently started publishing patent indicators, [35] beginning with the first edition of *Main Science and Technology Indicators* in 1988. In 1994, the organization produced a methodological manual on collecting and interpreting patent statistics, written by F. Laville, from the French OST, with collaborators from the CSI (École des mines). [36]

[32] *Ibid*.
[33] OECD (1979), The Development of Indicators to Measure the Output of R&D : Some Preliminary Results and Plan for Future Work, *op.cit*., pp. 22-23 ; OECD (1980), Preliminary Report of the Results of the Conference on Science and Technology Indicators, *op. cit*. pp. 13-15.
[34] OECD (1983), State of Work on R&D Output Indicators, *op.cit*., p. 11.
[35] The data came from the World Intellectual Property Organization (WIPO) and Computer Horizons Inc. (CHI).
[36] OECD (1994), *The Measurement of Scientific and Technical Activities: Data on Patents and Their Utilization as Science and Technology Indicators*, Paris.

Patents were only one indicator for measuring invention. While patents were being introduced into OECD statistics, indicators of innovation output were also beginning to gain in popularity, and were said to be more appropriate for measuring innovative activities. However, because they required proper surveys, [37] the OECD waited until the 1990s before developing such indicators. Since then, patent statistics have become increasingly fashionable, at least at the OECD, [38] but remain limited in the organization's studies because of the too aggregated level of the data (lack of details on technological groups, industrial sectors). [39]

**Table 1.**

**Patent Indicators Appearing in *MSTI***

- National patent applications.
- Resident patent applications.
- Non-resident patent applications.
- External patent applications.
- Dependency ratio.
- Autosufficiency ratio.
- Inventiveness coefficient.
- Rate of diffusion.

[37] OECD (1977), Responses by the Secretariat to the Questions of the Ad Hoc Group, *op.cit*., p. 12.
[38] OECD (1994), *Workshop on Innovation, Patents and Technological Strategies: Summaries of Contributions*, DSTI/EAS/STP/NESTI (94) 14; OECD (1997), *Patents and Innovation in the International Context*, OECD/GD (97) 201; OECD (1999), *The Internationalization of Technology Analyzed with Patent Data*, DSTI/EAS/STP/NESTI (99) 3; OECD (1999), *Patents Counts as Indicators of Technology Output*, DSTI/EAS/STP/NESTI (99) 5; OECD (1999), *Patent Applications and Grants*, DSTI/EAS/STP/NESTI (99) 6; OECD (2000), *Counting Patent Families: Preliminary Findings*, DSTI/EAS/STP/NESTI/RD (2000) 11; OECD (2001), *Patent Families: Methodology*, DSTI/EAS/STP/NESTI (2001) 11.
[39] For an exception, see: OECD (1983), *Experimental Studies on the Analysis of Output: Patents and the Science and Technology System*, op. cit.

The Technological Balance of Payments

The next two indicators were spin-offs of the OECD study on technological gaps of the late sixties, [40] and concern commercial exchanges between countries. This concern probably has its origins in the European balance-of-payments deficits that were at the heart of the launching of the US Marshall Plan in 1948, [41] and the trade deficits of the early 1970s in the United States. [42]

The first indicator was the Technological Balance of Payments (TBP). If patent statistics were developed without much hesitation, the TBP was the first output indicator to undergo detailed scrutiny at the OECD. In fact, in 1981, the first in a series of OECD workshops on output indicators was dedicated to the TBP (1981). [43] From the beginning, the workshop identified three types of problems that persist to this day: [44]

1) Content:
    - The TBP excludes international technology flows that do not give rise to specific financial flows. By definition, the TBP cannot record invisible technology transfers (transfer of funds between multinational-enterprise subsidiaries and the parent company).
    - Among the financial flows the TBP records, there may be some which do not represent any real transfer of technology. Taxation policies, national regulations or monetary considerations all influence financial transfers and produce overestimates.

[40] OECD (1968), *Gaps in Technology: Analytical Report*, Paris.
[41] See I. Wexler (1983), *The Marshall Plan Revisited: The European Recovery Program in Economic Perspective*, Westport: Greenwood Press.
[42] M. Boretsky (1971), *Concerns About the Present American Position in International Trade*, Washington: National Academy of Engineering.
[43] OECD (1982), *Report of the Workshop on the Technological Balance of Payments*, DSTI/SPR/82.9.
[44] Already discussed in the seventies: OECD (1977), *Data Concerning the Balance of Technological Payments in Certain OECD Member Countries: Statistical Data and Methodological Analysis*, DSTI/SPR/77.2. Se also: OECD (1983), *Experimental Studies on the Analysis of Output: The Technological Balance of Payments*, op. cit. pp. 17ss.

- o The TBP usually includes payments for patents, licenses and know-how, but some countries also include trademarks, technical assistance, and management fees or payments for taking out and renewing patents.
- o Methods for collecting the data vary depending on the country: surveys, declarations by banking institutions.

2) Classification:
   a. Type of transaction: it is not always possible to break down receipts and expenditures between different categories (licenses, trademarks, know-how).
   b. Type of firm: it is difficult to identify the portion of receipts and payments transacted between affiliated companies.
3) International comparability.

In the light of these limitations, the workshop's experts suggested proceeding with caution: a negative TBP is not necessarily a sign of technological weakness. The deficit may instead be a sign, as in Japan's case, of an active policy for increasing the country's economic competitiveness. [45] All in all, the TBP should be used only in conjunction with other indicators. [46] Thus, the workshop recommended attempting international harmonization and preparing a compendium of methods. A methodological manual would indeed be written in 1983 by B. Madeuf, [47] revised and published in 1990. [48] That same year, the OECD launched its first international TBP survey and began publishing indicators in *MSTI*. The results of the surveys were quite dissatisfying, however. Three fourths of the countries did not adequately detail and document their statistics, and there was a gap ranging from 60% to 120% between the amounts declared by the money recipients and those by funders. [49] A

[45] OECD (1982), Report of the Workshop on the Technological Balance of Payments, *op.cit*., p. 9.
[46] *Ibid*. p. 7.
[47] B. Madeuf (1984), International Technology Transfers and International Technology Payments: Definitions, Measurement and Firms' Behaviour, *Research Policy*, 13: 125-140. France was indeed one of the first and most active countries to promote TBP statistics at the OECD. See for example: OECD (1964), *Governments and Innovation: Progress Report*, CMS-CI/GD/64/7, pp. 9-10.
[48] OECD (1990), *The Measurement of Scientific and Technical Activities: Proposed Standard Practice for the Collection and Interpretation of Data on the Technological Balance of Payments*, Paris.
[49] OECD (1992), *Les statistiques d'échanges techniques internationaux et de brevets d'invention: état des données de l'OCDE et perspectives de développement*, DSTI/STII/STP/NESTI/RD (92) 6.

revision of the manual was therefore envisaged in 1994 but never realized. For the OECD, the state of the indicator is actually the following one: [50]

> Given that few countries have supplied [enough] detailed statistics, and that the data lack uniformity (across countries) and stability (over time), it has not been possible to test the data properly and make wider use of them in research and publications dealing with S&T indicators. This has led to a vicious circle where users, feeling dissatisfied, see no reason to provide more resources to producers, who are consequently held back.

**Table 2.**

**TBP Indicators Appearing in *MSTI***

- Receipts.
- Payments.
- Balance.
- Coverage ratio.
- Total transactions.

<u>Trade in High Technology</u>

If the TBP was, and remains, a controversial indicator, indicators of high technology were subject to even greater controversy, particularly in countries like Canada that do not fare very well on such measures. [51] The problem stemmed from the fact that each country had its own idea of what constituted high technology and used its own vocabulary in describing: advanced technologies, strategic technologies, critical technologies, core technologies, basic technologies, new technologies. [52] As the OECD wrote: “The concept of high technology became part of our every day vocabulary before economists and

[50] OECD (1994), *Possible Revision of the TBP Manual*, DSTI/EAS/STP/NESTI (94) 10, p. 3.
[51] J.R. Baldwin and G. Gellatly (1998), *Are There High-Tech Industries or Only High-Tech Firms? Evidence From New Technology-Based Firms*, Research Paper Series, No. 120, Statistics Canada; K.S. Palda (1986), Technological Intensity: Concept and Measurement, *Research Policy*, 15, pp. 187-198.
[52] OECD (1993), *Summary of Replies to the Questionnaire on Methodology*, DSTI/EAS/IND/STP (93) 4.

scientists had even managed to produce a precise and generally accepted definition of the term". [53]

The work on high technology at the OECD was influenced by two factors: one analytical, the other political. The influence of the first factor was related to the OECD's attempts to analyze of R&D trends, [54] and to develop statistics for classifying countries [55] and industries [56] according to R&D effort or intensity. High technology was in fact the extension to industry of the GERD/GDP indicator for countries. [57] As shown below, the OECD developed ratios of intramural R&D divided by value added, and classified industries – and countries' performances – according to three groups – high, medium, low – depending on whether they were above or below the average level of R&D investment. [58] Thus, an industry that invested above the going average in R&D was considered to be a high-technology industry.

The second factor that influenced the development of high technology indicators was a request in 1982 by the OECD Council of Ministers asking the Secretariat to examine the problems that could arise in the trade of high-technology products. High technology trade had in fact gained strategic importance in the economic and political context of the 1970s, particularly in the USA (security and economic concerns), [59] but also in other OECD Member countries: high-tech industries were expanding more rapidly than other industries in international trade. The Industry Committee and the Committee for Scientific and Technological Policy of the Directorate for Science, Technology and Industry (DSTI) thus studied approaches in international trade theory, [60] and conducted two series of analyzes:

[53] OECD (1988), *La mesure de la haute technologie: méthodes existantes et améliorations possibles*, DSTI/IP/88.43, p. 3.
[54] OECD (1979), *Trends in Industrial R&D in Selected OECD Member Countries, 1967-1975*, Paris.
[55] OECD (1984), *Science and Technology Indicators*, Paris, pp. 24-25.
[56] OECD (1978), *Problems of Establishing the R&D Intensities of Industries*, DSTI/SPR/78.44.
[57] The first statistical exercise on "research-intensive industries" is to be found in OECD (1963), *Science, Economic Growth and Government Policy*, Paris, pp. 28-35; OECD (1970), *Gaps in Technology*, Paris, pp. 206-212 and 253-260.
[58] OECD (1978), Problems of Establishing the R&D Intensities of Industries, *op. cit*. p. 16.
[59] Council on Competitiveness, Department of Commerce, National Critical Technologies Panel.
[60] OECD (1981), *Analysis of the Contribution of the Work on Science and Technology Indicators to Work on Technology and Competitiveness*, DSTI/SPR/81.21.

six case studies of specific industrial technologies plus some reflections on defining high technology in terms of five characteristics (that went beyond mere R&D investment ratios). [61] It reported back to the Council in 1985. [62] For its part, the statistical unit organized a workshop on methodologies linking technology and trade. [63] Some of the first statistics were published in 1986 in the second issue of *Science and Technology Indicators*. [64]

The early OECD analytical work on high technology was based on a US classification scheme. [65] In fact, the first influential analyses on the subject were conducted in the United States [66] – but were inspired by the OECD concerns with technological gaps in the 1960s. [67] The US Department of Commerce developed a list of ten high-technology industries based on ratios of R&D expenditures to sales. The first OECD list of high-technology industries extrapolated the structure of American industry onto the entire area covered by the OECD, and was criticized for this reason. [68] The OECD consequently organized a workshop in 1983 [69] in which the literature on international trade theory [70] was studied to learn how to develop high technology trade indicators. The workshop concluded on the need for such

[61] OECD (1984), *Background Report on the Method of Work and Findings of the Studies Carried Out by the Industry Committee and the Committee for Scientific and Technological Policy*, DSTI/SPR/84.1.

[62] OECD (1985), *An Initial Contribution to the Statistical Analysis of Trade Patterns in High Technology Products*, DSTI/SPR/84.66. Analytical work continued in the following decade under the label "technology and competitiveness". See: OECD (1991), *TEP: International Conference Cycle*, pp. 61-68; OECD (1992), *Technology and the Economy*, chapter 11; OECD (1996), *Technology and Industrial Performance*, chapter, 5.

[63] OECD (1984), *Summary Record of the Workshop on Technology Indicators and the Measurement of Performance in International Trade*, DSTI/SPR/84.3.

[64] Part II, chapter 2.

[65] In fact, before the OECD Secretariat worked on the topic, no country had developed much work apart from the United States. See: OECD (1993), *Summary of Replies to the Questionnaire on Methodology*, DSTI/EAS/IND/STP (93) 4. Canada tried once to apply the US classification; see: MOSST (1978), *Canadian Trade in Technology-Intensive Manufactures, 1964-76*, Ottawa.

[66] For the Department of Commerce (DOC), see: M. Boretsky (1971), *op.cit*; R. Kelly (1977), *The Impact of Technology Innovation on International Trade Patterns*, US Department of Commerce, Washington; L. Davis (1982), *Technology Intensity of US Output and Trade*, US Department of Commerce, International Trade Administration, Washington. For the NSF, see the 1974 edition of *Science Indicator* and the followings. For other countries, see : OECD (1988), La mesure de la haute technologie: méthodes existantes et améliorations possibles, *op.cit*, pp. 10-14.

[67] OECD (1968), Gaps in Technology: Analytical Report, *op.cit*.

[68] OECD (1980), *International Trade in High R&D Intensive Products*, STIC/80.48; OECD (1983), Experimental Studies on the Analysis of Output: International Trade in High Technology Products – An Empirical Approach, *op. cit.*

[69] OECD (1984), *Summary Record of the Workshop on Technology Indicators and the Measurement of Performance in International Trade*, DSTI/SPR/84.3.

[70] Export/import, specialization (advantages), competitiveness (market share).

indicators based on the following "fact": "direct investment or the sale of technology are as effective as exports in gaining control of market". [71]

In collaboration with the Fraunhofer Institute for Systems and Innovation Research (Germany), the OECD thus developed a new classification based on a sample of eleven countries. [72] But there were still problems of regarding the lack of sufficiently disaggregated sectorial data: the list was based on industries rather than products. [73] All products from high-technology industries were qualified as high-tech even if they were not, simply because the industries that produced them were classified as high-tech. And, conversely, all high-tech products from low-technology industries were qualified as low-tech. Another difficulty was that the indicator did not take technology diffusion into account, but only R&D. An industry was thus reputed to be high-technology intensive if it had high levels of R&D, even if it did not actually produce or use much high-technology products and processes. Finally, the data upon which the list was based dated from 1970-80, [74] whereas high-technology products were known to be continuously evolving.

The list was therefore revised in the mid-nineties in collaboration with Eurostat [75] and following a workshop held in 1993. [76] It used much more recent data, and included embodied technology. Two lists were in fact developed. The first concerned high-technology industries, and considered both direct (R&D) [77] and indirect [78] intensities. [79]

[71] OECD (1984), Summary Record of the Workshop on Technology Indicators and the Measurement of Performance in International Trade, *op.cit*., p. 4.
[72] OECD (1984), *Specialization and Competitiveness in High, Medium and Low R&D-Intensity Manufacturing Industries: General Trends*, DSTI/SPR/84.49.
[73] OECD (1978), Problems of Establishing the R&D Intensities of Industries, *op.cit*.
[74] OECD (1988), La mesure de la haute technologie: méthodes existantes et améliorations possibles, *op.cit*.; OECD (1991) *High Technology Products: Background Document*, DSTI/STII (91) 35.
[75] *OECD* (1994), *Classification of High-Technology Products and Industries*, DSTI/EAS/IND/WP9 (94) 11; *OECD (1995), Classification of High-Technology Products and Industries*, DSTI/EAS/IND/STP (95) 1; OECD (1997), *Revision of the High Technology Sector and Product Classification*, DSTI/IND/STP/SWP/NESTI (97) 1.
[76] OECD (1994), *Seminar on High Technology Industry and Products Indicators: Summary Record*, DSTI/EAS/IND/STP/M (94) 1.
[77] R&D expenditures to output ratios were calculated in 22 sectors of the 10 countries that accounted for more than 95% of the OECD industrial R&D, then, using purchasing power parities, each sector was weighted according to its share of the total output.
[78] Input-Output coefficients.

Four groups of industries were identified, with medium technology being divided into high and low. But limitations persisted: high-technology intensities were calculated on the basis of the principal activity of the firms that made up the industry, and there was a lack of disaggregated details. In addition, the OECD recognized that: "the classification of the sectors in three or four groups in terms of their R&D intensity is partly a normative choice". [80]

**Table3.**

**OECD List of Technology Groups** (1997)

**HIGH**

Aircraft and Spacecraft (ISIC 353)
Pharmaceuticals (ISIC 2423)
Office, accounting and computing machinery (ISIC 30)
Radio, TV and communications equipment (ISIC 32)
Medical, precision and optical instruments (ISIC 33)

**MEDIUM-HIGH**

Electrical machinery and apparatus nec (ISIC 31)
Motor vehicles, trailers and semi-trailers (ISIC 34)
Chemicals excluding pharmaceuticals (ISIC 24 *less* 2423)
Railroad equipment and transport equipment nec (ISIC 352 + 359)
Machinery and equipment nec (ISIC 29)

**MEDIUM-LOW**

Coke, refined petroleum products and nuclear fuel (ISIC 23)
Rubber and plastic products (ISIC 25)
Other non-metallic mineral products (ISIC 26)
Building and repairing of ships and boats (ISIC 351)
Basic metals (ISIC 27)
Fabricated metal products, except machinery & equipment (ISIC 28)

**LOW**

Manufacturing nec ; Recycling (ISIC 36-37)
Wood and products of wood and cork (ISIC 20)
Pulp, paper, paper products, printing and publishing (ISIC 21-22)
Food products, beverages and tobacco (ISIC 15-16)
Textiles, textile products, leather and footwear (ISIC 17-19)

[79] For details on calculations, see: OECD (1995), *Technology Diffusion: Tracing the Flows of Embodied R&D in Eight OECD Countries*, DSTI/EAS (93) 5/REV1; G. Papaconstantinou et al. (1996), *Embodied Technology Diffusion: An Empirical Analysis for 10 OECD Countries*, OECD/GD (96) 26.

This led to the development of the second list, which was based on products rather than industries and was solely concerned with products in the high-technology category. [81] All products with R&D intensities above the industry average, i.e. about 3,5% of total sales, were considered high-tech. This list excluded products that were not high-tech, even if they were manufactured by high-tech industries. Moreover, the same products were classified similarly for all countries. But there are still two limitations remaining today. Firstly, the indicator is not totally quantitative: it is partly based on expert opinion. Secondly, the data are not comparable with other industrial data.

**Table 4.**

**High Technology Indicators Appearing in *MSTI***

- Export/import ratio: Aerospace industry.
- Export/import ratio: Electronic industry.
- Export/import ratio: Office machinery and computer industry.
- Export/import ratio: Drug industry.
- Export/import ratio: Other manufacturing industries.
- Export/import ratio: Total manufacturing.

This work on high technology never led to a methodological manual. Several times, among them during the 1992 revision of the Frascati manual, a manual devoted to high technology was envisioned, [82] but never written. Nevertheless, indicators were published regularly in *MSTI* from 1988, and R&D intensities between countries were discussed at length in the first edition of *Science and Technology Indicators* (1984).

[80] *OECD (1995), Classification of High-Technology Products and Industries*, DSTI/EAS/IND/STP (95) 1, p. 8.

[81] The SPRU conducted one of the first analyses of this kind for the OECD in the 1960s. See: OECD (1970), *Gaps in Technology*, Paris, pp. 211 and 231-232.

[82] OECD (1991), *Future Work on High Technology*, DSTI/STII/IND/WP9 (91) 7; OECD (1991), *High Technology Products*, DSTI/STII (91) 35; OECD (1992), *High Technology Industry and Products Indicators: Preparation of a Manual*, DSTI/STII/IND/WP9 (92) 6; OECD (1993), *Seminar on High Technology Industry and Products Indicators: Preparation of a Manual*, DSTI/EAS/IND/STP (93) 2.

## Controlling the Instrument

Besides discussing indicators of economic output and of the impact of science and technology, the OECD and Member countries regularly discussed university output indicators in the 1980s and 1990s. [83] Yet, no bibliometric indicators were ever developed. A manual was planned, [84] drafted, [85] but transformed in a working paper because its structure and coverage did not bore any relationship to a manual. [86] The idea of an Academic Structural Analysis Database was also considered, [87] but promptly abandoned. In sum, "the OECD has never been a primary actor in this field and is unlikely to do so in the future". [88]

The participants in the 1980 Conference on output indicators were nevertheless enthusiastic about bibliometrics. They agreed that bibliometric indicators can yield reliable information, but that care was needed in interpreting them. [89] The initial enthusiasm soon faded, however. In a document synthesizing its work on output indicators and distributed to Member countries in 1983, the OECD Secretariat emphasized two main areas of uncertainty or disagreement about bibliometrics: conceptual problems (indicators of what?) and relevance problems (indicators for whom?). [90] These uncertainties would dominate the workshop on higher education held in 1985 in which the OECD announced that it would

[83] OECD (1980), Preliminary Report of the Results of the Conference on Science and Technology Indicators, *op.cit.*: 25-30; OECD (1985), *Summary Record of the OECD Workshop on Science and Technology Indicators in the Higher Education Sector*, DSTI/SPR/85.60; OECD (1987), *Record of the NESTI Meeting*, DSTI/SPR/87.42; S. Herskovic (1998), *Preliminary Proposal for the Development of Standardized International Databases on Scientific Publications and Patent Applications*, DSTI/EAS/STP/NESTI/RD (98) 11.

[84] OECD (1991), *Record of the NESTI Meeting*, DSTI/STII/STP/NESTI/M (91) 1; OECD (1997), *Record of the NESTI Meeting*, DSTI/EAS/STP/NESTI (97) 1.

[85] OECD (1995), *Understanding Bibliometrics: Draft Manual on the Use of Bibliometrics as Science and Technology Indicators*, DSTI/STP/NESTI/SUR (95) 4.

[86] Y. Okubo, *Bibliometric Indicators and Analysis of Research Systems: Methods and Examples*, OECD/GD (97) 41.

[87] OECD (1991), *Record of the NESTI Meeting*, DSTI/STII/STP/NESTI/M (91) 1; OECD (1992), *Combined Program of Work*, DSTI/STII/IND/STP/ICCP (92) 1.

[88] OECD (1994), *Statistics and Indicators for Innovation and Technology*, DSTI/STP/TIP (94) 2, p. 11.

[89] OECD (1980), Preliminary Report of the Results of the Conference on Science and Technology Indicators, *op.cit.*, p. 29.

[90] OECD (1983), State of Work on R&D Output Indicators, *op.cit.*, p. 22-23.

not set-up a bibliometric database because of the indicators' costs and limitations. [91] The position of most countries, including the OECD in general, was that offered by J. Moravcsik: [92]

> Bibliometics is, by no means, an uncontroversial method of assessing the output and impact of research. The methods have been criticized, and sometimes rightly so, for being based on over-simple assumptions and for failing to take into account international biases in the data.

What were those limitations? The 1989 supplement to the Frascati manual, which was concerned with problems of measurement in the higher education sector listed at length the (supposed) limitations that prevented Member countries for getting involved in bibliometrics: [93]

- Orally communicated ideas between scientists are not included.
- Analyses are based on scientific journals to the exclusion of books.
- Documents can be cited for reasons other than their positive influence on research.
- Most far-reaching ideas soon cease to be cited formally.
- Some scientists and researchers cite their own papers excessively.
- Non-English language publications are cited less frequently that those published in English.
- There is a time-lag between the publication of results and the citation of the article.
- Scientists and researchers with the same name can often be confused.
- There is a bias in favor of the first author of multi-authored publications.

Were these limitations really the heart of the matter? For example, the OECD constantly reminded its audience that no indicators were without limitations, but that they should nevertheless be used. In the case of patents, for example, the OECD wrote: "There are obvious limitations (…). Patent data, however, are no different from other S&T indicators

[91] OECD (1985), Summary Record of the OECD Workshop on Science and Technology Indicators in the Higher Education Sector, *op.cit*., p. 35.
[92] *Ibid*. p. 27.
[93] OECD (1989), *The Measurement of Scientific and Technical Activities: R&D Statistics and Output Measurement in the Higher Education Sector*, Paris, p. 50-51.

in this regard" and "patent data should be part of this mix". [94] Similarly, concerning the highly contested high technology indicator, the OECD once stated: "Obviously, one has to be very careful in making policy conclusions on the basis of statistically observed relationships between technology-intensity measures and international competitiveness. Yet, as emphasized by one participant, to deny that policy conclusions can be made is to ignore some of the most challenging phenomena of the last decade". [95]

How, then, could the limitations of bibliometrics be perceived as any worse than the limitations of other indicators? There are two types of explanations. To begin with, several factors contributed to focusing output indicators on the economic dimension of science and technology. The first factor was related to the organization's mission, namely economic co-operation and development. It is therefore natural that most of its work dealt with indicators of an economic nature. Secondly, economists have been the main producers and users of S&T statistics and indicators and have constituted the bulk of OECD consultants because they were, until recently, among the only analysts that worked systematically with statistics: "one would have thought that political science, not economics, would have been the home discipline of policy analysis. The reason it was not was that the normative structure of political science tended to be squishy, while economics possessed a sharply articulated structure for thinking about what policy ought to be". [96] Thirdly, the economic dimensions of reality are the easiest to measure. Science and technology, particularly university research, involve invisibles and intangibles that still challenge statisticians. Lastly, at the time the OECD started working on output indicators, the state of the art of bibliometrics was not what it now is. It was then a new and emerging specialty that was widely criticized – by scientists among others.

But the main reason the OECD did not get involved in bibliometrics had to do with the control of the field of measurement, and this explains why Member countries prevented the OECD from developing bibliometric indicators. History has shown how "the census

[94] OECD (1980), Preliminary Report of the Results of the Conference on Science and Technology Indicators, *op. cit*. p. 14-15.
[95] *Ibid*. p. 18.

became authoritative in part through efforts by state officials to defeat or limit the scope of other ways of determining population". [97] National statistical offices applied similar efforts in rejecting outside data, including them bibliometric data. Firstly, official documents not uncommonly contained negative remarks about outsider data like the following: "their methodology may not come up to the standards" [98] But it is worth bearing in mind that these standards were solely determined by the statistical agencies themselves. Secondly, output measurements were often criticized for being "adapted from existing data sources, [for being] themselves proxies and [for giving] only partial measures of R&D output". [99] As the Frascati manual reported on these indicators: "one of the main problems is due to the type of data used. Data used to measure output have not, generally, been collected for that purpose and, thus, it is necessary to adjust them considerably (…)". [100] And the manual mentioned "another problem": the data were collected by different organizations – central banks or patent offices, trade departments, private firms, academics. [101]

National statistical offices explicitly rejected other kinds of data and activities. For example, although repertories of institutions are essential for conducting surveys, the task of compiling them is no longer (but has been for some time) considered part of a statistical agency's mandate because other departments now collect this information. [102] Similarly, benchmarking is said to be "an exercise neither for a statistical office (Statistics Canada) nor a statistical division (EAS)". [103] Finally, databases on new products and processes were rejected in the late 1980s to measure innovation. The survey of innovative activities was preferred. [104] In sum, the lesson is clear: the main tool of official statisticians is not the survey *per se* but rather the <u>official</u> survey that they control. As one participant to an NSF/OECD workshop noted in 1997: "The [R&D] questionnaire implicitly is built upon

[96] R.R. Nelson (1977), *The Moon and the Ghetto*, New York: Norton, p. 30.
[97] B. Curtis (2000), *The Politics of Population*, University of Toronto Press, p. 32.
[98] OECD (1994), *Statistics and Indicators for Innovation and Technology: Annex I*, DSTI/STP/TIP (94) 2/ANN 1, p. 6.
[99] *Ibid*. p. 10.
[100] OECD (1981), *op. cit*. p. 131.
[101] *Ibid*. p. 132.
[102] H. Stead, *The Development of S&T Statistics in Canada: An Informal Account*, Montreal: OST.
[103] OECD (2001), *Summary Record of the NESTI Meeting*, DSTI/EAS/STP/NESTI/M (2001) 1, p. 6.
[104] B. Godin (2002),

the basic assumption that the source data under S&T indicators come fundamentally from surveys linked to the Statistical Office". [105]

**Conclusion**

Input indicators went hand in hand with early science policies that were devoted to funding research for its own sake: "during the period when it was believe that fundamental research was the pivot of economic and industrial development and, therefore, merited preferential treatment, the only conceivable research policy was to expand". [106] Therefore, input indicators were developed to enlighten government decisions concerning funding. The second period of science and technology measurement was marked by the development of output indicators in the aim of evaluating science and technology as well as the results of government investments in these activities: "today, it is clear that it is neither absolute expenditures nor percentages which matter but the purposes for which human and financial resources are used". [107] "National science policies are going to be more and more concerned with oriented scientific research". [108] The OECD developed three indicators to this end: patents, technological balance of payments, and high technology trade. Innovation indicators were added in the early nineties, but the survey measured activities, not outputs. More recently, studies have begun to appear on the links between S&T and productivity. All in all, however, input indicators still remain the favorites. A recent OECD mini survey revealed that Member countries used output indicators less frequently than any other type of indicator. [109] Whereas indicators based on input (GERD) got over 80% of favorable responses, indicators based on patents, technological balance of payments, and high technology trade balance got less that 50%.

[105] OECD (1998), *The Use of S&T Indicators in Policy: Analysing the OECD Questionnaire*, DSTI/EAS/STP/NESTI/RD (98) 6.
[106] OECD (1974), *The Research System*, Vol. 3: 172.
[107] *Ibid*. p. 175.
[108] *Ibid*. p. 187.
[109] OECD (1998), *How to Improve the Main Science and Technology Indicators: First Suggestions from Users*, DSTI/EAS/STP/NESTI/RD (98) 9.

Keeping to the OECD vocabulary, I have used the term "output" throughout this paper. But "output" has often been understood to mean "impact". There was always confusion between the outputs and impacts of science and technology. While outputs are the direct results or products of research, impacts are the indirect effects of research on society and the economy. Both were, more often than not, amalgamated under the term output. Patents are output indicators, but other indicators are in fact measures of the economic impacts of science and technology: TBP, high technology trade, and productivity.

Be that as it may, the OECD never got involved in bibliometrics, although one can find some bibliometric statistics now and again in several reports. [110] And although it did conduct conduct some reflections on the evaluation of university research, [111] the OECD never developed output indicators for evaluating it. Nor did it produce indicators on the social impacts of research, although it conducted several qualitative exercises on the social assessment of technology and its methodologies. [112]

It therefore seems clear that immediate economics and industrial preoccupations drove the measurement of science and technology. This was a constant trend throughout the 1960-2000 period. Most Member countries never conducted regular surveys of either university or government R&D, but they did conduct industrial R&D surveys on a systematic basis. Now as then, university data and government activities are, for the most part, based on estimates budget documents, respectively. [113] Contrary to what had originally been planned, there are still no databases for university research or any methodological manual for bibliometrics or the classification or government R&D by socio-economic objectives. [114]

[110] See: OECD (1965), *Chapters From the Greek Report*, DAS/SPR/65.7; OECD (1968), *Fundamental Research and the Universities: Some Comments on International Differences*, Paris; OECD (1988), *Science and Technology Policy Outlook*, Paris, pp. 45ss; OECD (1999), *Science, Technology and Industry Scoreboard*, Paris, p. 89; OECD (2001), *Science, Technology and Industry Scoreboard*, Paris, pp. 63, 113. European Union's *European Report on S&T Indicators* also contains bibliometric indicators.
[111] See, for example: OECD (1987), *Evaluation of Research*, Paris; OECD (1997), *The Evaluation of Scientific Research: Selected Experiences*, OECD/GD (97) 194.
[112] B.Godin (2002), *Are Statistics Really Useful? Myths and Politics of Science and Technology Indicators*, Montreal: OST.
[113] B. Godin (2000), *Metadata: How Footnotes Make for Doubtful Numbers*, Montreal: OST.
[114] *Ibid*. See also: B. Godin (2001), *Innovation and Tradition: The Historical Contingency of R&D Statistical Classifications*, Montreal: OST.

As a result, data on university research are the poorest of all DSTI data. Besides the absence of R&D surveys and output measurement, there were two historical limitations affecting the available data. Firstly, the difficulty of measuring basic research led more and more countries to abandon the concept as a means of classifying university R&D. [115] Secondly, the functional classification of university research by scientific disciplines is unanimously qualified as outdated. [116] As the OECD once admitted regarding university R&D, we are in "a vicious circle whereby the lower the quality of the data, the less it can be used in policy and analytical studies and, the less it appears in such studies, the lower the pressure to improve the data". [117] Hence, the prioritization of economics and industry in statistics … and policies.

[115] B. Godin (2002), *Measuring Science: Is There Basic Research without Statistics?*, Montreal: OST.
[116] B. Godin (2001), *Innovation and Tradition: The Historical Contingency of R&D Statistical Classifications*, Montreal: OST.
[117] OECD (1995), *NESTI and its Work Relating to the Science System*, DSTI/STP/NESTI/SUR (95) 2, p. 9.