The Obsession for Competitiveness and its Impact on Statistics: the Construction of High-Technology Indicators

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Project on the History and Sociology of S&T Statistics
Working Paper No. 25

2004

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Early official economic statistics dealt with national income, industrial production, and productivity. Following World War II, international trade was increasingly added to statistical series. [1] In fact, international relations between countries, growing trading exchanges and competitiveness came to dominate the political agendas of several governments.

It was in this context that two of the main science and technology indicators that are currently in vogue came to be developed: the technological balance of payments (TBP) and high technology. This paper deals with the emergence of the latter. High technology (or technology intensity) is an indicator much in vogue in OECD countries, for it is a symbol of an "advanced" economy. The indicator is in fact the analog to industry of the GERD/GDP indicator for countries: a ratio of R&D divided by production. Industries are classified according to whether they are above or below the average ratio. An industry that invests above the average in R&D is considered to be a high-technology industry.

The indicator remains a controversial one for conceptual and for methodological reasons. Nevertheless, governments use it continually as part of their economic and innovation policy. As the US National Science Foundation (NSF) summarized the situation, high-technology industries are important to nations for several reasons: [2]

1. High-technology firms innovate, and firms that innovate tend to gain market share, create new products/markets, and/or use resources more productively;

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[1] J. Tomlinson (1996), Inventing Decline: the Falling Behind of the British Economy in the Postwar Years, *Economic History Review*, 69 (4), pp. 731-757.
[2] NSF (2002), *Science and Engineering Indicators*, Washington, p. 6-5.

2. Industrial R&D performed by high-technology industries benefits other commercial sectors by generating new products and processes that increase productivity, expand business and create high-wage jobs;

3. High-technology firms develop high-valued-added products and are successful in foreign markets, which results in increased competition.

What is characteristic about the indicator on high technology is its linkage to competitiveness issues. This paper explains that the reason has to do with the fact that the indicator emerged in the context of debates on the competitiveness of countries and their efforts to maintain or improve their positions in world trade. High technology rapidly came to be viewed as the solution to the issue, and statistics were developed to document the case.

Some authors have qualified the debates on competitiveness as obsessive. For P. Krugman, for example, countries do not compete economically with each other as corporations do. [3] But the metaphor "derives much of its attractiveness from its seeming comprehensibility" (p. 39). First, the competitive image is exciting, and thrills sell tickets. Second, the metaphor makes difficulties easier to solve (subsidize high technology or be tough on competitors). Third, it is a political device that assists in justifying choices. This article shows how statistics contributed to the rhetoric on competitiveness, looking at the efforts of official statisticians to rhetorically transform early statistics on R&D into indicators on high technology.

Where does the indicator come from? Who was behind its construction? What discourses did governments conduct using the indicator? This paper intends to answer these questions. It is divided into three parts. The first looks at the basic statistics behind the indicator, statistics developed in early analyses of industrial R&D surveys. The second part traces the evolution of the statistic through its use as an indicator of research or

[3] P. Krugman (1994), Competitiveness: A Dangerous Obsession, *Foreign Affairs*, 73 (2), pp. 28-44.

technological intensity. The third part discusses the internationalization of the indicator via the OECD.

A Very Basic Ratio

The simplest indicator on high technology is constructed by dividing R&D expenditures by production (i.e.: value-added, turn-over or sales) and then classifying industries according to this ratio. As R. N. Anthony, author of an influential survey on industrial R&D, once wrote: "Use of this ratio implies that there is some relationship between research spending and sales; to the extent that sales is a measure of the size of the company, this implication is in general warranted". [4]

The indicator has precursors that go back to the 1930s: analyses of industrial R&D have always calculated ratios of R&D to sales. The US National Research Council (NRC) conducted the first such analysis among the industrialized countries. In 1933, its Division of Engineering and Industrial Research tried to assess the effect of the Great Depression on industrial laboratories. [5] The report classified companies according to whether they spent over 10% of sales revenue on R&D, 5-10%, 1-5% or under 1%. With the data in hand, the authors concluded: "it appears that those companies the products of which more nearly approach the classification of raw materials spent a smaller percentage of their sales income for research than the companies in which products are of a **highly** manufactured character" (p. 3).

The following industrial surveys in the United States were conducted by or with the National Association of Manufacturers (NAM). In 1941, NAM participated in an industrial survey conducted by the National Resources Planning Board (NRPB). The report measured that: "the median expenditure of the companies for industrial research was (…) 2 percent of gross sales income". This was the only number on R&D

[4] R. N. Anthony and J. S. Day (1952), *Management Controls in Industrial Research Organizations*, Boston: Harvard University Press, p. 295.
[5] M. Holland and W. Spraragen (1933), *Research in Hard Times*, Division of Engineering and Industrial Research, National Research Council, Washington.

expenditures in the report, because the questionnaire had concentrated on personnel data (man-years), which were easier to obtain from companies. Eight years later, NAM published the results of a survey of industrial R&D in which these statistics appeared again. [6] NAM reported that in 1947, companies displayed an average ratio of research expenditures to estimated sales of 1.6%. [7] A larger proportion of the sales dollar was being spent by companies making professional, scientific and control instruments and photographic supplies, and electrical goods, the ratios being respectively 3.34% and 2.80%.

In the early 1950s, the US Bureau of Labor Statistics continued with similar statistics, locating some industries over the average (2.0%) – aircraft, electrical machinery, professional and scientific instruments, chemicals – and others under. [8] The practice was thereafter carried over into publications of the NSF – the official producers of R&D statistics in the United States. The first NSF survey of industrial R&D, conducted by the Bureau of Labor Statistics (BLS), related R&D expenditures to sales – and tentatively to assets. [9] Then, in its third industrial survey, the NSF calculated a second kind of ratio: R&D expenditures to value-added. R&D to capital was also calculated, a statistic that was said to "reflect more completely the magnitude of the manufacturing activities of a company or group of companies than do net sales". [10] The NSF calculated that the value-added ratio was 4.8%, versus 2.0% for net sales. The statistic was short lived, however, since the NSF abandoned the ratio in the following editions of the series.

Ratios of R&D expenditures to sales were not confined to the United States. Similar statistics appeared in an early industrial R&D survey conducted in the United Kingdom

[6] National Resources Planning Board (1941), *Research: A National Resource (II): Industrial Research*, Washington: USGPO, p. 124.
[7] National Association of Manufacturers (1949), *Trends in Industrial Research and Patent Practices*, p. 3, 77-79.
[8] Bureau of Labor Statistics (1953), *Industrial R&D: A Preliminary Report*, Department of Labor and Department of Defense, pp. 12-13; Bureau of Labor Statistics (1953), *Scientific R&D in American Industry: A Study of Manpower and Costs*, Bulletin no. 1148, Washington, pp. 26-29; D. C. Dearborn, R. W. Kneznek and R. N. Anthony (1953), *Spending for Industrial Research, 1951-1952*, Division of Research, Graduate School of Business Administration, Harvard University, pp. 29ss.
[9] NSF (1956), *Science and Engineering in American Industry: Final Report on a 1953-1954 Survey*, Bureau of Labor Statistics, NSF 56-16, Washington, pp. 33ss.

(R&D to turn-over; [11] R&D to net output [12]) and Canada (R&D as a percentage of sales). [13]

In general, the ratio was presented as a useful guide for managers interested in comparing their performance to other companies. For example, the NSF suggested: "In deciding upon their research budget, company officials frequently give consideration to certain objective financial standards, such as the ratio of R&D expenditures to sales. Such standards are seldom used in a rigid way but, rather, serve as a guide to management in determining the size of a research budget". [14] From an analytical point of view, the statistic served to assess and compare the relative efforts of industries in terms of R&D, and look at the impact of R&D on industries' economic performances. The message was to influence policies supporting R&D, particularly in big firms that invest more than others. A totally different rhetoric accompanies the indicator on high technology.

Variations on a Theme

What characterized the construction of the high technology indicator was that a specific rhetoric came to be associated with the statistic. Firstly, labels were now associated with the ratio of R&D expenditures to sales: research intensity, technology intensity, high technology. Secondly, the indicator was developed and increasingly used in the context of debates on the competitiveness of countries. The United States was at the origins of the rhetoric, and the OECD was at the heart of the indicator's worldwide dissemination.

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[10] NSF (1960), *Funds for R&D in Industry: 1957*, NSF 60-49, Washington, p. 28.
[11] Federation of British Industries (1952), *R&D in British Industry*, London: FBI, p. 7.
[12] DSIR (1958), *Estimates of Resources Devoted to Scientific and Engineering R&D in British Manufacturing, 1955*, London: HMSO. p. 17.
[13] Dominion Bureau of Statistics (1956), *Industrial R&D Expenditures in Canada, 1955*, Reference paper no. 75, Ottawa, p. 15.
[14] NSF (1956), Science and Engineering in American Industry, *op. cit*. p. 33.

Research Intensity

In 1958, E. Hoffmeyer coined the term **research-intensity** to talk about the performances of industries in terms of R&D effort. [15] The balance of payments deficit in the United States was the context in which Hoffmeyer published his analysis of US foreign trade over the 20th Century. In fact, in the late 1950s, the balance of payments came to be an important economic issue (for the second time in a decade), and the competitiveness of countries was measured according to the measure. A country was considered to be competitive if its exports exceeded its imports. Many countries began expressing concerns about their competitiveness as understood in this sense. Britain, for example, seconded by the OEEC's numbers, increased its laments on "economic decline", [16] particularly in light of its balance-of-payments deficit. [17] France launched a campaign against foreign investment [18] that led to the well-known debate on technological gaps. [19] The United States was no exception. Concerns over the US balance of payments occurred in the late 1950s and early 1960s. [20] Science and technology would soon come to be regarded as a source of strength in economic growth and foreign trade.

Using the NSF ratios of R&D expenditures to sales, Hoffmeyer looked at the structure of US foreign trade: eleven industries were classified into four groups according to their research effort or intensity. With the data, Hoffmeyer showed that the United States had a competitive advantage in the research-intensive industries. To the best of my knowledge, Hoffmeyer was the first to use this term, as well as the first to use it in the context of an

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[15] E. Hoffmeyer (1958), *Dollar Shortage and the Structure of US Foreign Trade*, Amsterdam: North-Holland.

[16] J. Tomlinson (1996), Inventing Decline: the Falling Behind of the British Economy in the Postwar Years, *op. cit*.

[17] J. M. McGeehan (1968), Competitiveness: A Survey of Recent Literature, *The Economic Journal*, 78 (3), pp. 243-262.

[18] A. W. Johnstone (1965), *United States Direct Investment in France: An Investigation of the French Charges*, Cambridge (Mass.): MIT Press.

[19] B. Godin (2003), *Technological Gaps: Quantitative Evidence and Qualitative Arguments*, Project on the History and Sociology of S&T Statistics, Montreal.

[20] Joint Economic Committee (1962), *Factors Affecting the United States Balance of Payments*, Subcommittee on International Exchange and Payments, Congress of the United States, Washington: USGPO; H. G. Johnson (1963), The International Competitive Position of the United States and the Balance of Payments Prospect for 1968, *Review of Economics and Statistics*, 66, February, pp. 14-32.

analysis of international trade. He would soon be imitated worldwide, first of all at the OECD.

In 1963, the OECD published a study it presented to the first ministerial meeting on science. The study, written by C. Freeman, R. Poignant and I. Svennilson, was the result of the OECD's early research program on the economics of science. Using available statistics, the authors looked at industrial R&D, and constructed three industry groups classified according to the ratio of R&D expenditures to sales. [21] The first group (Group A) was called **research-intensive industries** and was composed of aircraft, vehicles, electronics, other electrical, machinery, instruments, and chemicals. The study measured that "all the industrial countries considered show over two-thirds (the United States and the United Kingdom over nine-tenths) of their industrial R&D expenditure in Group A which comprises the research-intensive industries (…)" (p. 30). For the authors, research-intensive industries had several characteristics that made them valuable from the point of view of policies: 1) they were generally the fastest-growing industries (p. 29), 2) their share of world trade was growing (p. 32), and 3) they had the highest balance of technological payments (p. 33).

Such a term contributed to the OECD campaign for science policies. In fact, in the early 1960s, the OECD was campaigning to convince governments to develop science policies and set up ministries to this end. [22] Thus, research-intensive industries were a phenomenon that policies should work on, but also a symbol with rhetorical overtones that precisely fit the efforts of the organization to convince officials to get their country into the modern economy. The R&D intensity ratio would be calculated regularly in the following decades, particularly in OECD ISY studies and analyses on trends in R&D. [23]

A few years after the 1963 report, the OECD took part in a second campaign, this one calling for the closing of the technological gaps between European countries and the

[21] OECD (1963), *Science, Economic Growth and Government Policy*, Paris, p. 81.
[22] B. Godin (2002), *Are Statistics Really Useful? Myths and Politics of Science and Technology Indicators*, Project on the History and Sociology of S&T Statistics, Montreal.

United States. In its main report, the OECD introduced a new term: **science-based industries**. [24] Using the same criteria as in 1963 (R&D as a percentage of sales), industries were classified into four groups: science-based, mixed, average, and non-science based (Table 1). The report calculated that the United States had the highest proportion of R&D activity in the science-based industries, and found the largest difference between the United States and other countries in this group.

The OECD study took things one step further than the previous study, looking at product groups instead of industries: "a distinction must be made between the industry group and the product field", stated the OECD. While firms are usually classified in an industry group according to their main activity, an industry "may be relevant to several products". The OECD thus classified industrial R&D according to fifty products. It then used the data to study the role of science and technology, particularly science-based industries, in the international competitive position of countries as measured by export performance. [25]

Table 1.

OECD Research-Intensity Levels (1970)

Science Based	Mixed	Average	Non-Science Based
Aircraft	Machinery	Non ferrous metals	Textiles
Electronics	Fabricated metal products	Ferrous metals	Paper
Drugs	Petroleum	Other transport equipment	Food and drink
Chemicals			Miscellaneous Manufacturing

[23] B. Godin (2002), *The Most Cherished Indicator: Gross Domestic Expenditures on R&D (GERD)*, Project on the History and Sociology of S&T Statistics, Montreal.
[24] OECD (1970), *Gaps in Technology: Comparisons Between Member Countries in Education, R&D, Technological Innovation, International Economic Exchanges*, Paris, p. 135ss.
[25] *Ibid*. pp. 206ss and 253ss.

In fact, this was a time when several economists began integrating science into models of international trade. [26] Until the 1960s, the current model of international trade, known as Heckscher-Ohlin-Samuelson, centered on resource endowments as the main factor explaining international trade patterns. In the late 1960s, however, authors began introducing additional factors, among them technology (generally measured by R&D), to explain why some countries led in terms of trade and others lagged. [27] This interest in using technology to explain international trade appeared in response to the persistent and structural shortage of dollars in the world, and the ensuing foreign-trade patterns. The new studies suggested that countries were not equal in terms of publicly available science and technology. Some became leaders because they innovated and disseminated technologies before others. [28]

The OECD study – the empirical material for which came from Science Policy Research Unit (SPRU) researchers – was one of the first conducted worldwide linking science and trade. It confirmed earlier findings of the organization. Research-intensive groups accounted for a large share of manufacturing exports, and the Americans had the lead over Europe, followed by the medium-sized countries, then the smaller industrialized OECD member countries: "there is a high concentration of United States exports in those product groups where there is a high concentration of R&D effort" (p. 255). However, the OECD calculated that the share of the United States in OECD exports has declined from 23.7% in 1962 to 21.3% in 1966 as a result of the catching-up by other OECD countries.

[26] For an overview, see: P. Krugman (1995), Technological Change in International Trade, in P. Stoneman (ed.), *Handbook of the Economics of Innovation and Technological Change*, Oxford: Blackwell, pp. 342-365.

[27] M. V. Posner (1961), International Trade and Technical Change, *Oxford Economic Papers*, 13, pp. 323-341; R. Vernon (1966), International Investment and International Trade in the Product Cycle, *Quarterly Journal of Economics*, 80, pp. 190-207; R. Vernon (ed.) (1970), *The Technology Factor in International Trade*, NBER, New York: Columbia University Press; D. B. Keesing (1967), The Impact of R&D on United States Trade, *Journal of Political Economy*, 25 (1), pp. 38-48; W. Gruber, D. Mehta, R. Vernon (1967), The R&D Factor in International Trade and International Investment of United States Industries, *Journal of Political Economy*, 25 (1), pp. 20-37.

[28] M. Abramovitz (1986), Catching Up, Forging Ahead, and Falling Behind, *Journal of Economic History*, XLVI (2), pp. 385-406; J. Fagerberg (1994), Technology, and International Differences in Growth Rates,

Technology Intensity

It was precisely in the context of issues on international competitiveness that a new term – technology intensity – appeared to describe the same phenomenon. In the course of the debate on the technological gaps between Europe and the United States, the US government set up an interdepartmental committee to study the issue. [29] At the request of the (Hornig) committee, the Department of Commerce conducted one of the first surveys of American investments and operations in Europe. To the best of my knowledge, it is this survey that coined the term **technology-intensive industries** to document the structure of US direct investment in Western Europe. [30] According to the committee, 80% of all US direct investments in manufacturing in Western Europe were in technology-intensive industries, and Americans controlled large segments of the market in such technology-intensive products as computers.

As a follow-up to its report, the committee recommended that the Department of Commerce "conducts on a continuing basis in-depth analytical studies on the economic and technological questions related to technological disparities and to the international flow of technology, trade, and investments" (p. v). The Department of Commerce responded with further studies and reports that brought onto the scene the concept of technology intensity, and the decline of the United States in technology-intensive industries. M. T. Boretsky, director of the Technological Gap Study Program (1967-69) at the Department of Commerce, launched the research program.

Until then, as we have seen above, "research-intensive industries" were defined as those that had a high R&D/sales ratio. Boretsky instead used three statistics (or criteria, as he called them) to construct what he called **technology-intensive products** (although he

Journal of Economic Literature, 32, pp. 1147-1175; J. Fagerberg, B. Varspagen and N. von Tunzelmann (1994), *The Dynamics of Technology, Trade and Growth*, Aldershot (Hants): Edward Elgar.

[29] B. Godin (2003), Technological Gaps: Quantitative Evidence and Qualitative Arguments, op. cit.

[30] *Report of the Interdepartmental Committee on the Technological Gap*, Report submitted to the President, December 22, 1967, White House, pp. 13-14.

used industries as unit, not products): [31] R&D, scientific and technical manpower, and the skill level of workers. The following industries were thus identified as belonging to the category: chemicals, non-electrical machinery, electrical machinery and apparatus (including electronics), transportation equipment (including automobiles and aircraft), and scientific and professional instruments and controls. The industries responsible for these products represented 14% of GDP in the United States, employed 60% of all scientific and engineering manpower, and performed 80% of non-defense industrial R&D.

Boretsky showed that the United States was in danger of losing its preeminence in advanced technologies, particularly those that are important in world trade. American exports of technology-intensive manufactured products were leveling off. This was so mainly because of the narrowing of the gap with other OECD countries, and because of faster growth rates in these countries. Ironically, "if, in the 1960s, any country's economically-relevant R&D performance could be described as having had the characteristics of a gap, the description should have been accorded to the United States rather than to the major countries of Europe, or to Japan", concluded M. Boretsky. [32]

The Department of Commerce continued to develop and improve the indicator in the following years, [33] and used the data to document America's competitiveness. [34] In fact, the 1980s was a time when the US government became obsessed with international competitiveness: "the United States is playing a relatively smaller role in the world

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[31] M. Boretsky (1971), *Concerns About the Present American Position in International Trade*, Washington: National Academy of Engineering, pp. 18-66; M. Boretsky (1975), Trends in US Technology: A Political Economist's View, *American Scientist*, 63, pp. 70-82; *Science* (1971), Technology and World Trade: Is There Cause for Alarm, 172 (3978), pp. 37-41; M. Boretsky (1973), *US Technology: Trends and Policy Issues*, Revised version of a paper presented at a seminar sponsored by the Graduate Program in Science, Technology and Public Policy of the George Washington University, Washington.

[32] M. Boretsky (1973), US Technology: Trends and Policy Issues, *op. cit*. p. 85.

[33] R. K. Kelly (1976), *Alternative Measurements of Technology-Intensive Trade*, Office of International Economic Research, Department of Commerce; R. Kelly (1977), *The Impact of Technology Innovation on International Trade Patterns*, Department of Commerce, Washington; L. Davis (1982), *Technology Intensity of US Output and Trade*, Department of Commerce, International Trade Administration, Washington; L. A. Davis (1988), *Technology Intensity of US, Canadian and Japanese Manufacturers Output and Exports*, Office of Trade and Investment Analysis, Department of Commerce.

economy", stated the report of the President on US competitiveness in 1980. [35] Indeed, in 1971, the US balance of trade turned to a deficit for the first time since 1893, and in 1986 the US trade performance in technology-intensive industries would dip into a $2.6 billion deficit for the first time. But now, it was Japan rather than Europe that was the target: "Japan has joined the United States in having a comparative advantage in technology-intensive products (…)", warned the document. In response, the US government set up a Commission on Industrial Competitiveness in 1983, [36] then the Council on Competitiveness in 1986, [37] and the Competitiveness Policy Council in 1992. [38] It also set up the Critical Technologies Institute in 1991 (renamed the Science and Technology Policy Institute in 1998) which periodically identified technologies critical for the future. [39] It was in this context that concepts like critical technologies, core technologies, basic technologies, advanced technologies, new technologies, strategic technologies and emerging technologies came onto the scene. [40]

In its methodological works, DOC used more or less the same criteria as initially suggested by Boretsky, but more work was conducted at the level of product groups (R. Kelly) and on embodied technology (L. A. Davis). Soon, other US organizations started developing their own classifications, among them the Department of Labor, [41] the Bureau

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[34] US Department of Commerce (1983), *An Assessment of US Competitiveness in High Technology Industries*, International Trade Administration; V. L. Hatter (1985), *US High Technology Trade and Competitiveness*, Department of Commerce, International Trade Administration, Washington.

[35] *Together with the Study on US Competitiveness*, Report of the President on US Competitiveness, Office of Foreign Economic Research, Department of Labor, 1980.

[36] *Global Competition: the New Reality*, 1985.

[37] Influential reports were: *America's Competitive Crisis*, 1987; *US Competitiveness: A Ten-Year Strategic Assessment*, 1996.

[38] *Building a Competitive America*, 1992, Washington.

[39] For criticisms of the exercises, see: M. E. Mogee (1991), *Technology Policy and Critical Technologies: A Summary of Recent Reports*, National Academy Press; L M. Branscomb (1993), Targeting Critical Technologies, in *Empowering Technology*, Cambridge: MIT Press, pp. 36-63.

[40] National Research Council (1983), *International Competition in Advanced Technology: Decisions for America*, Washington: National Academy Press; US Department of Commerce (1987), *The Status of Emerging Technologies: An Economic/Technological Assessment to the Year 2000*, NBSIR 87-3671, Washington; H. Giersch (ed.) (1982), Emerging Technologies: Consequences for Economic Growth, Structural Change and Employment, Tubinger, Mohr; Science Council of Canada (1986), A National Consultation on Emerging Technologies, Ottawa; OECD (1985), *Analytical Report of the Ad Hoc Group on Science, Technology and Competitiveness*, SPT (84) 26.

[41] C. M. Aho and H. F. Rosen (1980), *Trends in Technology-Intensive Trade with Special Reference to US Competitiveness*, Office of Foreign Economic Research, US Department of Labor.

of Census, [42] and the NSF. [43] The NSF's work in fact started soon after Boretsky's, and was intended to add new indicators to its recent *Science Indicators* series. The organization defined technology intensity using two criteria: R&D as a percentage of sales, and number of scientists and engineers engaged in R&D.

From these efforts, the use of the indicator soon spread to other countries [44] and international organizations like the European Commission [45] and the OECD.

High Technology

In the mid-1980s, the term **high technology** began to be used concurrently or in place of technology intensity, as evidenced in DOC reports (see footnote 34). [46] Nothing really new had changed with regard to the statistic, however, but a valued and prestigious label (high) was now assigned to it. The OECD was an important catalyst in the dissemination of this term.

As early as 1980, the Committee for Scientific and Technological Policy (CSTP) set up an *ad hoc* group on science, technology and competitiveness to get a better understanding of international competitiveness and its relations to technology. The group delivered its

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[42] G. Worden (1986), *Problems in Defining High-Technology Industries*, Bureau of Census, Washington; T. Abbott et al. (1989), *Measuring the Trade Balance in Advanced Technology Products*, Center for Economic Studies, US Bureau of Census, Washington; T. A. Abbott (1991), Measuring High Technology Trade: Contrasting International Trade Administration and Bureau of Census Methodologies and Results, *Journal of Economic and Social Measurement*, 17, pp. 17-44; R. H. McGuckin et al. (1992), Measuring Advanced Technology Products Trade: A New Approach, *Journal of Official Statistics*, 8 (2), pp. 223-233; M. E. Doms and R. H. McGuckin (1992), Trade in High Technology Products, *Science and Public Policy*, 19 (6), pp. 343-346.

[43] See *Science Indicators* (1974) and the following editions. Starting with the 1993 edition, new indicators were constructed by researchers from the Georgia Institute of Technology (A. L. Porter and J. D. Roessner).

[44] OECD (1988), *La mesure de la haute technologie: méthodes existantes et améliorations possibles*, DSTI/IP/88.43, pp. 10-14. For the United Kingdom, see: R. L. Butchart (1987), A New UK Definition of the High-Technology Industries, *Economic Trends*, 400, pp. 82-88; For Canada, see: Ministry of State, Science and Technology (1978), *Canadian Trade in Technology-Intensive Manufactures, 1964-1976*, Ottawa.

[45] European Commission (1994), *First European Report on Science and Technology Indicators*, Brussels.

[46] An early use of the term appears in R. N. Cooper (1971), Technology and US Trade: A Historical Review, in National Academy of Engineering, *Technology and International Trade*, Proceedings of a Symposium Held on October 14 and 15, 1970, Washington: NAE, p. 9.

analytical report in 1984. According to the group, "differences in R&D intensities are best interpreted as signifying, first that in some industries technology is more immediately geared to R&D than it is in others, and second that *such industries may also represent the technology base on which other industrial sectors rely and from which inter-sectoral transfers of technology must take place* (…)". [47] The main thesis of the report was therefore: "changes in the nature and location within industry of *core technologies* are probably associated with extensive economic and industrial changes of a structural type, both at the domestic and at the international level, many of which will bear directly on the competitiveness of firms and economies". [48]

The real impetus to work on high technology, however, came from the OECD Council of Ministers that asked the Secretariat in 1982 to examine the problems that could arise in the trade of high-technology products. High-technology trade had now gained strategic importance in the economic and political context of the time, particularly in the United States (for security reasons and economic concerns), but also in other OECD member countries: high-tech industries were expanding more rapidly than other industries in international trade, and were believed to be an important policy option for economic progress. The Industry Committee and the CSTP of the Directorate for Science, Technology and Industry (DSTI) thus studied approaches to international trade theory, [49] and conducted two series of analyses: six case studies of specific industrial technologies, plus some reflections on defining high technology in terms of five characteristics or criteria (which went beyond mere ratios of R&D expenditures to sales). [50] It reported back to the Council in 1985. [51]

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[47] OECD (1985), Analytical Report of the Ad Hoc Group on Science, Technology and Competitiveness, *op. cit*. p. 11.
[48] *Ibid*. p. 14.
[49] OECD (1981), *Analysis of the Contribution of the Work on Science and Technology Indicators to Work on Technology and Competitiveness*, DSTI/SPR/81.21.
[50] 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.
[51] OECD (1985), *An Initial Contribution to the Statistical Analysis of Trade Patterns in High Technology Products*, DSTI/SPR/84.66.

The first international statistics were published in 1986 in the second issue of the OECD's *Science and Technology Indicators*. The organization improved over previous works, in two senses. Firstly, it began using a new label systematically – high technology. Secondly, it broke down the statistics into subclasses. Up until now, there was only one class of industries or products classified according to technology intensity. Others were simply forgotten or called non-technology-intensive. With the OECD, three categories of technology intensity were now constructed: high, medium, and low (Table 2). The source and origin of this innovation is unclear to me, except that it appeared shortly after Boretsky's study, and is present in a US Tariff Commission report published in 1973. [52] An early use of a similar classification outside the United States is also found in Canada. [53] The Canadian Ministry of State Science and Technology (MOST) had divided industries according to four levels of research intensity: research-intensive (a ratio of R&D to value-added over 3%), medium-research intensive (1-3%), low-research intensive (less than 1%), and no R&D. The purpose, however, was not to study trade performances, but other economic characteristics of R&D spenders – growth in employment, output, productivity and prices.

With its new classification, the OECD calculated that the R&D-intensive industries [54] were responsible for 51% of total industrial R&D of OECD countries during the period 1970-1980. [55] The organization also found that these industries have the highest growth, and show a positive correlation between R&D intensity and exports. The United States and Japan were at the forefront. In the next decade, all statistical analyses on competitiveness conducted by the Directorate showed the same patterns. [56]

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[52] US Tariff Commission (1973), *Implications of Multinationals Firms for World Trade and Investment and for US Trade and Labor*, Washington.
[53] Ministry of State, Science and Technology (1978), *Performance of Canadian Manufacturing Industries by Levels of Research Intensity*, Background Paper, Ottawa.
[54] R&D intensity is used in the OECD text despite the fact that the chapter dealt with technology intensity.
[55] OECD, *Science and Technology Indicators*, Paris, pp. 58-74.
[56] OECD (1992), *Technology and the Economy: the Key Relationships*, Paris, chapter 11; OECD (1992), *Science and Technology Policy Outlook*, Paris, chapter 2; OECD (1996), *Technology and Industrial Performance*, Paris, chapter 5.

Table 2.

OECD Technology Intensity Levels (1986)

High	**Medium**	**Low**
Aerospace	Automobiles	Stone, clay, glass
Office machines, computers	Chemicals	Food, beverage, tobacco
Electronics and components	Other manufacturing	Shipbuilding
Drugs	Non-electrical machinery	Petroleum refineries
Instruments	Rubber, plastics	Ferrous metals
Electrical machinery	Non-ferrous metals	Fabricated metal products
		Paper, printing
		Wood, cork, furniture
		Textiles, footwear, leather

The early OECD analytical work on high technology was based on the US classification scheme. [57] The US Department of Commerce had 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. [58] The OECD consequently organized a workshop in 1983 [59] in which the literature on international trade theory and its main concepts [60] was studied to learn how to develop high-technology trade indicators. The workshop concluded on the need for such indicators based on the following "fact":

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[57] 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.

[58] 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.*

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

[60] Export/import, specialization (advantages), competitiveness (market share). For more recent discussions, see: T. Hatzichronoglou (1996), *Globalization and Competitiveness: Relevant Indicators*, OECD/GD(96)43.

"direct investment or the sale of technology are as effective as exports in gaining control of markets". [61]

In collaboration with the Fraunhofer Institute for Systems and Innovation Research (Germany), the OECD then developed a new classification based on a broader sample of eleven countries. [62] But there were still problems regarding the lack of sufficiently-disaggregated sectoral data: the list was based on industries rather than products. [63] 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 dissemination 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 in the way of high-technology products and processes. Finally, the data upon which the list was based dated from 1970-80, [64] whereas high-technology products were known to be continuously evolving. [65]

The list was therefore revised in the mid-1990s in collaboration with Eurostat [66] and following a workshop held in 1993. [67] It used much more recent data, and included a new dimension to take technology dissemination, as embodied technology (technology incorporated in physical capital), into account. Two lists were in fact developed. The first

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[61] OECD (1984), Summary Record of the Workshop on Technology Indicators and the Measurement of Performance in International Trade, *op. cit.* p. 4.

[62] OECD (1984), *Specialization and Competitiveness in High, Medium and Low R&D-Intensity Manufacturing Industries: General Trends*, DSTI/SPR/84.49.

[63] OECD (1978), *Problems of Establishing the R&D Intensities of Industries*, DSTI/SPR/78.44.

[64] 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.

[65] All these problems were already identified in R. K. Kelly (1976), Alternative Measurements of Technology-Intensive Trade, *op, cit.*

[66] 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.

[67] OECD (1994), *Seminar on High Technology Industry and Products Indicators: Summary Record*, DSTI/EAS/IND/STP/M (94) 1.

concerned high-technology industries, and considered both direct (R&D) [68] and indirect [69] intensities. [70] Four groups of industries were identified, with medium technology being divided into high and low (Table 3). 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". [71]

This led to the development of the second list, which was based on products rather than industries, and which was solely concerned with the high-technology category. 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 were and still remain two limitations. Firstly, the indicator was not totally quantitative: it was partly based on expert opinion. Secondly, the data were not comparable with other industrial data.

[68] R&D expenditure-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.
[69] Input-output coefficients.
[70] 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.
[71] *OECD (1995), Classification of High-Technology Products and Industries,* DSTI/EAS/IND/STP (95) 1, p. 8.

Table 3.
OECD List of Technology Industries (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 (ISIC 31)
Motor vehicles, trailers and semi-trailers (ISIC 34)
Chemicals excluding pharmaceuticals (ISIC 24 *less* 2423)
Railroad equipment and transport equipment (ISIC 352 + 359)
Machinery and equipment (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; 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)

Contrary to other OECD science and technology indicators, the work of the organization on high technology never led to a methodological manual. Several times, among them during the fourth revision of the Frascati manual, a manual devoted to high technology was envisioned, [72] but never written. Nevertheless, indicators on international trade in high technology industries were published regularly in *Main Science and Technology Indicators* (MSTI) from 1988 (Table 4).

[72] 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.

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.

Conclusion

How has the concept of high technology improved over the previous concepts? Certainly, one could argue with Kelly that: "research-intensity and technology-intensity are not necessarily the same concept. What one is really trying to measure [with technology intensity] is the degree of technical sophistication of products that gives them a competitive edge (…)".[73] However, it should have become clear from the above analysis that both concepts are actually the same, according to their measurement. Because, as Kelly himself admitted: "as in many areas of economics, proxies must be used as an indicator (…). [And we] chose the R&D intensity". The OECD technology intensity indicator is also based on R&D expenditures to sales ratios, and is frequently discussed in terms of R&D intensity rather than technology intensity.

When more than one criterion is used, the criteria usually center around Boretsky's three, to the point that "limited progress appears to have been made on the measurement of technology intensiveness since the original Boretsky paper",[74] except rhetorical inventiveness. For example, a newly-coined concept appeared recently at the OECD in its

[73] R. K. Kelly (1976), R. K Kelly (1976), Alternative Measurements of Technology-Intensive Trade, *op. cit*. p. 8.
[74] F. Chesnais and C. Michon-Savarit (1980), Some Observations on Alternative Approaches to the Analysis of International Competitiveness and the Role of Technology Factor, STIC/80.41, OECD, p. 14.

work on the knowledge-base economy: **knowledge-based industries**. [75] Knowledge-based industries are defined as those that have the following three characteristics: 1) a high level of investment in innovation, 2) intensive use of acquired technology, and 3) a highly-educated workforce. [76] This is a perfect example of a variation on the high technology indicator.

Briefly stated, if technology intensity is a replica of research intensity, high technology is simply a rhetorical exercise renaming technology intensity. Why? The label was the way to link and align the statistical work to political and normative issues, where buzzwords are the rule. In fact, high technology is the perfect example of a fuzzy concept of much value for rhetorical purposes. Officials use it constantly without any systematic definition, simply for its prestigious appeal.

Academics are no better. [77] What role have they played in all this? It is clear that the indicator originally came from official organizations. In general, academics (economists) satisfied themselves with models correlating R&D with exports to assess the role of science on trade performances [78]. But they also acted as consultants to public organizations, helping to define indicators on technology intensity, [79] and increasingly used the high-technology label and its indicators in the 1990s or developed their own classifications. [80] Above all, they were at the heart of the rhetoric on competitiveness. [81]

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[75] B. Godin (2003), *The Knowledge-Based Economy: Conceptual Framework or Buzzword*, Project on the History and Sociology of S&T Statistics, Montreal.

[76] C. Webb (2000), *Knowledge-Based Industries*, DSTI/EAS/IND/SWP (2000)5; C. Webb (2001), *Knowledge-Based Industries*, DSTI/EAS/IND/SWP (2001)13.

[77] Y. Baruch (1997), High Technology Organizations: What It Is, What It Isn't, *International Journal of Technology Management*, 13 (2), pp. 179-195.

[78] T. C. Lowinger (1975), The Technology Factor and the Export Performance of US Manufacturing Industries, *Economic Inquiry*, 13, pp. 221-236; F. Wolter (1977), Factor Proportions, Technology and West German Industry's International Trade Patterns, *Weltwirtschaftliches Archiv*, 113, pp. 250-267; H. Legler (1987), West German Competitiveness of Technology Intensive Products, in H. Grupp (ed.), *Problems of Measuring Technological Change*, Kohl: Verlag, pp. 171-190; J. Fagerberg (1988), International Competitiveness, *The Economic Journal*, 98, pp. 353-374; G. Dosi and L. Soete (1988), Technical Change and International Trade, in G. Dosi et al., *Technical Change and Economic Theory*, London: Frances Pinter, pp. 401-431.

[79] C. Freeman (SPRU); T. A. Abbott (Rutgers University); A. L. Porter and J. D. Roessner (Georgia Institute of Technology).

[80] E. Papagni (1992), High-Technology Exports of EEC Countries: Persistence and Diversity of Specialization Patterns, *Applied Economics*, 24, pp. 925-933; G. Amendola and A. Perrucci (1994), European Structures of Specialization in High-Technology Products: A New Approach, *STI Review*, 14, pp.

Today, the indicator remains a highly-contested measure. The main criticism has to do with the basic statistics behind the indicator: R&D expenditures. Some authors therefore have suggested replacing R&D with patents, [82] and others have argued for using several dimensions and statistics to define the indicator. [83] A second frequently-voiced criticism has to do with the fact that a firm may not be considered technology-intensive only because it conducts R&D, but also if it purchases and uses advanced technologies in its activities and employs highly-trained workers. [84] A third criticism refers to the fact that there is no standardization yet, and therefore organizations and authors produce different results. T. A. Abbott, for example, has documented how a surplus of $3.5 billion (1985-88) is measured when products are used as units, and a deficit ($17 billion) appears when the measurement is based on industries. [85]

Certainly, the indicator brought simplification to statistical analyses. Before high-technology groups appeared, analysis of R&D and trade was conducted according to industrial classes individually. [86] The high-technology indicator reduced the classification to only three groups. But the indicator also highlighted statistical discrepancies between

163-191; H. Grupp (1995), Science, High Technology and the Competitiveness of EU Countries, *Cambridge Journal of Economics*, 19, pp. 209-223; P. Guerrieri and C. Milana (1995), Changes and Trends in the World Trade in High-Technology Products, *Cambridge Journal of Economics*, 19, pp. 225-242; J. D. Roessner et al. (1996), Anticipating the Future High-Tech of Nations: Indicators for 28 Countries, *Technological Forecasting and Social Change*, 51, pp. 133-149; A. L. Porter et al (1996), Indicators of Technology Competitiveness of 28 Countries, *International Journal of Technology Management*, 12 (1), pp. 1-32.

[81] M. E. Porter (1990), *The Competitive Advantage of Nations*, New York: Free Press.

[82] L. Soete (1987), The Impact of Technological Innovation on International Trade Patterns: The Evidence Reconsidered, *Research Policy*, 16, pp. 101-130.

[83] E. Sciberras (1986), Indicators of Technical Intensity and International Competitiveness: A Case for Supplementing Quantitative Data with Qualitative Studies in Research, *R&D Management*, 16 (1), pp. 3-14; K. Hughes (1988), The Interpretation and Measurement of R&D Intensity: A Note, *Research Policy*, 17, pp. 301-307; D. Felsenstein and R. Bar-El (1989), Measuring the Technological Intensity of the Industrial Sector: A Methodological and Empirical Approach, *Research Policy*, 18, pp. 239-252.

[84] K. S. Palda (1986), Technological Intensity: Concept and Measurement, *Research Policy*, 15, pp. 187-198; 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.

[85] T. A. Abbott (1991), Measuring High Technology Trade: Contrasting International Trade Administration and Bureau of Census Methodologies and Results, *op. cit*.

[86] For example, see: B. Balassa (1962), Recent Developments in the Competitiveness of American Industry and Prospects for the Future, in Joint Economic Committee, Factors Affecting the United States Balance of Payments, *op. cit*, pp. 27-54; W. H. Branson and H. B. Junz (1971), Trends in US Trade and Comparative Advantage, *Brooking Papers on Economic Activity*, 2, pp. 285-345.

studies. As the OECD itself argued, each author, organization or country has its own idea of what constitutes high technology and uses its own vocabulary. [87] The OECD was only partly right, however, when it suggested that “the concept of high technology became part of our everyday vocabulary before economists and scientists had even managed to produce a precise and generally-accepted definition of the term”. [88] Very early on, official economists (and statisticians) invented the concept and constructed a measurement – which more or less focused on data on R&D. The problem stems rather from the political obsession to which it was applied – competitiveness [89] – and the urge to support the case quantitatively.

[87] OECD (1993), *Summary of Replies to the Questionnaire on Methodology*, DSTI/EAS/IND/STP (93) 4.
[88] OECD (1988), *La mesure de la haute technologie: méthodes existantes et améliorations possibles*, DSTI/IP/88.43, p. 3.
[89] To get an idea of the reports produced in several countries in the early 1990s, see: OECD (1995), *Competitiveness: An Overview of Reports Issued in Member Countries*, DSTI/IND (95) 15.