What is Science?
Defining Science by the Numbers, 1920-2000

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Abstract

"What is science?" is an old question. Scientists, and also philosophers, sociologists and economists, have all developed their own definitions of science. While these contributions have been intensively analyzed in the literature, there remains one influential definition of science that has never been examined from an historical point of view: the official (or government) definition. Since the 1920s, governments have used a specific definition of science to comprehend this phenomenon that was increasingly shaping society and the economy. This definition centers on research, or R&D.

This paper examines the official definition of science, and its construction, over the period 1920-2000. The definition of science as research owes much of its origin to statistics. Among all the scientific activities, research was the activity on which government started collecting numbers in the 1920s. Defining science as research was standardized in 1962 in a methodological manual known as the OECD Frascati manual. Several alternative definitions have been suggested since then, but all have failed to modify or extend the definition to be more inclusive of science's diverse activities or dimensions.

What is Science?
Defining Science by the Numbers, 1920-2000

Introduction

"What is science?" (or a scientist) is an age-old question. That some disciplines have, for decades, been considered more scientific and held a status superior to is a well-known fact to historians. [1] Behind the hierarchy stands a definition of science and criteria for qualification (maturity). For early scientists and philosophers, science was defined as knowledge and on epistemic grounds. The method of producing true knowledge was what distinguished science from other kinds of knowledge: observation, induction, and deduction were the key terms of the debates. Such an understanding, however, was not without its opponents. [2] Soon, it was the turn of the social sciences and humanities to be confronted with questions as to whether they really were sciences. People were divided into two camps: those who thought the social sciences should adopt the method of the natural sciences and search for laws, and those who insisted on the individuality of the social sciences and humanities. [3] To the latter group, composed of W. Dilthey, H. Rickert and M. Weber, among others, social sciences and humanities aimed at understanding rather than (solely) explaining.

[1] A.H. Dupree (1976), The National Academy of Sciences and the American Definition of Science, in A. Oleson and J. Voss (eds.), *The Organization of Knowledge in Modern America, 1860-1920*, Baltimore: Johns Hopkins University Press, pp. 342-363; O. N. Larsen (1992), *Milestones and Millstones: Social Science at the NSF, 1945-1991*, New Brunswick: Transaction Publishers; D. O. Belanger (1998), *Enabling American Innovation: Engineering and the NSF*, West Lafayette: Purdue University Press.
[2] W. B. Gallie (1957), What Makes a Subject Scientific?, *British Journal of the Philosophy of Science*, 8, pp. 188-139; R. M. Blake, C. J. Ducasse and E. H. Madden (1960), *Theories of Scientific Method: The Renaissance through the Nineteenth Century*, New York: Gordon and Breach (1989); R. Laudan (1981), *Science and Hypothesis*, Dordrecht: Reidel Publishing; R. Yeo (1993), *Defining Science: William Whewell, Natural Knowledge and Public Debate in Early Victorian Britain*, Cambridge: Cambridge University Press.
[3] P. Winch (1958), *The Idea of Social Science and its Relation to Philosophy*, New York: Routledge; K. O. Apel (1984), *Understanding and Explanation: A Transcendental-Pragmatic Perspective*, Mass. (Cambridge): MIT Press, pp. 1-79.

This century saw one more philosophical debate on defining science. The logical positivists defended a peculiar definition of science in order to eliminate metaphysics, but also to unite all sciences under one model. To the Vienna Circle, a scientific statement was a logical and verifiable statement, and what was verifiable was only what could be observed. [4]

Scientists and philosophers are not the only intellectuals trying to define science (and demarcate it from other knowledge). In this century, economists have developed a specific definition of science, centered on information. Science thus defined has specific characteristics that make of it a pure public good: indivisibility, inappropriability and uncertainty were the characteristics of scientific knowledge. This conception of science had important consequences for government policies: the lesson was for government to fund basic research because firms under-invest in this kind of research. [5]

Sociologists, for their part, have defined science, not on epistemic grounds, but as simply what scientists do and produce. R. Merton and his followers looked at science from an institutional and professional point of view. [6] Science as knowledge was taken for granted. What needed explanation were the social factors and norms that drive the system of science. Similarly, social constructivists, aided by the symmetry principle, never questioned scientific knowledge itself: science is what scientists do. [7]

This article looks at a neglected attempt to define science in recent history: the government (or official) definition of science. This definition appears in surveys and methodological manuals devoted to measuring science, particularly the OECD Frascati

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[4] P. Achinstein and S. T. Barker (1969), *The Legacy of Logical Positivism*, Baltimore: Johns Hopkins University Press.

[5] R. R. Nelson (1959), The Simple Economics of Basic Research, *Journal of Political Economy*, 67, pp. 297-306; K.J. Arrow (1962), Economic Welfare and the Allocation of Resources for Invention, in National Bureau of Economic Research, *The Rate and Direction of Inventive Activity: Economic and Social Factors*, Princeton: Princeton University Press, pp. 609-626.

[6] R. K. Merton (1973), *The Sociology of Science: Theoretical and Empirical Investigations*, Chicago: University of Chicago Press; J. Ben-David (1971), *The Scientist's Role in Society: A Comparative Study*, Chicago: University of Chicago Press.

manual. The latter, now in its sixth edition, offers guidelines to national statisticians for measuring research: definitions, classifications and survey methods. Historians have studied definitions of science for decades, particularly in the context of the relationships between science and technology and the specificity of engineering knowledge. [8] But no one has examined systematically official definitions. Yet, definitions are an important issue for science policy: they dictate who gets funding (or not) and what gets funded. It is the thesis of this paper that statistics and its methodology are a valuable source of information in looking for definitions of science, since collecting data and producing tables require precise definitions of the object to be measured: measurement usually starts with naming the concept to be measured, then defining this concept, and then classifying its elements into dimensions.

Four characteristics have characterized the official definition of science over the twentieth century. First, science has been defined and measured by officials based on the concept of "research". This is a purely social construction, since science could also be defined otherwise. We mentioned that scientists and philosophers have long defined science by its content (knowledge) and method, economists have defined it as information, and sociologists have defined it by its institutions and practices. Early officials' definitions also varied. The USSR and the communist countries, for example, used a broader definition, in which science covered more than research, i.e.: covered areas excluded from the OECD definition of research since they were qualified as related scientific activities, for example scientific information and standardization. [9] UNESCO,

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[7] D. Bloor (1976), *Knowledge and Social Imagery*, Chicago: University of Chicago Press (1991). For a recent analysis of science as practice rather than knowledge, see: A. Pickering (ed.) (1992), *Science as Practice and Culture*, Chicago: Chicago University Press.

[8] The literature on the subject is voluminous. For historical analyses, see: R. Kline (1995), Construing Technology as Applied Science: Public Rhetoric of Scientists and Engineers in the United States, 1880-1945, *ISIS*, 86, pp. 194-221; E. T. Layton (1976), American Ideologies of Science and Engineering, *Technology and Culture*, 17 (4): 688-700.

[9] 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, pp. 27-30, 99-152; C. Freeman (1969), The Measurement of Scientific and Technical Activities, ST/S/15, Paris: UNESCO, pp. 7, 11-12.

for its part, developed the concept of scientific and technological activities, which included research, education and related scientific activities [10]

The second characteristic of the official definition of science is that research has come to be defined as R&D. This latter concept includes more than just research. In fact, over two-thirds of R&D expenditures are currently devoted to development. Early on, this practice was criticized, but without consequences on measurement. A third characteristic of the official definition of science is that R&D has been defined and measured as institutionalized and systematic R&D. Systematic here means R&D conducted on a regular basis. Since only large laboratories correspond to such a definition, a large part of R&D was badly covered by the surveys, for example small and medium-sized firms. Related to this bias, R&D has usually been defined as taking place for manufacturing activities (rather than for service businesses) and as technological (rather than organizational) innovation.

A fourth characteristic of the official definition of science is that its measurement has concentrated on measuring the inputs devoted to research activities: monetary expenditures and human resources. To governments, their policy-makers and statisticians, science is an activity, measurable in dollars spent on "systematic" research and personnel, rather than consisting of knowledge, which is essentially immeasurable.

It took fifty years for a worldwide standardized definition of science to arrive (1920-1970), but the ensuing thirty years have seen the definition challenged from various perspectives. What united the challengers was their desire to broaden the scope of the definition, to make it more inclusive of science's diverse activities and outputs. They had few successes. Something held the conventional definition together: history, ideology, politics and … statistics.

[10] UNESCO (1978), *Recommendation Concerning the International Standardization of Statistics on Science and Technology*, Paris: UNESCO.

This paper documents how research became the central concept for measuring and talking about science, and the central role of statistics in this development. It draws on archival material from international (OECD, UNESCO) and national organizations (United States, Great Britain, Canada), and has benefited from the input of several key players who have been involved in science statistics since the 1950s. [11] Part 1 serves as background and traces the history of official statistics on science over the 20th Century. Part 2 looks at the concept of research in official statistics through the categories or types of research, like basic and applied research, that first served as definitions. Part 3 turns to definitions of research proper, centered on an institutionalized conception of science. Parts 4 and 5 look at the efforts of individuals and organizations to broaden the definition to a larger set of science activities: related scientific activities, education and training, and innovation.

The Development of Statistics on Science

We owe a large part of the development of official measurement of science in western countries to the United States. It was there that the first experiments emerged in the 1920s. Two factors were at work that explained this phenomenon: the need to manage industrial laboratories, and the need to plan government scientific and technological activities, particularly in the event that they might be needed for war (mobilization of scientists). [12] Canada followed a decade later, with the same objectives, and Great Britain in the decade after that. All in all, it seems that before the 1960s, the collection of statistics on science was mainly an Anglo-Saxon phenomenon. [13]

The very first official measurement of science activities came from the US National Research Council. During World War I, the US National Academy of Sciences convinced

[11] The following individuals has been interviewed and were members of an electronic network of exchanges set up by the author of this paper: K. Arnow, J. Bond, H. Brooks, J. Dryden, C. Falk, C. Freeman, D. Gass, P. Hemily, A. King, B. Martin, G. McColm, G. Muzart, K. Pavitt, I. Perry, J. J. Salomon, A. Seymour, G. Sirilli, H. Stead, G. Westholm, A. Wycoff and A. Young.
[12] On the early efforts at planning in science, see: A. H. Dupree (1957), *Science in the Federal Government: A History of Policies and Activities to 1940*, New York: Harper and Row, pp. 344s.
[13] B. Godin (2005), *Measurement and Statistics on Science and Technology: 1920 to the Present*, London: Routledge.

the federal government to give scientists a voice in the war effort. The National Research Council was thus created in 1916 as an advisory body to the government. Rapidly, a research information committee, then a Research Information Service, was put into place. The Service was concerned with the inter-allied exchange of scientific information. [14] After the war however, these activities were closed, and the Service reoriented its work toward other ends. The Service became "a national center of information concerning American research work and research workers, engaged in preparing a series of comprehensive card catalogs of research laboratories in this country, of current investigations, research personnel, sources of research information, scientific and technical societies, and of data in the foreign reports it received". [15] It was as part of these activities that the Service developed directories on research in the United States. Beginning in 1920, the Service regularly compiled four types of directory, the raw data of which were published extensively in the Bulletin of the National Research Council, sometimes accompanied by statistical tables. One directory was concerned with industrial laboratories. [16] The first edition listed approximately 300 laboratories, and contained information on fields of work and research personnel. A second directory dealt with sources of funds available for research, [17] a third with fellowships and scholarships, [18] and a fourth with societies, associations and universities, covering both the United States and Canada. [19]

The Council directories were used to conduct the first official statistical analyses of research, particularly industrial research. The Council itself conducted two such surveys. One in 1933, by the Division of Engineering and Industrial Research, tried to assess the

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[14] R. C. Cochrane (1978), *The National Academy of Sciences: The First Hundred Years 1863-1963*, Washington: National Academy of Sciences, pp. 240-241.
[15] *Ibidem*.
[16] National Research Council, Research Laboratories in Industrial Establishments of the United States of America, *Bulletin of the NRC*, vol. 1, part 2, March 1920.
[17] National Research Council, Funds Available in 1920 in the United States of America for the Encouragement of Scientific Research, *Bulletin of the NRC*, vol. 2, part I, no. 9, 1921.
[18] National Research Council, Fellowships and Scholarships for Advanced Work in Science and Technology, *Bulletin of the NRC*, 7 (38), Part II, November 1923. From 1920 onward, the Council also reprinted statistical series from *Science* and *School and Society* on doctorates conferred. See: National Research Council, Doctorates Conferred in the Sciences in 1920 by American Universities, *Reprint and Circular Series*, 12, November 1920.

effect of the Great Depression on industrial laboratories. [20] The other was conducted in 1941 for the National Resources Planning Board. [21] Besides the Council itself, government departments and institutions also used the Council's industrial directories to survey research, among them the Works Projects Administration, which looked at the impact of new industrial technologies on employment. [22]

It was not long, however, before the federal government started conducting its own surveys. It began in 1938, when the National Resources Committee, the successor to the National Resources Board, published the first systematic analysis of government research, intended to document how to plan and coordinate government scientific activities. [23] The report, concluding that research – particularly academic research – could help the nation emerge from the depression, was based on a survey of government research, including universities. For the first time, a survey of research included the social sciences, and this would later become the practice for surveys of government research in OECD countries (two years later, the National Resources Committee – now called the National Resources Planning Board – published a study by the Social Science Research Council that looked at social research in industry – but without statistics). [24]

We had to wait until 1945 to see new official measurements of research appear in the United States. Two of these deserve special mention. First, V. Bush offered some data on research in *Science: The Endless Frontier*, the blueprint for science policy in the United States. [25] But the data were either based on previously published numbers, like those from the National Research Council, or of dubious quality, like the estimates on basic

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[19] National Research Council, Handbook of Scientific and Technical Societies and Institutions of the United States and Canada, *Bulletin of the NRC*, no. 58, May 1927.
[20] M. Holland and W. Spraragen (1933), *Research in Hard Times*, Division of Engineering and Industrial Research, National Research Council, Washington.
[21] National Research Council (1941), *Research: A National Resource (II): Industrial Research*, National Resources Planning Board, Washington: USGPO.
[22] G. Perazich and P. M. Field (1940), *Industrial Research and Changing Technology*, Works Projects Administration, National Research Project, report no. M-4, Pennsylvania: Philadelphia.
[23] National Resources Committee (1938), *Research: A National Resource (I): Relation of the Federal Government to Research*, Washington: USGPO.
[24] Social Science Research Council (1941), *Research: A National Resource (III): Business Research*, National Resources Planning Board, Washington: USGPO.
[25] V. Bush (1945), *Science: The Endless Frontier*, North Stratford: Ayer Co. Publishers, 1995, pp. 85-89.

research. Slightly better were the numbers included in a second experiment, the so-called Steelman report. [26] The president's adviser tried, to some extent, to measure research in every sector of the economy: industry, government and university. To estimate the importance of research in the economy at large, he collected statistics wherever he could find them – and whatever their quality – adding very few numbers of his own – as Bush has done. [27] There was no time for an original survey since the report had to be delivered to the president ten months after the executive order. The report innovated, however, on several fronts: definition of research categories, research expenditures as a percentage of GDP as an indicator of R&D effort, and original estimates on manpower for discussing shortages. It also suggested numerical targets for science policy for the next ten years.

Other compilations were of better quality, but limited to government research. Senator H. M. Kilgore estimated the wartime effort (1940-1944) in research for a Committee of Congress, [28] and the Office of Scientific Research and Development measured its own activities for the period 1940-1946. [29] Finally, the Bureau of Budget started compiling a government "research and development budget" in 1950. [30]

From then on, the locale for official science measurement in the United States came to be the National Science Foundation (NSF). This was in fact the result of a compromise for the Bureau of Budget. The Bureau had always been skeptical of research funding by the federal government, particularly the funding of basic research. [31] President H. Truman's

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[26] President's Scientific Research Board (1947), *Science and Public Policy*, New York: Arno Press, 1980.
[27] Most of the new numbers concern university research. See also: Bush (1945), Science: The Endless Frontier, *op. cit*., pp. 122-134.
[28] H. M. Kilgore (1945), *The Government's Wartime Research and Development, 1940-44: Survey of Government Agencies*, Subcommittee on War Mobilization, Committee on Military Affairs, Washington.
[29] OSRD (1947), *Cost Analysis of R&D Work and Related Fiscal Information*, Budget and Finance Office, Washington.
[30] Bureau of Budget (1950), *R&D Estimated Obligations and Expenditures*, 1951 Budget (9 January 1950), Washington. Data from 1940 through 1949 can also be found in *The Annual Report of the Secretary on the State of the Finances for the Fiscal Year ended June 30, 1951*, Washington, p. 687. The very first estimates on a government budget for "research-education-development" were: E. B. Rosa (1921), Expenditures and Revenues of the Federal Government, *Annals of the American Academy of Political and Social Sciences*, 95, May, pp. 26-33. See also: E. B. Rosa (1920), Scientific Research: The Economic Importance of the Scientific Work of the Government, *Journal of the Washington Academy of Science*, 10 (12), pp. 341-382.
[31] J. M. England (1982), *A Patron for Pure Science: The NSF'S Formative Years, 1945-1957*, Washington: NSF, p. 82; H. M. Sapolsky (1990), *Science and the Navy: The History of the Office of Naval Research*, Princeton: Princeton University Press, pp. 43, 52, chapter 4; L. Owens (1994), The Counterproductive

adviser and director of the Bureau, Harold Smith, once argued that the real title of *Science: The Endless Frontier* should be *Science: The Endless Expenditure*. [32] In order to accept the degree of autonomy asked by the NSF, the Bureau required that the organization produce regular evaluations of the money spent. According to the Bureau's W. H. Shapley, the Bureau was mainly interested in identifying overlap among agencies and programs. [33] In 1950, therefore, the law creating the NSF charged the organization with funding basic research, but it also gave it a role in science measurement. The NSF was directed to "evaluate scientific research programs undertaken by the Federal Government (…) [and] to maintain a current register of scientific and technical personnel, and in other ways provide a central clearinghouse for the collection, interpretation, and analysis of data on scientific and technical resources in the United States". [34] In 1954, the president specified in an executive order that the NSF should "make comprehensive studies and recommendations regarding the Nation's scientific research effort and its resources for scientific activities" and "study the effects upon educational institutions of Federal policies and administration of contracts and grants for scientific R&D". [35]

When the NSF entered the scene in the early fifties, difficulties were increasingly encountered as soon as one wanted to compare the data from different sources, or to develop a historical series. [36] Definitions of research differed, as did methodologies for collecting data. According to R.N. Anthony (Harvard university), author of an influential study for the US Department of Defense, accounting practices could result in variations of up to 20% in numbers on industrial research. [37] The NSF standardized the research surveys by monopolizing official measurement and imposing its own criteria. The

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Management of Science in the Second World War: Vannevar Bush and the OSRD, *Business History Review*, 68: pp. 533-537; National Resources Committee (1938), *op. cit*., pp. 18, 74.

[32] C. E. Barfield (1997), *Science for the 21st Century: The Bush Report Revisited*, Washington: AEI Press, p. 4.

[33] W. H. Shapley (1959), Problems of Definition, Concept, and Interpretation of R&D Statistics, NSF (1959), *The Methodology of Statistics on R&D*, NSF 59-36, Washington, p. 8.

[34] Public Law 507 (1950).

[35] Executive Order 19521 (1954).

[36] See: US Department of Commerce and Bureau of Census (1957), Research and Development: 1940 to 1957, in *Historical Statistics of the United States*, pp. 609-614.

Harvard Business School survey was influential here. It developed concepts and definitions that the NSF reproduced – like those of research, basic research, and non-research activities – as well as methodologies. By 1956, the NSF has surveyed all sectors of the economy: government, industry, university and non-profit.

By 1960, several industrialized countries had more-or-less similar definitions and methodologies for surveying R&D. Canada had conducted its first survey of industrial research in 1939 [38] with the declared aim "to mobilize the resources of the Dominion for the prosecution of the war", that is, to build a directory of potential contractors. The survey was followed by a Department of Reconstruction and Supply survey on government research in 1947. [39] Regular and periodic surveys on industrial research by the Dominion Bureau of Statistics resumed in 1955. [40] The systematic survey of government research followed in 1960. [41] For its part, the British government had from the start been involved in estimating total research expenditures for the country. From 1953-54, the Advisory Council on Science Policy published annual data on government funding of civilian research, and from 1956-57 it undertook triennial surveys of national research expenditures. [42] These measurements were preceded by those of the Federation of British Industries, which surveyed industries in 1947. [43]

In light of these experiences, particularly that of the NSF, in the early 1960s the OECD gave itself the task of conventionalizing existing statistical practices. Member countries adopted what came to be known as the Frascati manual, a methodological manual

[37] R. N. Anthony (1951), *Selected Operating Data: Industrial Research Laboratories*, Harvard Business School, Division of Research, Boston, p. 3.
[38] Dominion Bureau of Statistics (1941), *Survey of Scientific and Industrial Laboratories in Canada*, Ottawa.
[39] Department of Reconstruction and Supply (1947), *Research and Scientific Activity: Canadian Federal Expenditures 1938-1946*, Government of Canada: Ottawa.
[40] Dominion Bureau of Statistics (1956), *Industrial Research-Development Expenditures in Canada, 1955*, Ottawa.
[41] Dominion Bureau of Statistics (1960), *Federal Government Expenditures on Scientific Activities, Fiscal Year 1958-1959*, Ottawa.
[42] Appeared in the *Annual Reports of the ACSP* from 1956-57 to 1963-64, London: HMSO.
[43] Federation of British Industries (1947), *Scientific and Technical Research in British Industry*, London.

concerned with conventions to follow in conducting surveys of R&D. [44] The manual proposed precise definitions of concepts to be measured; it suggested classifications of the activities measured; it made recommendations on numbers and indicators to be produced.

Defining Science by Classifying Types of Research

It took several decades before science came to be defined precisely for measurement purposes, but this did not prevent measurement. At the beginning, "What is science?" was often left to the questionnaire respondent to decide. The first edition of the US National Research Council directory of industrial research laboratories reported using a "liberal interpretation" that let each firm decide which activities counted as science: "all laboratories have been included which have supplied information and which by a liberal interpretation do any research work". [45] Consequently, any studies that used National Research Council numbers, like those by M. Holland and W. Spraragen [46] and by the US Works Projects Administration [47] were of questionable quality: "the use of this information [National Research Council data] for statistical analysis has therefore presented several difficult problems and has necessarily placed some limitations on the accuracy of the tabulated material". [48] Twenty years later, in its study on industrial research conducted for the US National Resources Planning Board, the National Research Council still used a similar practice: the task of defining the scope of activities to be included under research was left to the respondent. [49] In Canada as well, the first study by the Dominion Bureau of Statistics contained no definition of research. [50]

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[44] OECD (1962), *The Measurement of Scientific and Technical Activities: Proposed Standard Practice for Surveys of Research and Development*, DAS/PD/62.47.
[45] National Research Council (1920), Research Laboratories in Industrial Establishments of the United States of America, *op. cit*., p. 45.
[46] M. Holland and W. Spraragen (1933), Research in Hard Times, *op. cit*.
[47] G. Perazich and P. M. Field (1940), Industrial Research and Changing Technology, *op. cit*.
[48] *Ibid*. p. 52.
[49] National Research Council (1941), Research: A National Resource (II): Industrial Research, *op. cit*, p. 173.
[50] Dominion Bureau of Statistics (1941), Survey of Scientific and Industrial Laboratories in Canada, *op. cit*.

As we will see below, the situation improved in the 1950s and 1960s thanks wholly to the US National Science Foundation (NSF) and the OECD. Research then came to be defined as "creative work undertaken on a systematic basis to increase the stock of scientific and technical knowledge and to use this stock of knowledge to devise new applications". [51] In the meantime, however, two situations prevailed. First, research was "defined" either by simply excluding routine activities, or by a list of activities designed only to help respondents decide what to include in their responses to the questionnaires. Among these activities were basic and applied research, but also engineering, testing, prototypes, and design, which would later come to be called development. No disaggregated data were available for calculating statistical breakdowns, however. In fact, "in these early efforts, the primary interest was not so much in the magnitude of the dollars going into scientific research and development, either in total or for particular agencies and programs, but in identifying the many places where research and development of some sort or other was going on (…). [52]

Although no definition of research *per se* existed, "statisticians" soon started "defining" research by way of categories. This was the second situation. The most basic taxonomy relied on an age-old dichotomy: pure vs. applied research. [53] Three typical cases prevailed with regard to the measurement of these two categories. The first was an absence of statistics because of the difficulty of producing any numbers that met the terms of the taxonomy. The British and left-wing scientists J. D. Bernal, for example, was one of the first academics to conduct measurements of science in a western country, although he used available statistics and did not conduct his own survey. In *The Social Function of Science* (1939), Bernal did not break the research budget down by type of research or "character of work" — such statistics were not available. "The real difficulty (…) in economic assessment of science is to draw the line between expenditures on pure

[51] OECD (1970), *The Measurement of Scientific and Technical Activities: Proposed Standard Practice for Surveys of Research and Experimental Development*, Paris, p. 8.
[52] W. H. Shapley (1959), Problems of Definition, Concept, and Interpretation of Research and Development Statistics, *op. cit*.
[53] B. Godin (2003), Measuring Science: Is There Basic Research without Statistics, *Social Science Information*, 42 (1), pp. 57-90.

and on applied science", Bernal said. [54] He could only present total numbers, sometimes broken down by economic sector (industry, government, university, non-profit), but he could not figure out how much was allocated to basic research and applied research.

The second case with regard to the pure vs. applied taxonomy was the use of proxies. In his well-known report, *Science: The Endless Frontier* (1945), V. Bush elected to use the term basic research, and defined it as "research performed without thought of practical ends". [55] He estimated that the nation invested nearly six times as much in applied research as in basic research. [56] The numbers were derived by equating college and university research with basic research, and equating industrial and government research with applied research. More precise numbers appeared in appendices, such as ratios of pure research in different sectors – 5% in industry, 15% in government, and 70% in colleges and universities [57] – but the sources and methodology behind these figures were conspicuously absent from the report.

The third case was skepticism about the utility of the taxonomy, to the point that authors rejected it outright. For example, *Research: A National Resource* (1938), one of the first measurements of science in government in America, explicitly refused to use any categories but research: "There is a disposition in many quarters to draw a distinction between pure, or fundamental, research and practical research (…). It did not seem wise in making this survey to draw this distinction". [58] The reasons offered were that fundamental and applied research interact, and that both lead to practical and fundamental results. This was just the beginning of a long series of debates on the classification of research according to whether it is pure or applied. [59]

We owe to another British and left-wing scientist, J. S. Huxley, the introduction of new terms and the first formal taxonomy of research (Table 1). The taxonomy had four

[54] J. D. Bernal (1939), *The Social Function of Science*, Cambridge (Mass.): MIT Press, 1973, p. 62.
[55] V. Bush (1945), Science: The Endless Frontier, *op. cit*, p. 18.
[56] *Ibid*. p. 20.
[57] *Ibid*. p. 85.
[58] National Resources Committee (1938), Research: A National Resource (I): Relation of the Federal Government to Research, *op. cit*, p. 6.

categories: background, basic, ad hoc and development. [60] The first two categories defined pure research: background research is research "with no practical objective consciously in view", while basic research is "quite fundamental, but has some distant practical objective (…). Those two categories make up what is usually called pure science". [61] To Huxley, ad hoc meant applied research, and development meant more or less what we still mean by the term today: "work needed to translate laboratory findings into full-scale commercial practice".

Despite having these definitions in mind, however, Huxley did not conduct any measurements. Nevertheless, Huxley's taxonomy had several influences. V. Bush used the same newly-coined term "basic research" as Huxley for talking of pure research. The concept of "oriented basic research", later adopted by the OECD, comes from Huxley's definition of basic research. [62] Above all, the taxonomy soon came to be widely used for measurement. We owe to the US President's Scientific Research Board (PSRB) the first such use.

Table 1.
Taxonomies of Research

J. Huxley (1934)	background/basic/ad hoc/development
J. D. Bernal (1939)	pure (and fundamental)/applied
V. Bush (1945)	basic/applied
Bowman (in Bush, 1945)	pure/background/applied and development
US PSRB (1947)	fundamental/background/applied/development
Canadian DRS (1947)	pure/background/applied/development/analysis & testing
R. N. Anthony	uncommitted/applied/development
US NSF (1953)	basic/applied/development
British DSIR (1958)	basic/applied and development/prototype
OECD (1963)	fundamental/applied/development

[59] B. Godin (2003), Measuring Science: Is There Basic Research Without Statistics?, *op. cit*.
[60] J. S. Huxley (1934), *Scientific Research and Social Needs*, London: Watts and Co.
[61] *Ibid*. p. 253.

In 1947, president H. Truman, unsatisfied with the Bush report, asked the economist J. R. Steelman, then director of the Office of War Mobilization and Reconstruction, as science advisor, to prepare a report on what the government should do for science. Adapting Huxley's taxonomy, the Board conducted the first real survey of resources devoted to "R&D" – the first time the term appeared in a statistical report [63] – using precise categories, although these did not make it "possible to arrive at precisely accurate research expenditures" because of the different definitions and accounting practices employed by institutions. [64] In the questionnaire it sent to government departments (other sectors like industry were estimated using existing sources of data), it included a taxonomy of research that was inspired directly by Huxley's four categories: fundamental, background, applied and development. [65] With these definitions, the Board estimated that basic research accounted for about 4% of total research expenditure in the United States in 1947, [66] and showed that university research expenditures were far lower than government or industry expenditures, that is, lower than applied research expenditures, which amounted to 90% of total research. [67]

It is to R. N. Anthony, from Harvard Business School, that we owe the first measurements of all of the terms in the taxonomy. [68] By that time, however, the taxonomy was reduced to three terms, as it continues to this day: basic research, applied research, and development. An important measurement issue before the 1950s concerned the demarcation of research and non-research activities. Anthony identified two problems: there were too many variations on what constituted research, and too many

[62] OECD (1970), The Measurement of Scientific and Technical Activities: Proposed Standard Practice for Surveys of Research and Experimental Development, *op. cit*. p. 10.
[63] The US Office of Scientific Research and Development (OSRD), created in 1941 to support the Federal efforts on research for war, is responsible for the widespread use of the acronym. See: B. Godin (2006), Research and Development: How the "D" got into R&D, *Science and Public Policy*, February, forthcoming.
[64] President's Scientific Research Board (PSRB) (1947), *Science and Public Policy*, Washington: USGPO, p. 73.
[65] *Ibid.* pp. 299-314.
[66] *Ibid.* p. 12.
[67] *Ibid*. p. 21.
[68] B. Godin (2006), Research and Development: How the "D" got into R&D, *op. cit.*

differences among firms on which expenses to include in research. [69] Although routine work was almost always excluded, there were wide discrepancies at the frontier between development and production, and between scientific and non-scientific activities: testing, pilot plants, design, and market studies were sometimes included in research and at other times not. To Anthony, the main purpose of a survey was to propose a definition of research and then to measure it.

In the early 1950s, the US Department of Defense Research and Development Board asked Anthony to conduct a survey of industrial research to enable the government to locate available resources in the event of war, that is, to "assist the military departments in locating possible contractors for R&D projects". [70] Anthony had just conducted a survey of management controls in industrial research laboratories for the Office of Naval Research in collaboration with the corporate associates of the Harvard Business School, [71] and was about to start another survey to estimate amounts spent on research. The Board asked both the Harvard Business School and the Bureau of Labor Statistics to conduct a joint survey of industrial research. The two institutions coordinated their efforts and conducted three surveys. The results were published in 1953. [72]

The Bureau of Labor Statistics report does not have detailed statistics on categories of research, but Anthony's report does. The survey included precise definitions that would have a major influence on the NSF – and the OECD. Anthony's taxonomy had three items: [73]

[69] 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, p. 91.
[70] Bureau of Labor Statistics (1953), *Scientific R&D in American Industry: A Study of Manpower and Costs*, Bulletin no. 1148, Washington, pp. 1, 51-52.
[71] R. N. Anthony and J. S. Day (1952), *Management Controls in Industrial Research Organizations*, Boston: Harvard University.
[72] D. C. Dearborn, R. W. Kneznek and R. N. Anthony (1953), Spending for Industrial Research, 1951-1952, *op. cit*; US Department of Labor, Bureau of Labor Statistics, Department of Defense (1953), Scientific R&D in American Industry: A Study of Manpower and Costs, *op. cit*.
[73] D. C. Dearborn, R. W. Kneznek and R. N. Anthony (1953), Spending for Industrial Research, 1951-1952, *op. cit*. p. 92.

- Uncommitted research: pursue a planned search for new knowledge whether or not the search has reference to a specific application.
- Applied research: apply existing knowledge to problems involved in the creation of a new product or process, including work required to evaluate possible uses.
- Development: apply existing knowledge to problems involved in the improvement of a present product or process.

Along with the definitions, Anthony specified precisely the activities that should be included in development (scale activity, pilot plants and design) and those that should be excluded (market research, legal work, technical services, and production). The survey revealed that industry spent 8% of its research budget on basic research (or uncommitted research), 42% on new products (applied research) and 50% on product improvement (development). [74] Anthony's study would strongly influence subsequent measurements, both in the United States and elsewhere in the world. In the 1950s, the NSF extended Anthony's definitions to all sectors of the economy – industry, government, university, and non-profit – and produced the first national numbers on research so broken down. The development category, originating in industry, was now applied to the national research budget. The three components of research were separated, and a national total was calculated for each based on the following definitions: [75]

- Basic or fundamental research: research projects which represent original investigation for the advancement of scientific knowledge and which do not have specific commercial objectives, although they may be in the fields of present or potential interest to the reporting company. [76]
- Applied research: research projects which represent investigation directed to discovery of new scientific knowledge and which have specific commercial objectives with respect to either products or processes.

[74] *Ibid*. p. 47.
[75] The one important difference with Anthony here is that the NSF definitions were based on motives while Anthony's were result (or product)-oriented.
[76] The last part of the definition was, and still is, used for the industrial survey only.

- Development: technical activity concerned with non-routine problems which are encountered in translating research findings or other general scientific knowledge into products or processes.

The NSF surveys showed that, for the nation as a whole, the numbers were 9.1% of the research budget for basic research, 22.6% for applied research, and 68.3% for development. [77]

By the early 1960s, most countries had more or less similar definitions of research and its components. [78] The OECD gave itself the task of conventionalizing these definitions. In 1962, OECD member countries adopted a methodological manual for conducting R&D surveys. The Frascati manual included precise instructions for separating research from related scientific activities [79] and non-research activities, [80] and development from production. The manual also recommended collecting and tabulating data according to the three components of research. [81]

At about the same time, in light of increasing expenditures on research as reported in official statistics, particularly military research, some began questioning what really goes into statistics on research. David Novick, from RAND Corporation, suggested: "we should stop talking about research and development as though they were an entity and examine research on its own and development as a separate and distinct activity." [82] The rationale for this suggestion was one provided by S. Kuznets and J. Schmookler a few years earlier: "development is a job of adjustment (…); it is not original invention"; [83]

[77] NSF (1962), Trends in Funds and Personnel for Research and Development, 1953-61, *Reviews of Data on R&D*, 33, April, NSF 62-9, p. 5.
[78] J. C. Gerritsen (1961), *Government Expenditures on R&D in France and the United Kingdom*, EPA/AR/4209, Paris: OEEC; J. C. Gerritsen (1963), *Government Expenditures on R&D in the United States of America and Canada*, DAS/PD/63.23, Paris: OECD.
[79] Scientific information, training and education, data collection, testing and standardization.
[80] Legal administrative work for patents, routine testing and analysis, technical services.
[81] OECD (1962), *The Measurement of Scientific and Technical Activities: Proposed Standard Practice for Surveys of Research and Development*, DAS/PD/62.47, p. 12.
[82] D. Novick (1965), The ABC of R&D, *Challenge*, June, p. 13. See also: D. Novick (1960), What do we Mean by R&D?, *Air Force Magazine*, October, 114-118.
[83] S. Kuznets (1962), Inventive Activity: Problems of Definition and Measurement, in NBER, *The Rate and Direction of Inventive Activity: Economic and Social Factors*, Princeton: Princeton University Press, p. 35.

"while the problems dealt with in development are non-routine, their solution often does not demand the creative faculty which the term invention implies". [84] All three authors lost this argument. Development got into R&D because of its importance in industrial (and military) research and the priority technological development had on the science policy agenda. [85]

Towards a Definition of Research Proper

The development of taxonomies of types of research was only the first step toward a more generic definition of research. The idea of "systematicness" would soon come to define research. This had important consequences for statistics and policies. The definition of research as systematic or "organized research" came from industrialists, assisted by the US National Research Council. The more developed official argumentation, however, came from the US Works Projects Administration, an organization created in 1935 with a mandate of economic recovery, reemployment and national planning.

Industrial research underwent expansion after World War I. Most big firms became convinced of the necessity to invest in research and began building laboratories for the purpose of conducting research: [86] research had to be "organized and systematized". The

[84] J. Schmookler (1962), Comment on S. Kuznets' paper, in NBER, The Rate and Direction of Inventive Activity: Economic and Social Factors, *op. cit*. p. 45.
[85] B. Godin (2006), Research and Development: How the "D" got into R&D, *op. cit*.
[86] On the history of industrial research laboratories, see: NRC (1941), Research: A National Resource (II): Industrial Research, *op. cit*.; G. Wise (1985), *W. R. Whitney, General Electric, and the Origins of US Industrial Research*, New York: Columbia University Press; L. S. Reich (1985), *The Making of American Industrial Research: Science and Business at GE and Bell, 1876-1926*, New York: Cambridge University Press; D. A. Houndshell and J. K. Smith (1988), *Science and Corporate Strategy: Du Pont R&D, 1902-1980*, New York: Cambridge University Press; A. Heerding (1986), *The History of N. V. Philips' Gloeilampenfabriken*, New York: Cambridge University Press; J. Schopman (1989), Industrious Science: Semiconductor Research at the N. V. Philips' Gloeilampenfabriken, 1930-1957, *Historical Studies in Physical and Biological Sciences*, 19 (1), pp. 137-172; M. B. W. Graham and B. H. Pruitt (1991), *R&D for Industry: A Century of Technical Innovation at Alcoa*, New York: Cambridge University Press; M. A. Dennis (1987), Accounting for Research: New Histories of Corporate Laboratories and the Social History of American Science, *Social Studies of Science*, 17, pp. 479-518; D. Mowery (1984), Firm Structure, Government Policy, and the Organization of Industrial Research: Great Britain and the United States, 1900-1950, *Business History Review*, pp. 504-531; G. Meyer-Thurow (1982), The Industrialization of Invention: A Case Study from the German Chemical Industry, *ISIS*, 73, pp. 363-381; T. Shinn (1980), The Genesis of French Industrial Research, 1880-1940, *Social Science Information*, 19 (3), pp. 607-640. For statistical

issue of “systematically” organizing industrial research was on every manager’s lips: *The Organization of Industrial Scientific Research* (C. E. K. Mees, Kodak), *The Organization of Scientific Research in Industry* (F. B. Jewett, ATT), *Organized Industrial Research* (C. D. Coolidge, General Electric), *Organized Knowledge and National Welfare* (P. G. Nutting, Westinghouse) are only some of the numerous titles by industrialists that appeared between 1915 and 1935.

The US National Research Council was part of this “movement”. [87] Numerous discourses, similar in tone, were published in the *Reprint and Circular Series* of the Council between the 1910s and the 1930s. In 1932, for example, the National Research Council organized a conference in which industrialists, among them W. R. Whitney from General Electric, talked of *science as systematized knowledge and research as systematize search,* [88] and urged that “America must be foremost in *systematic, organized* research, or we shall be outdistanced by other countries”. [89] One year later, M. Holland, from the National Research Council Division of Engineering and Industrial Research, in an analysis of the last biennial National Research Council survey of industrial research laboratories, concluded that: “scientific research has made of invention a *systematic*, highly efficient process”. [90] The Council was here recalling the new interest of

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analyses, see: D. C. Mowery and N. Rosenberg (1989), The US Research System Before 1945, in D. C. Mowery and N. Rosenberg, *Technology and the Pursuit of Economic Growth*, New York: Cambridge University Press; D. C. Mowery (1983), Industrial Research and Firm Size: Survival, and Growth in American Manufacturing, 1921-1946: An Assessment, *Journal of Economic History*, 63 (4), pp. 953-980; D. E. H. Edgerton and S. M. Horrocks (1994), British Industrial Research and Development Before 1945, *Economic History Review*, 67 (2), pp. 213-238; S. M. Horrocks (1999), The Nature and Extent of British Industrial Research and Development, 1945-1970, *ReFresh*, 29, Autumn, pp. 5-9; D. C. Mowery (1986), Industrial Research, 1900-1950, in B. Elbaum and W. Lazonick, *The Decline of the British Economy*, Oxford: Clarendon Press; D. E. H. Edgerton (1993), British Research and Development After 1945: A Re-Interpretation, *Science and Technology Policy*, April, pp. 10-16; D. E. H. Edgerton (1987), Science and Technology in British Business History, *Business History*, 29 (4), pp. 84-103; M. Sanderson (1972), Research and the Firm in British Industry, 1919-1939, *Science Studies*, 2, pp. 107-151.

[87] For the movement or “propaganda” campaign in Great Britain, especially the support of industrial research associations by the DSIR, see: Committee on Industry and Trade (1927), *Factors in Industrial and Commercial Efficiency*, Part I, chapter 4, London: Majesty’s Stationery Office; D. E. H. Edgerton and S. M. Horrocks (1994), British Industrial R&D Before 1945, *op. cit*. pp. 215-216.

[88] W. R. Whitney and L. A. Hawkins (1932), Research in Pure Science, in M. Ross, M. Holland and W. Spraragen (eds.), *Profitable Practice in Industrial Research: Tested Principles of Research Laboratory Organization, Administration, and Operation*, New York: Harper and Brothers Publishers, p. 245.

[89] *Ibid*. p. 253.

[90] M. Holland and W. Spraragen (1933), Research in Hard Times, *op. cit*. p. 13.

industrialists in the organization of research in their firms. It gave itself the task of promoting these ideas.

After World War I, the National Research Council, "impressed by the great importance of promoting the application of science to industry (…), took up the question of the organization of industrial research, (…) and inaugurated an Industrial Research Section to consider the best methods of achieving such organization (…)." [91] "In the 1920s, the division had been a hotbed of activity, preaching to corporations the benefits of funding their own research. The campaign contributed to a fivefold increase from 1920 to 1931 in the number of US industrial labs". [92] The Division conducted special studies on industrial research, arranged visits to industrial research laboratories for executives, organized conferences on industrial research, helped set up the Industrial Research Institute – an organization that still exists today [93] – and compiled a biennial directory of laboratories from 1920 to the mid-1950s. [94]

We are also indebted to the National Research Council for one of the first historical analyses of industrial research in the United States. In the voluminous study on industrial research published by the National Resources Planning Board, the National Research Council (and historian H. R. Bartlett from MIT) narrated the development of industrial research as follows: "until the twentieth century, industrial research remained largely a matter of the unorganized effort of individuals. Early in the 1900s, a few companies *organized* separate research departments and began a *systematic* search not only for the

[91] NRC 1918-1919 report to the Council of National Defense; cited in A. L. Barrows, The Relationship of the NRC to Industrial Research, in National Research Council (1941), Research: A National Resource II: Industrial Research, *op. cit*. p. 367.
[92] G. P. Zachary (1997), *Endless Frontier: Vannevar Bush, Engineer of the American Century*, Cambridge (Mass.): MIT Press, 1999, p. 81.
[93] The Institute was launched in 1938 as the National Industrial Research Laboratories Institute, renamed the next year as the Industrial Research Institute. It became an independent organization in 1945.
[94] See A. L. Barrows (1941), The Relationship of the NRC to Industrial Research, *op. cit.*; R. C. Cochrane (1978), The National Academy of Sciences: The First Hundred Years 1863-1963, *op. cit*., pp. 227-228, 288-291, 388-346.

solution of immediate problems of development and production, but also for new knowledge that would point the way to the future". [95]

The US Works Projects Administration took the idea and developed a full-length argument defining research as systematic. In 1935, the organization started a project on *Reemployment Opportunities and Recent Changes in Industrial Techniques* "to inquire, with the cooperation of industry, labour, and government, into the extent of recent changes in industrial techniques and to evaluate the effects of these changes on employment and unemployment". [96] Out of this project came, among some sixty studies, some measures of research in industry. The organization used National Research Council directories of industrial laboratories to assess the scope of industrial research and innovation in the country, and published its analysis in 1940. [97] The report began with the following fact: "The *systematic* application of scientific knowledge and methods to research in the production problems of industry has in the last two decades assumed major proportions" (p. xi). The authors contrasted colonial times, when research was random, haphazard and unorganized because it was realized by independent inventors (pp. 46-47), with modern times when, between 1927 and 1938 for example, "the number of organizations reporting research laboratories has grown from about 900 to more than 1,700 affording employment to nearly 50,000 workers" (p. 40). And the report continued: "Industry can no longer rely on random discoveries, and it became necessary to organize the *systematic* accumulation and flow of new knowledge. This prerequisite for the rise of

[95] H. R. Bartlett (1941), The Development of Industrial Research in the United States, in National Research Council (1941), Research: A National Resource II: Industrial Research, *op. cit*. p. 19. A similar argument appeared in NRC's study of 1933 (M. Holland and W. Spraragen, Research in Hard Times, *op. cit*. pp. 12-13), but it was far less developed and articulated. The first such argument was offered by C. E. K. Mees (Kodak) in 1920: "The starting and development of most manufacturing businesses depended upon discoveries and inventions made by some individual or group of individuals who developed their original discoveries into an industrial process". For Mees, this was more often than not accidental. "With the increasing complexity of industry and the parallel growth in the amount of technical and scientific information necessitating greater specialization, the work of investigation and development formerly performed by an individual, has been delegated to special departments of the organization, one example of which is the modern industrial research laboratory". C. E. K. Mees (1920), *The Organization of Industrial Scientific Research*, New York: McGraw Hill, p. 5-6.

[96] On this project and the debate on technological unemployment, see A. S. Bix (2000), *Inventing Ourselves Out of Jobs? America's Debate over Technological Unemployment, 1929-1981*, Baltimore: Johns Hopkins University Press, pp. 56-74.

[97] G. Perazich and P. M. Field (1940), Industrial Research and Changing Technology, *op. cit*.

industrial research to its present proportions was being met by the formation of large corporations with ample funds available for investment in research" (p. 41).

This is the rationale behind the official definition of research. Research is organized research, i.e.: laboratory research. The meaning spread rapidly through surveys of research activities. For example, one of the first surveys of industrial research in the United States, conducted by the National Research Council in 1941, described industrial research as "*organized and systematic* research for new scientific facts and principles (…) and presupposes the employment of men educated in the various scientific disciplines". [98]

But it was the NSF and the OECD that generalized the concept. As early as its first survey in 1953 (concerned with non-profit institutions), the NSF defined research and development as "*systematic*, intensive study directed toward fuller knowledge of the subject studied and the *systematic* use of that knowledge for the production of useful materials, systems, methods, or processes". [99] The OECD followed with the 1970 edition of the Frascati manual: R&D is "creative work undertaken on a *systematic* basis to increase the stock of scientific and technical knowledge, including knowledge of man, culture and society and the use of this stock of knowledge to devise new applications". [100]

Two aspects of the official concept of research deserve analysis. First, the meaning of systematic used in defining research – and the statistics based thereon – has drifted from an emphasis on the *scientific method* to an emphasis on *institutionalized* research. This drift was closely related to the (modern) instrument used for measuring research, namely the survey, and to that instrument's limitations. Second, the definition had important consequences on the numbers generated, the most important one being the undercounting of research. Let us discuss both aspects.

[98] National Research Council (1941), Research: A National Resource II: Industrial Research, *op. cit.* p. 6.
[99] National Science Foundation (1953), *Federal Funds for Science: Federal Funds for Scientific R&D at Nonprofit Institutions 1950-1951 and 1951-1952*, Washington, p. 3.
[100] OECD (1993), The Measurement of Scientific and Technical Activities: Proposed Standard Practice for Surveys of Research and Experimental Development, *op. cit*. p. 29.

According to the Oxford Dictionary, the term "research" has French origins and appeared in the sixteenth century. [101] It is rooted in the term "search" invented in the fourteenth century, and defined as to "examine *thoroughly*". Research meant an "act of searching *closely and carefully*", or "intensive searching". The term was first applied to science in 1639 defined as "scientific inquiry", but rarely used in that context before the end of the nineteenth century. Twentieth century definitions of research all include the essential idea of *systematicness*. The 1939 edition of the Webster's dictionary, for example, defined research as "*diligent* inquiry or examination in seeking facts or principles", [102] while more recent definitions often specify "diligent *and systematic*".

The definition of research as an organized and formal activity was an important drift in the standard conception of research. One historical use of the term systematic in relation to research was associated with positivism, which defined science as a search for comprehensive regularity and general law. [103] *Inductivism* was closely associated with this definition. This is the understanding given by the Canadian Department of Reconstruction and Supply in its survey of government R&D in 1947: "(…) with the growth of modern scientific methods (…) which proceed by observation and experiment, and by the *systematizing of the resulting facts and relationships into truth or laws*, the search for new knowledge, especially in the scientific and technical fields has become more and more institutionalized and professionalized". [104] This meaning gave rise to and has been incorporated into the institutional definition of pure research as seeking for the general knowledge of nature and its laws: science is an activity that begins with observations and ends in truth and general laws. [105]

This meaning of systematic is closely related to a second one, that of *scientific method*. One can find it stated explicitly in UNESCO documents, for example. The first edition of

[101] *Oxford Dictionary of English Etymology*, C. T. Onions (ed.), Oxford: Clarendon Press, 1966; *The Shorter Oxford English Dictionary*, W. Little, H. M. Fowler, J. Coulson, Oxford: Clarendon Press, 1959.
[102] *Webster's 20th Century Dictionary of English Language*, New York: Guild Inc., 1939.
[103] C. Hempel and P. Oppenheim (1948), Studies in the Logic of Confirmation, *Philosophy of Science*, 15 (135), pp. 135-175.
[104] Department of Reconstruction and Supply (1947), Research and Scientific Activity, *op. cit.*, p. 5.

the *Guide to the Collection of Statistics on Science and Technology* defined scientific research using four elements, among them "the use of scientific methods, or work in a *systematic* way". [106] Elsewhere, we also read: "An activity can be said to be scientific, in fact, when it is based on a network of logical relationships which make it possible to obtain reproducible and measurable results. The methods used to obtain these results may be considered as techniques when the skills they employ are also *systematic*, when these skills are based on numerical measurements, and when the results which these measurements give are reliable". [107]

The model behind this understanding of research is, of course, the natural sciences, which proceed by way of (laboratory) experimentation. [108] The model was so pervasive that "E" (for experimentation) sometimes preceded the "D" of R&D. [109] The model also suggested, for some time, the exclusion of the social sciences and humanities from the definition of research, because these were not "organized", but rather individual, research. [110]

Despite these meanings, UNESCO documents also contained the third and most recent meaning of systematic science found in OECD documents, but in more explicit terms: [111]

> An activity to be considered at the international level of science statistics must be properly structured, i.e.: it must meet the minimum requirements of a *systematic* activity

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[105] See, for example: V. Bush (1945), Science: the Endless Frontier, *op. cit*. p. 81.
[106] UNESCO (1977), *Guide to the Collection of Statistics in Science and Technology*, ST.77/WS/4, Paris, p. 18. See also K. Messman (1977), *A Study of Key Concepts and Norms for the International Collection and Presentation of Science Statistics*, COM-75/WS/26, UNESCO, p. 20.
[107] J.-C. Bochet (1974), *The Quantitative Measurement of Scientific and Technological Activities Related to R&D Development*, CSR-S-2, UNESCO, p.1.
[108] Since the 1970 edition of the Frascati Manual, the OECD adds the adjective "experimental" to "development" in order to avoid confusion between development, a phase of R&D, and the same term in economics, and in order to use the same term as eastern European countries and UNESCO.
[109] This was the case for tax legislation in Canada and the United States. For the latter, see H. R. Hertzfeld (1988), Definitions of R&D for Tax Purposes, in O. D. Hensley (ed.), *The Classification of Research*, Lubbock (Texas): Texas Tech University Press, pp. 136-137.
[110] The rationale offered by officials for not surveying university research but estimating the amounts spent was often the same: university research is individual rather than organized research. See, for example: Statistics Canada (1993), Estimation of Research and Development Expenditures in the Higher Education Sector, *Service Bulletin*, 88-001, September.
[111] K. Messman (1977), A Study of Key Concepts and Norms for the International Collection and Presentation of Science Statistics, *op. cit.* p. 10.

such as: the person (s) exercising this activity must work during a significant number of hours per year; there must exist a programme of work; a certain amount of financial resources must be specifically allocated to the work.

This means that diffused, discontinued or scattered S&T activities, i.e.: activities carried out sporadically, or from time to time, within the various services of an institution, thus not meeting the above-mentioned minimum requirements of a systematic activity, should not be taken into account.

There follows, therefore, that non-institutionalized, individual and/or discontinued, diffused or scattered activities are to be excluded for the presentation of international statistics".

Why did the third meaning of systematic prevail over others? [112] Why focus on the organization rather than an epistemic understanding? To be sure, if one looks in dictionaries, "systematic" involves the idea of a system, and when the system concerns intellectual matters, systematic means using deduction and logic. The everyday use, on the other hand, means to proceed with method. "Organized" and "sustained" are mentioned as pejorative meanings only.

The origins of this state of affairs are due to the industrial survey and its influence on the whole methodology of questionnaires, including questionnaires for surveying government and university research. The main link here was Anthony. In the survey he conducted for the Department of Defense, Anthony showed that firm size was one of the main variables explaining R&D investment. Consequently, he suggested: [113]

> The fact that there are almost 3,000 industrial research organizations can be misleading. Most of them are small. (…) Over half employ less than 15 persons each, counting both technical and non-technical personnel. Many of these small laboratories are engaged primarily in activities, such as quality control, which are not research or development.
>
> [Therefore] this report is primarily concerned with industrial laboratories employing somewhat more than 15 persons.

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[112] In fact, people have often oscillated between the different meanings of systematic. W. R. Whitney, from General Electric and a member of the National Research Council, is a case in point: on one hand is the meaning of generic facts and principles (p. 245) discovered by experiments (p. 249); on the other, that of a system, mainly the European system of free men devoting their entire time to research with the assistance of students (pp. 247-248). See: W. R. Whitney and L. A. Hawkins (1932), Research in Pure Science, *op. cit*.

[113] R. N. Anthony and J. S. Day (1952), Management Controls in Industrial Research Organizations, *op. cit*. pp. 6-7.

Hence, research was thereafter equated with systematized research or large organizations with dedicated laboratories. [114] This rationale soon came to be related to another one: the costs of conducting a survey. Because there are tens of thousands of firms in a country, units surveyed have to be limited to manageable proportions. This was done by introducing a bias in industrial surveys: the survey identified all major R&D performers, that is big firms with laboratories (or "organized" research) and surveyed them all, but selected only a sample of smaller performers, when they selected any. This decision was also supported by the fact that only big firms had precise book-keeping practices on R&D since the activity could be located in a distinct and formal entity, the laboratory.

An important impact of the official concept of research was the undercounting of R&D and, therefore, neglecting to support some performers in science policies. In the 1980s, A. Kleinknecht conducted a study assessing the quality of the measures produced by official R&D surveys. He designed his own survey of industrial R&D and compared his results with those obtained by a government survey. He found large differences between the two types of survey, mainly for small and medium-sized enterprises (SMEs). The author measured four times as many man/years devoted to R&D in SMEs as what had been reported in the government survey. Overall, the official survey underestimated R&D by as much as 33%. [115]

The reason offered for the differences was that SMEs tend to conduct R&D in an informal way ("unorganized", some would say), rather than on a continuous basis or in a department of the firm exclusively devoted to R&D. [116] Non-budgeted R&D is the rule in

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[114] On academics' use of the idea, see:J. Schmookler (1959), Bigness, Fewness, and Research, *Journal of Political Economy*, 67 (6), pp. 628-632; F. Machlup (1962), *The Production and Distribution of Knowledge in the United States*, Princeton: Princeton University Press, pp. 82-83.

[115] A. Kleinknecht (1987), Measuring R&D in Small Firms: How Much Are We Missing?, *The Journal of Industrial Economics*, 36 (2), pp. 253-256; A. Kleinknecht and J. O. N. Reijnen (1991), More evidence on the undercounting of Small Firm R&D, *Research Policy*, 20, pp. 579-587. For similar numbers in France, see S. Lhuillery and P. Templé (1994), L'organisation de la R&D dans les PMI-PME, *Économie et Statistique*, 271-272, pp. 77-85.

[116] The NSF had already identified the problem in the 1950s. NSF (1956), *Science and Engineering in American Industry: Final Report on a 1953-1954 Survey*, NSF 56-16, Washington, p. 89 presented a questionnaire sent specifically to firms conducting negligible R&D activities; and NSF (1960), *Research and Development in Industry, 1957*, NSF 60-49, Washington, pp. 97-98 discussed informal R&D in small companies.

SMEs: "in small firms, development work is often mixed with other activities". Kleinknecht estimated that 33% of firms devoted less than one man/year to R&D. The number goes up to 50% of firms in the service industry. [117]

Contested Definitions

Defining research was only one of the challenges confronting analysts and policy-makers. The second problem of pre-1960s research surveys, closely related to the problem of definition, concerned the demarcation of research and non-research activities. Indeed, firms had accounting practices that did not allow these activities to be easily separated. [118] In 1959, K. Arnow, of the NSF, summarized the problem as follows:

> Even if all the organizations responding to the NSF's statistical inquiries shared, by some miracle, a common core of concepts and definitions, they might still not be able to furnish comparable data, since they draw on a diversity of budget documents, project reports, production records, and the like for estimating R&D expenditures. [119]

According to Anthony, accounting practices could result in variations of up to 20% for numbers on industrial R&D. [120] Both the US Bureau of Census [121] and the NSF also believed that only better accounting practices could correct such errors. At the time, the absence of norms made survey comparisons impossible before the 1960s, which resulted

[117] In 1993, the OECD agreed to discuss the issue during the fourth revision of the Frascati manual. Two options were discussed. One was the omission of references to "systematic" in the definition of R&D. This was rejected because it was felt that the term was useful in excluding non-R&D activities. The other option was to qualify systematic as "permanent and organized" in the definition of R&D. In fact, the word systematic has never been defined explicitly in any edition of the Frascati manual. This option was also rejected. However, a precise number was put forward and adopted for defining (core) R&D in the following editions of the manual: a minimum of one full-time equivalent person working on R&D per year. See: OECD (1991), *R&D and Innovation Surveys: Formal and Informal R&D*, DSTI/STII/(91)5 and annex 1.

[118] On accounting difficulties, see: O. S. Gellein and M. S. Newman (1973), *Accounting for R&D Expenditures, American Institute of Certified Accountants*, New York; S. Fabricant, M. Schiff, J. G. San Miguel and S. L. Ansari (1975), *Accounting by Business Firms for Investments in R&D*, Report submitted to the NSF, New York University.

[119] K. Arnow (1959), National Accounts on R&D: The NSF Experience, in NSF, *Methodological Aspects of Statistics on Research and Development: Costs and Manpower*, NSF 59-36, Washington: 58.

[120] R. N. Anthony (1951), *Selected Operating Data: Industrial Research Laboratories*, Harvard Business School, Division of Research, Boston, p. 3.

[121] H. Wood, Some Landmarks in Future Goals of Statistics on R&D, in NSF (1959), *Methodological Aspects of Statistics on Research and Development: Costs and Manpower*, NSF 59-36, Washington, p. 52; NSF (1960), Research and Development in Industry, 1957, *op. cit.* p. 99.

in statistics that were often of limited value. The US President's Scientific Research Board wrote that it was "not possible to arrive at precisely accurate research expenditures" because of three limitations: 1) variations in definition, 2) accounting practices, and 3) the absence of a clear division between science and other research activities. [122] Similarly, the NSF admitted that the industrial R&D surveys it conducted before 1957 were not comparable to those it conducted after that date. [123]

One way to deal with the problem was to draw boundaries between what is and what is not research. As the first edition of the Frascati manual stated: "Definitions are not sufficient in themselves. It is necessary to amplify them by standard conventions, which demarcate precisely the borders between research and non-research activities" (p. 12). The choice made over time was to separate research from other (routine) activities, however indispensable to research. The Harvard Business School study [124] and the NSF [125] both developed a whole series of specifications for defining and delimiting measurable activities. The first NSF industrial R&D survey, for example, included pilot plants, design, laboratory scale models and prototypes in its definition of research; and it excluded market and economic research, legal work and technical services (minor adaptations, licenses, advertising, patents and exploration).

The decision to concentrate on research, or R&D, however, was not without its opponents. As early as 1938, the US National Resources Committee defined research activities as "investigations in both the natural and social sciences, and their applications, including the collection, compilation, and analysis of statistical, mapping, and other data that will probably result in new knowledge of wider usefulness" (p.62). [126] The report recognized that: "the principal conflicts of opinion about the definition used in this study have revolved around the inclusion of the following activities as research" (p. 62): collection and tabulation of basic data, economic and social studies, mapping and

[122] President's Scientific Research Board (1947), Science and Public Policy, *op. cit.* pp. 73, 301.
[123] NSF (1960), *Funds for R&D: Industry 1957*, NSF 60-49, Washington, pp. 97-100
[124] D. C. Dearborn, R. W. Kneznek and R. N. Anthony (1953), Spending for Industrial Research, 1951-1952, *op. cit.* pp. 43-44, 92.
[125] National Science Foundation (1953), Federal Funds for Science, *op. cit.*, p. 16.
[126] National Resources Committee (1938), Research: A National Resource, *op. cit.*

surveying, library and archival services. It concluded that: “part of the difficulty with the adopted definition of research is due to attempts to distinguish between what might be designated as the “higher” and “lower” orders of research without admitting the use of those concepts” (p. 62). And it added: “it would probably be instructive to obtain separate estimates for these two “orders” (…). However, such a separation has proven impractical because of the budgetary indivisibility of the two types of research processes” (p. 62). [127]

Ten years later, the US President’s Scientific Research Board report *Science and Public Policy* borrowed the term “background research” from J. Huxley to define these activities identified by the National Resources Committee: “background research is the systematic observation, collection, organization, and presentation of facts, using known principles to reach objectives that are clearly defined before the research is undertaken, to provide a foundation for subsequent research or to provide standard reference data”. [128] This kind of activity was identified as such because the survey was concerned with government research: background activities are “proper fields for Government action” (p. 312), as already observed in the Bush report. [129] Since then, background activities, or related scientific activities as they came to be called, have been included in definitions and measured, the few times that they have been, for government activities only. [130]

To both the National Resources Committee and the President’s Scientific Research Board, the identification of specific activities besides R&D served to define what was to be included in the measurement of research. There was no breakdown of data according to the different types of activities. We owe to Canada and to the NSF the first measurements of related scientific activities.

[127] Concerning the difficulties of separating activities before the OECD standard, see for example: National Resources Committee (1938), Research: A National Resource, *op. cit*. pp. 6, 61-65; volume 2: 5-8, 173; US President’s Scientific Research Board (1947), Science and Public Policy, *op. cit*.: pp. 73, 300-302; NSF (1959), Methodological Aspects of Statistics on R&D Costs and Manpower, *op. cit.*
[128] President’s Scientific Research Board (1947), Science and Public Policy, *op. cit*. p. 300.
[129] V. Bush (1945), Science: The Endless Frontier, *op. cit.* p. 82.
[130] In the case of industrial R&D, the exception was: D. C. Dearborn, R. W. Kneznek and R. N. Anthony (1953), Spending for Industrial Research, 1951-1952, *op. cit*.

As early as 1947, the Canadian Department of Reconstruction and Supply, in a survey on government research conducted with the Canadian National Research Council, defined "scientific activities" as the sum of three broad types of activities: research (itself composed of pure, background, and applied), development, and analysis and testing. [131] Again, as in the US President's Scientific Research Board report, the background category served only to specify what defined research. No specific numbers were produced "because of the close inter-relationship of the various types of research undertaken by the Dominion Government" (p. 16), that is: because of the difficulty of separating R&D and related scientific activities in available statistics. However, separate numbers were produced for a new category of activities: it was reported that 12% of scientific activities in Canada were devoted to (routine) analysis and testing (p. 25), activities usually not measured in R&D surveys, but rather specifically excluded.

The NSF continued to innovate, while Canada performed no further surveys of government R&D until 1960, by which time the Canadian Dominion Bureau of Statistics had assimilated the NSF definitions. From the beginning of the 1950s, the NSF conducted regular surveys of government research. The results were published in a series titled *Federal Funds for Science*. [132] R&D data included "other scientific activities", as did most surveys of government research conducted at the time in other countries. [133] But these were not separated from R&D. Then in 1958, the NSF published *Funds for Scientific Activities in the Federal Government*. [134] The publication was, among other things, a reanalysis of the 1953-54 data. Scientific activities were discussed and defined as the "creation of new knowledge, new applications of knowledge to useful purposes, or the furtherance of the creation of new knowledge or new applications" (no page number). The activities were broken down into seven classes, the first three defining R&D and the last four defining "other scientific activities": R&D, planning and administration,

[131] Department of Reconstruction and Supply (1947), Research and Scientific Activity: Canadian Federal Expenditures 1938-1946, *op. cit*. p. 13.
[132] National Science Foundation (1953), Federal Funds for Science, *op. cit*.
[133] See J. C. Gerritsen et al. (1963), Government Expenditures on R&D in the United States of America and Canada: Comparisons with France and the United Kingdom on Definitions Scope and Methods Concerning Measurement, *op. cit*.
[134] National Science Foundation (1958), *Funds for Scientific Activities in the Federal Government, Fiscal Years 1953 and 195*4, NSF-58-14, Washington.

expansion of R&D plant, data collection, dissemination of scientific information, training, and testing and standardization. It was estimated that “other scientific activities” amounted to $199 million, or 7.8% of all scientific activities. Of these, data collection was responsible for nearly 70%, and dissemination of scientific information (6.5%) was said to be greatly underestimated, by a factor of at least three.

Subsequent editions of *Federal Funds for Science* (renamed *Federal Funds for R&D and Other Scientific Activities* in 1964) thereafter included data on “other scientific activities”. But these were restricted to only two categories: dissemination of scientific and technical information, and, for a shorter period, general purpose data collection. Over time, detailed sub-classes were developed for each of these categories, reaching a zenith in 1978 when scientific and technical information (STI) alone had four classes, which were in turn subdivided into eleven subclasses (p. 43) (Table 2). [135]

The NSF stopped publishing data on “other scientific activities” with the 1978 edition of *Federal Funds*. It measured these activities for the last time in a three-volume report titled *Statistical Indicators for Scientific and Technical Communication* written by King Research Inc. and published by NSF’s Division of Scientific Information. [136] That was the NSF’s last work on the subject, although the research was initially contracted “to develop and initiate a system of statistical indicators of scientific and technical communication” (p. V). [137]

Table 2.

Scientific and Technical Information (STI)

According to NSF (1978)

[135] National Science Foundation (1978), *Federal Funds for R&D and Other Scientific Activities: Fiscal Years 1976, 1977, 1978*, 78-300, Washington.

[136] King Research Inc. (1976), *Statistical Indicators of Scientific and Technical Communication: 1960-1980*, three volumes, Washington: National Science Foundation.

[137] Some of the statistics from the report were included in NSF, *Science and Engineering Indicators* (1977), Washington, pp. 59-63.

Publication and distribution
- Primary publication
- Patent examination
- Secondary and tertiary publication
- Support of publication

Documentation, reference and information services
- Library and reference
- Networking for libraries
- Specialized information centers
- Networking for specialized information centers
- Translations

Symposia and audiovisual media
- Symposia
- Audiovisual media

R&D in information sciences

Why did the NSF abandon the measurement of related scientific activities? The first reason has to do with the magnitude of the activities. Over the period 1958-1978, the surveys reported that information dissemination and data collection represented only about 1% to 2% of federal government-funded scientific activities. A survey of such a low volume of activities was not considered worth the effort. [138]

Not worth the effort, considering that, secondly, the NSF began publishing *Science Indicators* (*SI*) in 1973. [139] Everyone applauded the publication, including Congress and the press. [140] Among the indicators that soon appeared in *SI* were what were considered to be good statistics on scientific information – at least as far as the United States was

[138] A survey on scientific and technical information (STI) in industry was also planned as early as 1964, but was never, to the best of my knowledge, conducted. In 1961, however, the NSF conducted the first survey on publication practices in industry. But the survey was more concerned with measuring basic research than related scientific activities. See NSF (1961), *Publication of Basic Research Findings in Industry, 1957-59*, NSF 61-62, Washington.

[139] National Science Foundation (1973), *Science Indicators: 1972*, Washington.

[140] In October 1973, the National Science Board of the NSF estimated that approximately 11,000 copies had been distributed so far, and was pleased with the favourable press coverage. See: National Science Board, *Minutes of the 159th Session*, 18-19 October 1973. The recognition of the reputed quality of *SI* would be confirmed again in 1982 when Congress amended the law of NSF and asked, among other things, for a biennial report on science indicators. See: Public Law 97-375 (1982).

concerned: bibliometric indicators. [141] Indeed, for fifteen years, the United States was the only country to produce such statistics regularly. [142] For the NSF, counting publications became the main indicator for measuring scientific information.

Thirdly, over time, people became more interested in technologies associated with information and communication activities. Despite work by F. Machlup and others on the knowledge economy, [143] surveys increasingly focused on infrastructure and hardware. Over time, indicators on information technologies began replacing indicators on information activities.

All these efforts would coalesce into the first edition of the OECD Frascati manual. One aspect of the manual's first edition is the absence of a specific definition of research. [144] Categories or types of research activities were defined in precise terms (basic, applied and development), but the definition of R&D as systematic research would not appear until the second edition of the manual (1970). In the 1962 edition, research was essentially contrasted with routine work:

> The guiding line to distinguish R&D activity from non-research activity is the presence or absence of an element of novelty or innovation. Insofar as the activity follows an established routine pattern it is not R&D. Insofar as it departs from routine and breaks new ground, it qualifies as R&D (p. 16).

The manual dealt extensively with boundaries (frontiers) between routine work and R&D. It distinguished R&D from two other types of activities: related scientific activities and non-scientific activities (of which industrial production was perhaps the most

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[141] Besides the work of King Research, two other studies were contracted for developing bibliometric indicators at the NSF: National Federation of Abstracting and Indexing Services (1975), *Science Literature Indicators Study*, Washington: National Science Foundation; F. Narin (19776), *Evaluative Bibliometrics: The Use of Publication and Citation Analysis in the Evaluation of Scientific Activity*, Washington: National Science Foundation.

[142] F. Narin et al. (2000), The Development of Science Indicators in the United States, in B. Cronin and H. B. Atkins (eds.), *The Web of Knowledge: A Festschrift in Honor of Eugene Garfield*, Medford: Information Today Inc., pp. 337-360.

[143] F. Machlup (1962), The Production and Distribution of Knowledge in the United States, *op. cit*.; M. R. Rubin and M. T. Huber (1984), *The Knowledge Industry in the United States*, Princeton: Princeton University Press.

[144] This was standard practice in the UK and France at the time. See J. C. Gerritsen et al. (1963), Government Expenditures on R&D in the United States of America and Canada, *op. cit*.

important). It is here that the main differences were said to exist between member countries. According to the 1962 Frascati manual, related scientific activities fall into four classes: 1) scientific information (including publications), 2) training and education, 3) data collection, and 4) testing and standardization (p. 15). Non-scientific activities are of three kinds: 1) legal and administrative work for patents, 2) testing and analysis, and 3) other technical services (p. 16).

The manual stated that related scientific activities must be excluded from R&D unless they serve R&D directly (p. 16), and adds that: "It is not possible here to make a detailed standard recommendation for related scientific activities (…). The objective of this manual is to attain international comparability in the narrower field of R&D (…). Arising from this experience, further international standards can be elaborated by the OECD for related activities" (pp. 14-15). [145]

The recommendation was soon abandoned, despite talks about extending the Frascati manual to related scientific activities as early as 1964. [146] In 1967, the OECD concluded that: "these activities necessitate the formation of an *ad hoc* study group to elucidate the main problems which arise in measuring these activities". [147] Consequently, the suggestion to measure related scientific activities was dropped. The second edition of the manual (1970) concentrated on R&D, and no study group was ever created: "We are not concerned here with the problem of measuring related activities but with the conventions to be used to exclude them when measuring R&D activities" (p. 14). [148]

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[145] The Frascati manual nevertheless recommended that: "All calculation of deductions for non-research activities of research organizations, and of additions for R&D activities of non-research organizations should be made explicit, that is to say, recorded both by individual respondents and by those compiling national totals from the data furnished by individual respondents. Furthermore, whenever possible, related scientific activities such as documentation and routine testing, should be measured simultaneously with R&D and reported separately" (p. 14).

[146] OECD (1964), *Committee for Scientific Research: Programme of Work for 1965*, SR (64) 33, p. 12 and 18; OECD (1964), *Committee for Scientific Research: Programme of Work for 1966*, SR (65) 42, p. 23.

[147] OECD (1967), *Future Work on R&D Statistics*, SP(67)16, p. 9.

[148] The second edition of the Frascati manual was in fact the first step in a long series of boundary work. In 1970, the list of RSA excluded from R&D extended to seven classes: 1) scientific education, 2) scientific and technical information (itself subdivided into six sub-classes, then into eight in 1976), 3) general purpose data collection, 4) testing and standardization, 5) feasibility studies for engineering projects, 6) specialized medical care, and 7) patent and license work. Policy related studies were added in the 1976 edition, and routine software development in 1993.

Nevertheless, in 1968 the OECD Directorate of Scientific Affairs recommended that governments give high priority to a specific kind of related scientific activities – scientific and technical information – and offered proposals for a specific survey "to supply governments with a solid statistical foundation on which to build their national policy". [149] To that end, the German Heidelberg Studiengruppe fur Systemsforschung was contracted to develop a methodological document on scientific and technical information statistics. [150] Scientific and technical information activities were extensively defined in line with the NSF definition discussed above – and not yet concerned, as would soon occur with later OECD surveys, exclusively with technologies.

Early on, the methodology was tested in Norway and vehemently criticized at a meeting in Oslo in 1971, [151] particularly by countries where surveys were conducted. The methodology was qualified as too complicated and too clumsy and not providing governments with enough basic statistical data to formulate a scientific and technical information policy. [152] In 1973, the policy group on scientific and technical information concluded that "before fixing on such a methodology, it is necessary to identify the essential data and to define the indicators that are needed". [153]

To this end, the OECD Information Policy Group set up a steering committee on indicators for scientific and technical activities in 1974. Adopting once again the NSF definition then in vogue for measuring information and communication, the committee soon proposed a list of five classes of indicators, some of them already collected, "to assist countries to manage their information policy" (p.3): 1) financial resources allocated to scientific and technical information, 2) manpower, 3) information produced and used

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[149] OECD (1968), *Survey of STI Activities*, DAS/SPR/68.35, p. 2.
[150] OECD (1969), *The Measurement of Scientific and Technical Activities: Proposed Standard Practice for Surveys of STI Activities*, DAS/STINDO/69.9, Paris.
[151] OECD (1972), *Notes on the Meeting of Countries Collecting Statistics on Resources Devoted to STI*, DAS/STINFO/72.22.
[152] OECD (1973), *Collection of Statistical Data on STI*, DAS/SPR/73.94 (A); OECD (1973), *Economics of Information*, DAS/STINFO/73.18.
[153] OECD (1973), *Economics of Information*, DAS/STINFO/73.18, p. 3. In that same year, the result of a study on information needs and resources conducted with bibliometric data was published by the OECD Information Policy Group (IPG): G. Anderla (1973), *Information in 1985: A Forecasting Study of Information Needs and Resources*, Paris: OECD.

(publications, services, libraries, conferences), 4) computers and communication, and 5) potential users. [154]

The two instruments – the methodological manual and the list of indicators – produced by the OECD were never used to define science or to develop statistics for measuring science in general or related scientific activities in particular. We owe to UNESCO the furtherance of work on related scientific activities. The fact that the organization was devoted to educational and cultural development as much as economic development explains its interest in related scientific activities. The fact also that the organization was dominated by scientists, not economists as was the case at OECD, was also an influential factor for defining science differently. According to that organization, surveying national science and technology "should not be limited to R&D but should cover related scientific and technological activities (…). Such activities play an *essential* part in the scientific and technological development of a nation. Their omission from the survey would correspond to a too-restricted view of the scientific and technological potential, and would constitute an obstacle to the pursuance of a systematic policy of applying science and technology to development" (p.21). [155] The obstacle was perceived to be bigger in developing countries because of their reliance on knowledge produced elsewhere, that is, on knowledge transfer:

> What would be the use of transfer of technology or knowledge derived from R&D if the countries to which they were passed lacked the infrastructure necessary to make them operational? [156]
>
> Programmes of R&D in the developing countries are not sufficient to guarantee a rise in the scientific and technological activities of a country. In addition to those important activities it has been found necessary to create an infrastructure of scientific and technological services which, on the one hand, support and aid R&D proper, and on the

[154] OECD (1974), *Summary Record of the First Meeting of the Steering Group on Indicators for Scientific and Technical Information*, DAS/STINFO/74.28.
[155] UNESCO (1970), *Manual for Surveying National Scientific and Technological Potential*, NS/SPS/15, Paris.
[156] J.-C. Bochet (1977), *The Quantitative Measurement of Scientific and Technological Activities Related to R&D Development: Feasibility Study*, CSR-S-4, Paris: UNESCO, p. 5.

> other hand, serve to bring the results of R&D into the service of the economy and the society as a whole. [157]

Thus, very early on, UNESCO challenged the definition of science centered on R&D and insisted on adding related scientific activities. The official argument offered in document after document was the contribution of these activities to science:

> The priority given to R&D in data collection is only a matter of expediency, and does not mean that the importance of an integrated approach to R&D seen within a full context of educational and other services is underestimated. One may even argue that it is only in close conjunction with these services that R&D can be meaningfully measured – because they are *indispensable* for research efficiency (…) and should precede rather than follow the emergence of R&D in a country. [158]

UNESCO contracted two studies on related scientific activities. [159] In a perceptive comment, the author noted that "there does not seem to be any positive criterion by which activities related to R&D (are) defined". [160] The OECD definition currently in use was based on a negative criterion: related scientific activities consisted of scientific and technological activities that were not innovative in nature. J.-C. Bochet suggested three other definitions, more positive in nature. He defined related scientific activities as:

1. Activities which, whilst not being actually innovative in character, form the *infrastructure* necessary for the effectiveness of R&D;

2. Activities which, within the framework of science and technology, maintain the continuity of the routine *competence* necessary for R&D activity, although not playing a direct part in it;

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[157] J.-C. Bochet (1974), The Quantitative Measurement of Scientific and Technological Activities Related to R&D Development, *op. cit.*, p. I.
[158] Z. Gostkowski (1986), *Integrated Approach to Indicators for Science and Technology*, CSR-S-21, Paris: UNESCO, p. 2.
[159] J.-C. Bochet (1974), The Quantitative Measurement of Scientific and Technological Activities Related to R&D Development, *op. cit.* and J.-C. Bochet (1977), The Quantitative Measurement of Scientific and Technological Activities Related to R&D Development: Feasibility Study, *op. cit.*
[160] J.-C. Bochet (1974), The Quantitative Measurement of Scientific and Technological Activities Related to R&D Development, *op. cit.* p. 2.

3. Activities which, whilst not being innovative in character, have, in varying degrees, *connections* with R&D activities, created according to circumstances, either internally or externally to R&D.

From these reflections came a guide on scientific and technical information and documentation drafted in 1982, tested in seven countries, and published in a provisional version in 1984. [161] The guide was based on a study written for UNESCO in 1979 by D. Murphy from the Irish National Science Council. [162] The guide defined scientific and technical information and documentation as "the collection, processing, storage and analysis of quantitative data concerning information activities (…)" (p. 5).

UNESCO's interest in related scientific activities was the consequence of its basic goal of extending standardization beyond industrialized (i.e.: OECD) countries. The first step in that program, initiated in 1967, was Eastern Europe. As early as 1969, UNESCO published a paper titled *The Measurement of Scientific and Technical Activities*, written by C. Freeman. [163] The document was concerned with the standardization of data between western and eastern Europe (p. 7) and with the necessity of measuring related scientific activities (p. 10): R&D is "only part of the spectrum of scientific and technological activities (…). It is considered essential at the outset to visualize the whole and to begin to build the necessary framework for establishing a viable data collection system covering the whole field"(p. i). The document led to a guide [164] and a manual on science and technology statistics. [165]

What was peculiar to eastern countries at the time was the fact that R&D was not designated as such. The USSR, for example, put all its statistics on science and

[161] UNESCO (1984), *Guide to Statistics on Scientific and Technological Information and Documentation (STID)*, ST-84/WS/18, Paris.
[162] D. Murphy (1979), *Statistics on Scientific and Technical Information and Documentation*, PGI-79/WS/5, Paris: UNESCO.
[163] C. Freeman (1969), The Measurement of Scientific and Technical Activities, *op. cit*.
[164] UNESCO (1984), *Guide to Statistics on Science and Technology* (third edition), ST.84/WS/19, Paris.
[165] UNESCO (1984), *Manual for Statistics on Scientific and Technological Activities*, ST-84/WS/12, Paris, p. 6. The UNESCO manual was in fact a "duplicate" of the Frascati manual.

technology under the heading "science". [166] Moreover, government science, for example, included training, design and museums. UNESCO thus had to choose between two options for standardization: follow the OECD and concentrate on R&D, or measure, as in eastern Europe, both R&D and related scientific activities. The latter option prevailed.

In attempting to accommodate eastern Europe, however, UNESCO's efforts were guided as much by the desire to generate a larger range of standardization than the OECD as by an interest in related scientific activities *per se*. But the program for including eastern Europe failed, and UNESCO never collected data on related scientific activities. Why? The reasons are many. First, UNESCO itself concentrated on R&D. The activity was said to be easier to locate and to measure, and had the virtue of being an "exceptional" contribution to science and technology. Hence, while UNESCO pushed for the concept of related scientific activities, it simultaneously argued for the centrality of R&D. Here is one example, among many, of the rhetoric used:

> Because of the *unique (*"*exceptionnel*" in the French version) contributions that R&D activities make to knowledge, technology, and economic development, the human and financial resources devoted to R&D, which might be called the *core* of science and technology, are usually studied in greater detail (p. 6). [167]

The second reason that UNESCO never pursued work on related scientific activities was linked to the fact that, in the end, few countries were interested in these activities. [168] A meeting of experts in the methodology of data collection on scientific and technical information and documentation activities was held in 1985 to assess the lessons learned from the pilot surveys. It was reported that these activities were not deemed all that important or urgent, that the purpose for measuring them was not obvious, and that there were difficulties in interpreting the definition. [169]

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[166] C. Freeman and A. Young (1965), The R&D Effort in Western Europe, North America and the Soviet Union, *op. cit*., pp. 27-30, 99-152; C. Freeman (1969), The Measurement of Scientific and Technical Activities, *op. cit*., pp. 7, 11-12.

[167] UNESCO (1986), *Provisional Guide to the Collection of Science Statistics*, COM/MD/3, Paris, p. 6.

[168] The OECD's first *ad hoc* review group on S&T statistics argued the opposite in 1973: a majority of countries were said to be interested in related scientific activities. See OECD (1973), *Report of the Ad Hoc Review Group on R&D Statistics*, STP(73)14, Paris: pp.22-23.

[169] UNESCO (1985), *Meeting of Experts on the Methodology of Data Collection on STID Activities*, 1-3 October 1985, Background Paper, ST-85/CONF.603/COL.1, Paris, pp. 26-29.

But the main reason that UNESCO failed in its efforts to measure related scientific activities was that the United States left the organization in 1984, accusing UNESCO of ideological biases. The decision had a considerable impact on the UNESCO Division of Statistics in terms of financial and human resources. It led to the decline, and almost the disappearance, of UNESCO in the measurement of science and technology.

In the end, the fate of related scientific activities was decided by ideological and political factors. As early as 1962, the first edition of the Frascati manual recognized the centrality of related scientific activities to a country: [170]

> R&D activities are only one part of a broad spectrum of scientific activities which include scientific information activities, training and education, general purpose data collection, and (general purpose) testing and standardization. Indeed, in some countries one or more of these related scientific activities may claim a larger share of material and human resources than R&D. It may well be desirable for such countries to begin their statistical inquiries by surveying one or more of these areas rather than R&D.

But the main reason that related scientific activities were dealt with at length in the manual was to exclude them from R&D (other reasons are the methodological difficulties of separating R&D and related scientific activities and the discrepancies in data between countries). There was no interest in related scientific activities *per se*. It took fifteen years before a conceptual definition of related scientific activities appeared in the Frascati manual. Indeed, before the UNESCO recommendation (see below), related scientific activities were defined only as a list of activities, and there were, and still are, abundant examples of instructing the manual's users on how not to include and not to measure related scientific activities.

How do we explain the situation? One of the main reasons that related scientific activities were excluded from R&D was ideology: R&D was perceived as a higher order of activity. This was inspired by the way people valued types of personnel and their work.

[170] OECD (1962), The Measurement of Scientific and Technical Activities: Proposed Standard Practice for Surveys of Research and Development, *op. cit.* p. 13.

[171] As the US Work Projects Administration once observed: "The facilities available in the laboratories make it possible for the scientist to devote his time exclusively to *work of a professional caliber* [R&D]. He is not required to perform *routine* tasks of testing and experimentation but is provided with *clerical and laboratory assistants* who carry on this work". [172] No argument was needed to convince people of this hierarchy. It was taken for granted by almost everybody that "soft" activities like market studies or design, for example, were not part of science. This was the general understanding of the time. The little interest that did exist in related scientific activities was generally motivated by political considerations, such as the need to present a stronger science and technology performance, like the federal government in Canada, [173] or to display one's methodological competence in statistics on science, like UNESCO.

In fact, UNESCO became interested in related scientific activities for political reasons. First, the OECD surprised UNESCO when, in 1963, it published a standard methodology for conducting R&D surveys, a manual that, according to the OECD, "attracted considerable interest in other international organizations and in member countries (…), [and was] one of the most important [items] in the Committee's program". [174] As early as 1960, UNESCO was trying to assess resources devoted to science and technology in developing countries. [175] It was also aware of the difficulties of comparing data from different countries. Was it not UNESCO's role, then, to deal with international standards? By 1958, UNESCO had already produced standards for education and was working on further standards for periodicals (1964) and libraries (1970).

Given the OECD Frascati manual, if UNESCO wanted to get into the field of science measurement, it needed to distinguish itself. It did so by taking related scientific activities

[171] For an historical point of view, see: S. Shapin (1989), The Invisible Technician, *American Scientist*, 77, pp. 554-563; A.B. Usher (1955), Technical Change and Capital Formation, in NBER, *Capital Formation and Economic Growth*, Princeton: Princeton University Press, pp. 523-550.

[172] G. Perazich and P. M. Field (1940), Industrial Research and Changing Technology, *op. cit*. p. 43.

[173] B. Godin (2000), The Measure of Science and the Construction of a Statistical Territory: The Case of the National Capital Region (NCR), *Canadian Journal of Political Scien*ce, 33 (2), pp. 333-358.

[174] OECD (1964), *Committee for Scientific Research: Minutes of the 11th Session*, SR/M (64) 3, p. 11.

[175] For details, see UNESCO (1968), *General Surveys Conducted by UNESCO in the Field of Science and Technology*, NS/ROU/132, Paris; W. Brand (1960), *Requirements and Resources of Scientific and Technical Personnel in Ten Asian Counties*, ST/S/6A, Paris: UNESCO. See also: UNESCO (1968), *Provisional Guide to the Collection of Science Statistics*, COM/MD/3, Paris, chapter 1.

more seriously than did the OECD. But it was, in the end, only slightly more interested in the activities themselves than was the OECD. UNESCO had to find a niche where it could become a credible player in the methodology of science and technology statistics. Moreover, UNESCO simply followed eastern Europe's experience, since that was the easiest way to standardize statistics outside of OECD countries.

The OECD member countries refused to follow, which would have meant departing from their practices, because, as reported by the OECD Secretariat in its responses to the *ad hoc* review group on statistics, "les pays de l'OCDE *perdraient le contrôle complet* qu'ils détiennent actuellement sur leurs normes et méthodes": [176]

> The time is not ripe for "world-wide" science standards and (…) the official adoption of the current draft of the UNESCO Manual in a fit of *empty internationalism* would be unlikely to bring any practical benefits. (…) The current draft is, in our view, rather too ambitious and insufficiently based on practical experience to play this role. [177]

Broadening the Definition of Science

In its efforts to extend science measurement, UNESCO faced two challenges, corresponding to two groups of countries: "The methodology so developed [OECD] must be adapted for use by Member States at widely varying levels of development and with diverse forms of socio-economic organizations", UNESCO explained. [178] The first group [developing countries] had almost no experience in the field of science and technology statistics, whereas the second [eastern European countries] had an economic system that required important adaptations to fit OECD standards: [179]

> A statistical methodology developed in a country with 40,000 scientists and 200,000 engineers in all fields of science and technology may be of little use in a country with only 50 scientists and 200 engineers; a questionnaire suitable for use in a country with a

[176] The page where the citation appears is missing in the English version of the OECD's archives. OECD (1977), *Response by the Secretariat to the Questions of the Ad Hoc Group,* DSTI/SPR/77.52, p. 16.
[177] *Ibid.* p. 18.
[178] UNESCO (1966), *Science Statistics in UNESCO*, UNESCO/CS/0666.SS-80/3, p. 3.
[179] UNESCO (1966), *Problems Encountered in the Development of a Standard International Methodology of Science Statistics*, UNESCO/CS/0666.SS-80/5, p. 3.

> highly developed statistical organization may be impractical in a country where few professional statisticians are struggling to gather the most basic demographic and economic data essential to planning.

The task was enormous: "The Secretariat does not underestimate the formidable problems which are involved in such an undertaking, but is confident that, with the help of Member States having experience in this field of statistics, much progress can be made toward this goal". [180] "Worldwide" standards were consequently suggested as early as 1969. [181] The UNESCO manual dealt with the necessity to measure related scientific activities, as discussed above, but also with another concept, that of "scientific and technological activities":

> Broadening of the scope of science statistics is particularly appropriate to the conditions of most of the developing countries which are normally engaged in more general scientific and technological activities, rather than R&D solely. [182] In developing countries proportionally more resources are devoted to scientific activities related to the transfer of technology and the utilization of known techniques than to R&D per se. [183]

The concept of "scientific and technological activities" was the second effort of UNESCO to broaden the definition and measurement of science and would become the basis of UNESCO's philosophy of science measurement. Based on a study by K. Messman from the Austrian Central Statistical Office, [184] UNESCO drafted a recommendation on international standardization that was adopted by member countries in November 1978. [185] According to the recommendation, scientific and technological activities were composed of three broad types of activities: R&D, scientific and technical education and training, and scientific and technological services (or related scientific activities) (Figure 1).

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[180] *Ibid.* p. 4.
[181] C. Freeman (1969), The Measurement of Scientific and Technical Activities, *op. cit*.
[182] UNESCO (1969), *Science Statistics in Relation to General Economic Statistics: Current Status and Future Directions*, UNESCO/COM/CONF.22/2, p. 9.
[183] UNESCO (1972), *Considerations on the International Standardization of Science Statistics*, COM-72/CONF.15/4, p. 14.
[184] K. Messman (1975), A Study of Key Concepts and Norms for the International Collection and Presentation of Science Statistics, *op. cit*.
[185] UNESCO (1978), Recommendation Concerning the International Standardization of Statistics on Science and Technology, *op. cit*.

The concept of scientific and technological activities had precursors back to the 1930s and 1940s. The US National Resources Committee introduced the concept of "research activities" in its 1938 report. Similarly, the Canadian Department of Reconstruction and Supply brought forth the concept of "scientific activities" in 1947, followed by the NSF in 1958 and the OECD in 1963. Both concepts were used to cover R&D and related scientific activities. UNESCO's concept was broader still: it included education and training.

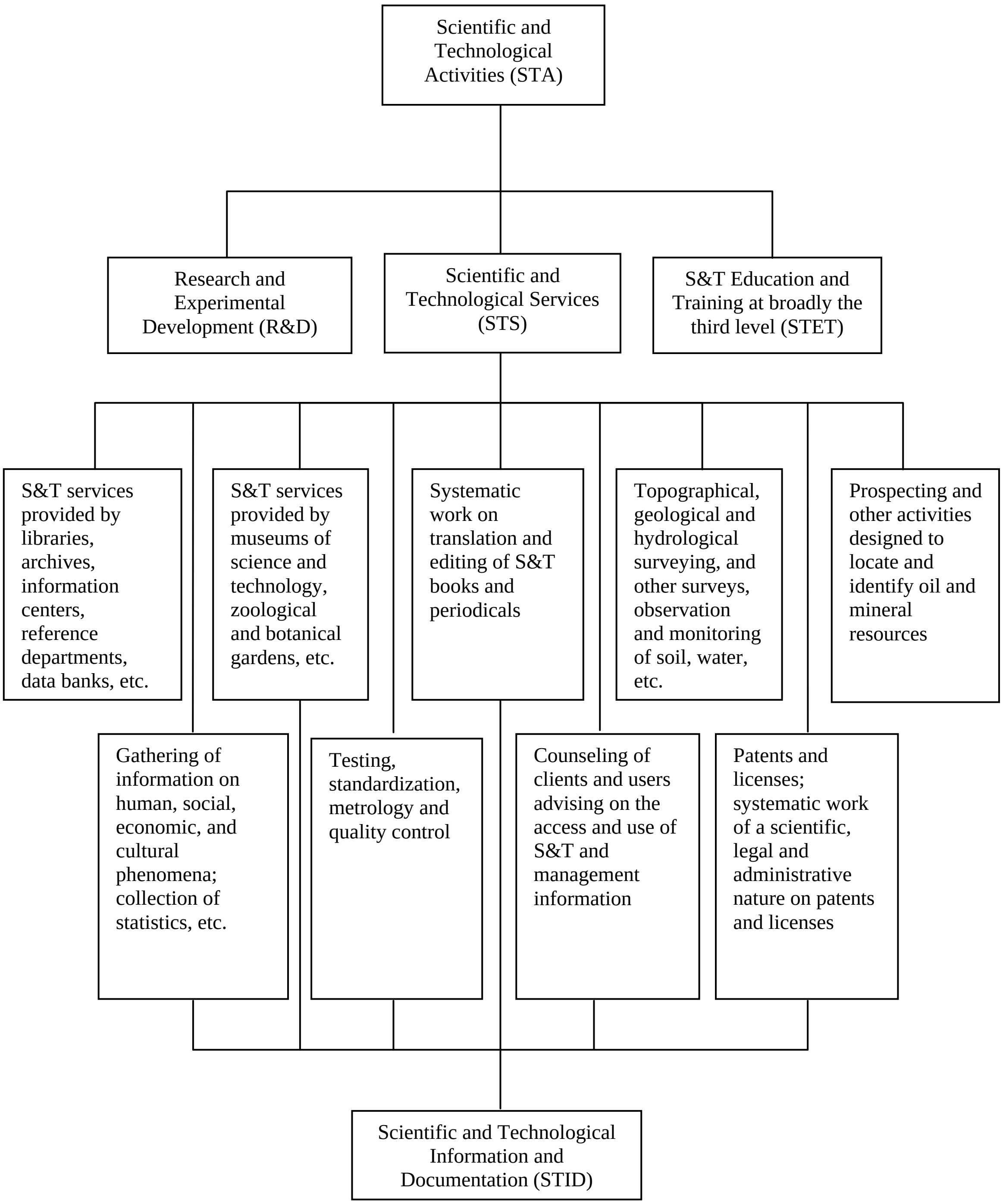
The UNESCO recommendation was short-lived. In 1986, the director of the UNESCO division of statistics on science and technology concluded that "Due to considerable costs and organizational difficulties, the establishment of a system of data collection covering at once the full scope of scientific and technological services and S&T education and training in a country has been considered not practicable. Some priorities have, thus, to be adopted for a selective and piecemeal extension of coverage of certain types of scientific and technological services and S&T education and training": [186]

> First stage: during this stage, i.e.: during the years immediately following the adoption of this recommendation [1978], international statistics should cover only R&D activities in all sectors of performance, together with the stock of S&T education and training and/or the economically active S&T education and training (…). Second stage: during that stage, the international statistics should be extended to cover scientific and technological services and S&T education and training. Subsequently, the international statistics relating to scientific and technological services and S&T education and training should be progressively extended to the integrated units in the productive sector. [187]

[186] Z. Gostkowski (1986), Integrated Approach to Indicators for Science and Technology, *op. cit*. p. i.
[187] UNESCO (1978), Recommendation Concerning the International Standardization of Statistics on Science and Technology, *op. cit*. pp. 10-13.

Figure 1.

S&T Activities (UNESCO)



In 1994, UNESCO called a meeting of experts to reassess the needs of member countries regarding concepts, definitions and classifications of science statistics. [188] The meeting concluded that UNESCO should continue to collect internationally comparable data on R&D, but that it should limit its program to the most basic statistics and indicators. It also recommended paying proper attention to statistics on human resources in every activity. [189] The recommendations were never implemented, however. The measurement of science at UNESCO remained minimal – R&D was surveyed at irregular intervals.

A few years after the UNESCO recommendation, the OECD appropriated the concept of scientific and technical activities in a new chapter added to the Frascati manual. [190] Certainly, the concept of "scientific activities" had already been present in the manual since 1962 and that of scientific and technical activities in the title of the manual. But now, it appeared in an introductory chapter "addressed principally to non-experts and (…) designed to put them in the picture" (p. 13). The purpose was not to measure scientific and technical activities but, again, "to distinguish R&D, which is being measured, from S&T education and training and scientific and technical services which are not" (p. 15). It had correspondingly few consequences on the standard definition of science and its measurement.

One decision, however, had a large impact. The same edition of the Frascati manual that introduced the concept of scientific and technical activities also discussed the concept of innovation. In fact, since its first edition, the Frascati manual dealt with another type of activity other than related scientific activities, and for which boundaries had to be drawn to distinguish it from R&D: non-scientific activities – from which the innovation concept emerged. According to the 1963 edition, non-scientific activities were composed of three items: legal and administrative work for patents, routine testing and analysis, and other

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[188] An additional evaluation exercise, although mainly concerned with indicators specific to western countries, was conducted in 1996 by R. Barré from the French OST: *UNESCO's Activities in the Field of Scientific and Technological Statistics*, BPE-97/WS/2.

[189] UNESCO (1994), *Meeting of Experts on the Improvement of the Coverage, Reliability, Concepts, Definitions and Classifications in the Field of Science and Technology Statistics*, ST.94/CONF.603/12, pp. 2-3.

[190] OECD (1981), The Measurement of Scientific and Technical Activities: Proposed Standard Practice for Surveys of Research and Experimental Development, *op. cit*. chapter 1.

technical services. These activities had to be excluded from R&D, as were related scientific activities. However, they are the kinds of work, or overhead costs as they were called in firms, that can be considered the industry equivalent of the government related scientific activities sometimes included in surveys of government R&D: [191] these activities are "related activities which are required during the realization of an innovation". [192] This was in fact what the OECD formalized in 1981 when it introduced the concept of *innovation* in the introductory chapter of the Frascati manual. Innovation was defined as:

> Transformation of an idea into a new or improved salable product or operational process (p. 15). It involved all those activities, technical, commercial, and financial steps, other than R&D, *necessary* for the successful development and marketing of a manufactured product and the commercial use of the processes and equipment (p. 28).

More specifically, innovation was defined as an activity itself composed of the following seven activities (p. 15-16):

1. R&D
2. new product marketing,
3. patent work,
4. financial and organization changes,
5. final product or design engineering,
6. tooling and industrial engineering,
7. manufacturing start-up.

Of all non-R&D activities and related scientific activities, innovation is the only one in the history of OECD statistics on science and technology that was given a certain autonomy and a status equivalent to R&D. In 1992, the OECD Member countries

[191] Indeed, patent work, for example, was transferred from non-scientific activities to related scientific activities in the 1970 edition of the Frascati manual.
[192] OECD (1981), The Measurement of Scientific and Technical Activities: Proposed Standard Practice for Surveys of Research and Experimental Development, *op. cit*. p. 16.

adopted a manual devoted specifically to the measurement of innovation – the Oslo manual. [193]

The concept of innovation was not without its own problems, however. [194] The concept goes back to J. Schumpeter's *The Theory of Economic Development*. Schumpeter defined innovation as consisting of any one of the following five phenomena: [195] 1) introduction of a new good; 2) introduction of a new method of production; 3) opening of a new market; 4) conquest of a new source of supply of raw materials or half-manufactured goods; and 5) implementation of a new form of organization Of all the science and technology statistics that were carried out before the 1970s, however, very few concentrated on innovation as defined by Schumpeter. Before the 1970s, innovation was usually measured with proxies, the most important of which were patents and industrial expenditures on R&D. Soon, it became clear that "innovation cannot be reduced to nor does it solely arise from R&D (…). It is probably quite as erroneous and misleading for appropriate and adequate policy making for technology and competitiveness to equate R&D with innovative capacity". [196] K. Pavitt, acting as consultant to the OECD, suggested that the organization thereafter define – and measure – innovation activities proper: [197]

[193] OECD (1992), *Proposed Guidelines for Collecting and Interpreting Technological Innovation Data* (Oslo Manual), DSTI/STII/IND/STP (91) 3.
[194] B. Godin (2005), The Rise of Innovation Surveys: Measuring a Fuzzy Concept, *Research Policy*, forthcoming.
[195] J. A. Schumpeter (1934), *The Theory of Economic Development*, London: Oxford, 1980, p. 66.
[196] OECD (1984), *Science, Technology and Competitiveness: Analytical Report of the Ad Hoc Group*, STP (84) 26, p. 40.
[197] OECD (1976), *The Measurement of Innovation-Related Activities in the Business Enterprise Sector*, DSTI/SPR/76.44, pp. 2-3. In 1965, the OECD had already distanced itself from Schumpeter's three-part definition of innovation (invention, innovation, imitation): "innovation should be interpreted more broadly to include all related activity resulting in improvements in processes and products (…)". See OECD (1965), The Factors Affecting Technical Innovation: Some Empirical Evidence, DAS/SPR/65.12, p. 5.

> Statistics on R&D have inherent limitations (…). They do not measure all the expenditures on innovative activities (…). In particular, they do not measure the expenditures on tooling, engineering, manufacturing and marketing start-up that are often *necessary* to turn R&D into economically significant technical innovations. Nor do they measure the informal and part-time innovative activities that are undertaken outside formal R&D laboratories (…). They do not indicate the objectives of R&D activities, for example, products or processes (…). They do not measure outputs, either in terms of knowledge, or in terms of new or better products and production processes.

Pavitt was in fact echoing an influential study from the US Department of Commerce. The Charpie report, as the study was called, defined and measured innovation in terms of five categories of activities: R&D, design engineering, tooling and engineering, manufacturing, and marketing. [198] Briefly stated, these were all activities that were usually called other activities or routine activities. The numbers produced by the Department of Commerce were soon contested, [199] but the definition helped policy analysts and statisticians turn toward developing a standard definition and measuring innovation activities.

The OECD definition of innovation carried several choices. The first consisted of choosing the approach. Should the definition and the survey consider innovation as an output or as an activity? Either innovation is the ensemble of activities aimed at bringing to market new products, processes or services (we speak here of Innovation with a capital "I"), or it is the result (output) of these activities: a new product, a new process or a new service (here we speak of an innovation). [200] Official statistics has chosen to define and measure innovation as an activity.

The Oslo manual called the first option the "object approach" (with the innovation itself serving as the unit of analysis) and the second option the "subject approach" (with the firm and the totality of its innovative activities serving as the unit of analysis). According

[198] US Department of Commerce (1967), *Technological Innovation: Its Environment and Management*, USGPO, Washington.
[199] E. Mansfield et al. (1971), *Research and Innovation in the Modern Corporation*, New York: Norton; H. Stead (1976), The Costs of Technological Innovation, *Research Policy*, 5, pp. 2-9.
[200] For similar distinctions on knowledge, see F. Machlup (1962), The Production and Distribution of Knowledge in the United States, *op. cit*.

to the manual, the object approach "results in a direct measure of innovation". [201] It "has the important advantage of asking questions at the project level, while in standard R&D and innovation surveys they tend to be asked at the firm level, forcing large firms to give some average answer across a number of projects". [202] The approach works as follows: "develop a list of significant innovations through literature searches or panels of experts, identify the firms that introduced the innovations, and then send questionnaires to those firms about the specific innovations". [203]

The OECD opted for the subject approach, however, relegating the discussion of the object approach to an appendix in the Oslo manual. There it mentioned that the two approaches could be combined, adding that in such cases the survey should be limited to the main innovations only, since most firms were ill-equipped to provide this kind of detailed information. This methodological consideration only played a secondary role in the decision, however. In fact, the OECD claimed that it preferred the subject approach because it is "firms that shape economic outcomes and are of policy significance". [204] The interest of the organization was in firms and the market, not in technology *per se*. The choice of the approach was, above all, in line with the way statistical offices have "controlled" the measurement of science and technology since the 1960s: the object approach is primarily an expertise developed (and owned) by academics like economists in the United States, [205] Science Policy Research Unit (SPRU) researchers in the United Kingdom, [206] and A. Kleinknecht et al. in the Netherlands; [207] whereas the firm-based

[201] OECD/Eurostat (1997), *The Measurement of Scientific and Technological Activities: Proposed Guidelines for Collecting and Interpreting Technological Innovation Data* (Oslo Manual), Paris, p. 85.
[202] *Ibid*. pp. 83-84.
[203] J. A. Hansen (2001), Technology Innovation Indicator Surveys, in J. E. Jankowski, A. N. Link and N. S. Vonortos (eds.), *Strategic Research Partnerships*, Proceedings from an NSF Workshop, NSF 01-336, Washington, p. 222.
[204] OECD/Eurostat (1997), The Measurement of Scientific and Technological Activities: Proposed Guidelines for Collecting and Interpreting Technological Innovation Data, *op. cit*. p. 29.
[205] J. Jewkes, D. Sawers, and R. Stillerman (1958), *The Sources of Invention*, St-Martin's Press; E. Mansfield (1968), Industrial Research and Technological Innovation, *op. cit*.; National Bureau of Economic Research (1962), *The Rate and Direction of Inventive Activity*, Princeton: Princeton University Press; E. Mansfield et al. (1977), Social and Private Rates of Return From Industrial Innovations, *Quarterly Journal of Economics*, pp. 221-240.
[206] As part of the Bolton Committee of Enquiry on Small Firms, the Science Policy Research Unit (SPRU) initiated a huge project in 1967 compiling all significant innovations in Britain: C. Freeman (1971), *The Role of Small Firms in Innovation in the United Kingdom*, Report to the Bolton Committee of Enquiry on Small Firms, HMSO; SAPPHO Project (1972), *Success and Failure in Industrial Innovation: A Summary*

survey (and its subject approach) has always been the characteristic instrument of statistical offices. [208]

The second choice concerned the definition's focus and coverage. Schumpeter suggested five types of innovation, including organizational and managerial innovation. The Oslo manual, however, concentrated solely on technological innovation. Although the second edition of the manual included (marketed) services, [209] it maintained a restricted and techno-centric view of innovation. [210] As H. Stead once stated, technological innovation "obviously excludes social innovation". [211] Non-technological innovation such as organizational change, marketing-related changes and financial innovations were discussed in the manual, but again, only as an afterthought in the appendices. [212]

This choice was by no means new. The measurement of science and technology had been biased by a hierarchical approach ever since the first edition of the Frascati manual. The manufacturing industries took precedence over the service industries in surveys, for

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of Project SAPPHO, London: Centre for the Study of Industrial Innovation; R. Rothwell et al. (1974), SAPPHO updated: Project SAPPHO Phase II, *Research Policy*, pp. 258-291; F. Henwood, G. Thomas, J. Townsend (1980), *Science and Technology Indicators for the UK - 1945-1979: Methodology, Problems and Preliminary Results*, STIC/80.39; J. Townsend et al. (1981), *Science Innovations in Britain Since 1945*, SPRU Occasional Paper series, no. 16, Brighton: SPRU; C. Debresson (1980), The Direct Measurement of Innovation, *op. cit*.; K. Pavitt (1983), Characteristics of Innovative Activities in British Industry, *Omega*, 11, pp. 113-130. The work of SPRU was preceded by that of Carter and Williams. See: C.F. Carter and B.R. Williams (1957), *Industry and Technical Progress: Factors Governing the Speed of Application of Science*, London: Oxford University Press, chapter 10; C.F. Carter and B.R. Williams (1958), *Investment in Innovation*, London: Oxford University Press, chapter 5.

[207] A. Kleinknecht (1993), Towards Literature-Based Innovation Output Indicators, *Structural Change and Economic Dynamics*, 4 (1), pp. 199-207; A. Kleinknecht and D. Bain (1993), *New Concepts in Innovation Output Measurement*, London: Macmillan; E. Brouwer and A. Kleinknecht (1996), Determinants of Innovation: A Microeconometric Analysis of Three Alternative Innovation Output Indicators, in A. Kleinknecht (ed.), *Determinants of Innovation: the Message from New Indicators*, Houndmills: Macmillan, pp. 99-124. See also: E. Santarelli and R. Piergiovanni (1996), Analyzing Literature-Based Innovation Output Indicators: the Italian Experience, *Research Policy*, 25, pp. 689-711; R. Coombs, P. Narandren and A. Richards (1996), A Literature-Based Innovation Output Indicator, *Research Policy*, 25, pp. 403-413.

[208] Australia and Canada tried to incorporate into the Oslo manual questions on the diffusion of advanced technology, but without success, because the subject approach took precedence in the end. See OECD (1991), Compte-rendu succinct de la réunion d'experts nationaux pour l'examen du projet de "Manuel Innovation", DSTI/STII/IND/STPM (91) 1, p. 6; B. Pattinson (1992), *Proposed Contents of an Addendum Dealing with Surveys of Manufacturing Technology*, DSTI/STII/STP/NESTI (92) 9.

[209] Excluding health care, however.

[210] F. Djellal and F. Gallouj (1999), Services and the Search for Relevant Innovation Indicators: A Review of National and International Surveys, *Science and Public Policy*, 26 (4), p. 231.

[211] H. Stead (1976), *The Measurement of Technological Innovation*, DSTI/SPR/76.44/04, p. 1.

[212] This changed with the third edition of the manual in 2005.

example, and national R&D surveys initially concentrated on the natural sciences and only later included the social sciences. Finally, related scientific activities have always been systematically excluded from surveys. All in all, current statistics "were built on the bricks and mortar model". [213]

A third choice involved in the definition of innovation was the concept of novelty. Some recent national innovation surveys had recorded a disproportionately high number of innovative firms. In a recent Canadian study, for example, over 80% of the firms surveyed declared themselves to be innovators! [214] The source of such estimations would seem to lie in the Oslo manual's decision to define novelty as something that a firm perceives as new rather than as what the market establishes as new. Why define novelty in this way? Because "firms generally know when a product or production process is new to their firms. Often they do not know whether it is also new to their industry, new to their country or region, or new to the world". [215]

Conclusion

Defining science has been a central issue for state statisticians for more than 80 years. Over this period, at least four choices were made. The first concerns defining (and measuring) science by way of research activities rather than by science's output, i.e.: knowledge. This last option prevailed in academic circles, [216] and is only beginning to appear in official statistics concerned with the knowledge-based economy. The second choice was defining research itself as R&D. Here, statisticians defined and measured

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[213] D. Guellec (2001), New Science and Technology Indicators for the Knowledge-Based Economy: Opportunities and Challenges, *STI Review*, 27, p. 9.
[214] Statistics Canada (2001), *Innovation Analysis Bulletin*, 88-003, 3 (2), p. 5.
[215] J. A. Hansen (2001), Technology Innovation Indicator Surveys, *op. cit*. p. 229.
[216] D. S. Price, (1951), "Quantitative Measures of the Development of Science," *Archives internationales d'histoire des sciences*, 5, pp. 85-93; D. S. Price (1956), "The Exponential Curve of Science," *Discovery*, 17, pp. 240-243; D. S. Price (1961), *Science since Babylon*, New Haven: Yale University Press, 1961; D. S. Price (1963), *Little Science, Big Science*, New York: Columbia University Press, 1963.J. Schmookler (1950), The Interpretation of Patent Statistics, *Journal of the Patent Office Society*, 32 (2):, pp. 123-146; J. Schmookler (1953), The Utility of Patent Statistics, *Journal of the Patent Office Society*, 34 (6), pp. 407-412; J. Schmookler (1953), Patent Application Statistics as an Index of Inventive Activity, *Journal of the Patent Office Society*, 35 (7), pp. 539-550; J. Schmookler (1954), The Level of Inventive Activity, *Review of Economics and Statistics*, pp. 183-190.

more than just research: development came to be added, specifically to better represent industrial activities and (military) technologies. A third choice regarded eliminating those related scientific activities essential to research because they were considered too routine to be included in a definition of science. The last choice was not to consider anything but research proper. Education statistics (scientists and engineers) for example, came to be dealt with in other departments of statistical agencies and governments than science statistics.

Why have governments defined and measured science via research? The first factor refers to the institutionalization of research as a major phenomenon of the 20th Century. By the 1960s, most large organizations have recognized research as a contributor to economic growth and performance, and many organizations were devoting an increasing share of their budget to these activities. Hence the need for a better understanding of what was happening and for measuring the efforts (as a first step in the measurement of science).

The second factor in understanding the definition of science as research, is accounting and its methodology. There are activities that are easily measurable and others that are not. There are activities for which numbers are available, and others for which they are not. There are activities that can be identified and distinguished easily, and some that in practice are difficult to separate. Officials chose to concentrate on the more easily measurable (R&D), for methodological reasons having to do with accounting (costs) and its measurement: research activities rather than research outputs (or knowledge), research activities rather than related scientific activities, and purely systematic research rather than (systematic and) *ad hoc*.

In spite of these factors, there was an influential precursor to a measurement of science as research: the very first statistics produced by the scientists themselves from the 19th Century. [217] From 1870, and more systematically after 1906, scientists' statistics on science were aimed at what was called the advancement of science. By advancement,

[217] B. Godin (2007), From Engenics to Scientometrics: Galton, Cattell and Men of Science, *Social Studies of Science*, forthcoming.

scientists really meant research. Statistics on "men of science" were measuring scientists as researchers, that is as workers and producers of new knowledge. [218]

While official statisticians, then, opted for a definition of science centered on institutional R&D, and classified types of research according to a very old distinction, that of the spontaneous philosophy of savants (basic/applied research, to which development has been added), there have been several tentative attempts to broaden the definition, but none has displaced the conventional one – although innovation could become a real competitor in the future. The last try at extending science measurement beyond R&D occurred twenty years ago: indicators, particularly indicators on output of research, and scoreboards, began to be developed in order to measure science on several dimensions. The idea was an old one, however. As early as 1963, Yvan Fabian, an ardent promoter of output indicators and a former director of the OECD Statistical Resource Unit, discussed the relevance of output indicators at the meeting that launched the Frascati manual. [219] He was ahead of his time. Although the OECD Committee for Scientific Research proposed as early as 1963 to review existing work on the matter, [220] output indicators would not become systematically available before the end of 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". [221] The manual nevertheless presented and discussed the potential of two output indicators: patents and technological payments. By 1981, the manual included an appendix specifically devoted to output, and discussed a larger number of indicators, namely innovations, patents, technological payments, and high-technology trade. 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

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[218] On a similar conception of science as work, scientists as workers, and scientific ideas as commodities, in early sociology of science (R.K. Merton), see: M.D. King (1971), Reason, Tradition, and the Progressiveness of Science, *History and Theory*, 10, pp. 3-32.
[219] Y. Fabian (1963), *Note on the Measurement of the Output of R&D Activities*, DAS/PD/63.48.
[220] OECD (1963), *Economics of Science and Technology*, SR (63) 33, p. 6; OECD (1965), *Committee for Scientific Research: Minutes of the 13th Session*, SR/M (65) 2, p. 18.
[221] OECD (1962), The Measurement of Scientific and Technical Activities: Proposed Standard Practice for Surveys of Research and Development, *op. cit.* p. 37.

moment, the only data which are available to measure output". [222] What has not really change is the complete absence of indicators on the social impacts of science. The official measurement of science is entirely economic-oriented.

[222] OECD (1981), The Measurement of Scientific and Technical Activities: Proposed Standard Practice for Surveys of Research and Experimental Development, *op. cit*. p. 131.