Outline for a History of Science Measurement

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Abstract

The measurement of science and technology (S&T) is now fifty years old. It owes a large part of its existence to the work of the National Science Foundation and the OECD in the 1950s and 1960s. Given the centrality of science and technology statistics in science studies, it is surprising that no history of the measurement exists in the literature. This paper outlines such a history.

The history is cast in the light of social statistics. Like social statistics, S&T indicators are produce mainly by governments, but differ in a number of aspects. First, they have not been developed in order to "control" individuals. Second, they have taken shape from the start at the international level. Third, they reflect a consensus among States and its organizations. The paper shows that this specificity is due to the socio-politics that drives S&T measurement.

Introduction

Governments and researchers from industrial countries have been measuring science and technology for over fifty years. The indicators in use today are derived from two sources. Firstly, quantitative information on science and technology is in great part due to the groundwork of governmental organizations such as the National Science Foundation (NSF) in the 1950s (NSF, 1959; Elkana and al., 1978) and intergovernmental organizations like the Organization for Economic Co-operation and Development (OECD) in the 1960s. There have doubtless been highly systematic attempts at measuring science and technology before the 1950s, but these were confined to Eastern Europe (Freeman and Young, 1965).

Secondly, a large debt is owed to the work of J. Schmookler (1950; 1954) and Derek J. De Solla Price (1961; 1963) during the 1950s and 1960s for directing the attention of university researchers to the measurement of science and technology. Following this work, the fields of scientometrics and, more particularly, bibliometrics have united several dozen researchers world-wide and yielded a variety of data for countless users (sociologists, historians, political scientists).

Given the centrality of science and technology statistics in science studies (economics, policy, sociology) and government action, the absence of any historical examination of the measurement is surprising. Many manuals summarize the field (Van Raan, 1988; Van Raan, Nederhof and Moed, 1989), and a voluminous literature consists of articles discussing or criticizing science and technology indicators *(Science and Public Policy,* 1992; *Research Evaluation,* 1995), but there is nothing approaching a history of the field. A preliminary outline for this yet-to-be-written sociopolitical history is sketched in the pages that follow.

This outline is placed in the light of the field of social statistics. Admittedly, the measurement of science and technology does not fit exactly the categories of social statistics as studied by historians today. Firstly, it is not concerned with the general *population* but rather with researchers and the knowledge and innovations they produce. Secondly, science and technology measurement does not constitute *economics* statistics, since it is not concerned, at least historically, with the measurement of "economic goods" produced by science, but rather with the activities of the producers of knowledge, among which are the universities. Various considerations explain the specificity of science and technology measurement, including ideological, political and methodological factors which we will later take up.

Despite these differences, the measurement of science and technology is, like social statistics, a statistic produced by the State. Looking at the measurement in the light of the literature on social statistics enables us to distinguish the specific characteristics of science measurement from other measurements administered by governments. The paper seeks precisely to identify those characteristics of official (governmental) science and technology measurement.

Three hypotheses guide our exposition – each is the object of the following three sections. Firstly, and contrary to what the history of social statistics could lead us to believe, the development of science and technology measurement was not motivated by the social control of actors. We take seriously Ian Hacking's remark that statistics offices were set up more for counting than for controlling: governments did not succeed in putting the aims of a moral economy into practice; instead, statistics departments developed according to an internal logic of their own (Hacking, 1982: 281-282). Secondly, science and technology measurement is an exercise that defined itself simultaneously at the international and national levels. It was not subject to the temporal linearity – the passage from diversity to a universality and standardization of definitions and methods – that seems to characterize other branches of statistics (and many technological norms). Finally, the institutional organization of science and technology measurement was not two-pronged, that is, it did not develop with reference to a debate between centralized statistics organizations and government departments as several social statistics have done. The measurement of science and technology constitutes a system of multiple actors operating according to a division of labour that is at once governed by a common ideology together with a variety of specific methodologies.

This papers concerns mainly the OECD. The organization is the main international player in the field of S&T measurement and the main forum for national governments to discuss the question. The period covered is 1963-1992, that is from the first edition of the international manual designed to guide statisticians in the conduct of R&D surveys (Frascati Manual, 1963) to the OECD program TEP (1992) that broadened the scope of S&T statistics.

The Art of (Not) Measuring Science

It hardly needs mentioning that statistics was developed in conjunction with the State and were driven with a view to population control and social intervention (Hacking, 1986; Desrosières, 1990; Porter, 1997; Brian, 1994). Whether it was the case of boosting the King's prestige and grandeur by displaying the number of his subjects, or of developing the modern state and its preoccupation with the "health" of its citizens, statistics was placed under the banner of instrumental rationality: the State invests in statistics with action as its goal.

Official statistics on science and technology are no exception to this rule: science is measured by governments because socio-economic ends motivate government interventions and discourses with respect to science and technology. However, these statistics possess their own particular characteristics.

Science and technology measurement is based upon a model, often implicit, of inputs and outputs (Figure 1) (OECD, 1993: 18; US Congress, 1993). Investments (inputs) are directed at research activities which produce results (outputs) and, ultimately, impacts. It is an idealized model: it identifies the principal dimensions of science and technology, but the statistics themselves do not measure all of these in the same way. Indeed, and until the early 1990s, official science and technology statistics rarely measure outputs (the "goods" produced) and impacts. Measurements are made chiefly of the inputs, that is, of the financial and human resources invested in science and technology. These are the dimensions of S&T for which governments have produced the earliest and longest time series of data, and the only dimensions for which there was an international manual of methodology until the 1990s.

Figure 1 – The Input/Output Model

Input → Activities → Output → Impact

Over the period, official statistics made essentially two measurements of science: the financial resources invested in research, which enable the calculation of what is called the Gross Domestic Expenditure on R&D (GERD), and the human resources devoted to these activities. Each of the measures is analyzed in terms of three dimensions. Firstly, the nature of the research, which is either basic, applied or concerned with the development of products and processes. As we shall see, this is the fundamental classification scheme of science and technology measurement. Secondly, the sectors that finance or execute the research: government, university, industry, non-profit organizations or foreign agencies. It is these institutions that are the object of measurement, and not the individuals of which they are composed. Finally, in relation to the former dimension, monetary and human resources are classified by discipline in the case of universities, by industrial sector in the case of firms, and by socio-economic objectives in the case of government departments.

More recently, official statistics measure innovation by comparing, for example, the number of patents and technological exchanges between countries (Balance of Technology Payments). But most of the effort over the period covered here was directed at the measurement of inputs. A glance at the set of indicators used in measuring science reveals that the farther we move away from inputs toward outputs and impacts, the less indicators there are available (Godin, 1996, 1997). There is one exception to this rule: the United States (via the NSF), where indicators of outputs were developed as early as the 1970s. At the international level however, we had to wait until the 1990s. Three factors are responsible for this situation: methodological, administrative, ideological.

Methodological difficulties

Although the measurement of research outputs is rare in official statistics, it is repeatedly discussed in methodology manuals and remains a constant on the agenda of international meetings of experts (OECD, 1963, 1980: Appendix 2, 1989: chapter 7; Freeman, 1970). But no measurement strikes a consensus with government authorities. The arguments developed in the manuals are essentially concerned with methodological and technical difficulties, and are too long to be taken up here. Let us focus our attention on the general picture that emerges from these manuals.

The OECD, the main authority on official science and technology measurement, sets forth two principal reasons why output measurements are so few and far between. First, the information on output is generally collated for administrative rather than measurement purposes and do not therefore allow for exhaustive measurements of the phenomena under scrutiny (OCDE, 1994: 18). Such is the case for patent and publication databases that are assembled respectively for legal and bibliographic purposes. Moreover, specific surveys on output would be far too consuming for the respondent if it were to give detailed information (OECD, 1997c: 123).

Second, and this is specific to university R&D, "[b]ecause of its basic nature, the results or outputs are difficult to quantify, and are largely in the form of publications and reports," states the OECD (OECD, 1989: 12). Since researchers essentially produce knowledge, "[o]uputs of R&D are not immediately identifiable in terms of new products or systems but are more vague and difficult to define, measure and evaluate." (OECD, 1989: 13)

The OECD nevertheless recommends that "[o]utputs of research *should* be measured wherever possible, bearing in mind the limitations of the methods being used" (OECD, 1989: 15) and by "drawing upon, whenever possible, not one isolated indicator, but several." (OECD, 1989: 47) It even states that « we are more interested in R&D because of the new knowledge and inventions that result from it than in the activity itself » (OECD, 1993: 18). Moreover, Christopher Freeman, the individual behind the Frascati Manual*,* writes that "[i]f we cannot measure *all* of [the information generated by R&D activities] because of a variety of practical difficulties, this does not mean that it may not be useful to measure *part* of it." (Freeman, 1970*:* 11) But statisticians are often opposed to such measurements (OECD, 1989: 50-51). In the absence of consensus and of a proper methodology manual, governments must content themselves with a working document where the measurement of university outputs is concerned (OECD, 1997a) rather than a methodological guide as for inputs.

Not only are university outputs not measured, but the measurement of university inputs is plagued by similar methodological shortcomings. For example, a great many countries refuse to carry out surveys on university inputs in R&D (OECD, 1997b). These are estimated indirectly. Although the OECD attempted to improve the situation with the publication in 1989 of the *Supplement* to the Frascati Manual (OECD, 1989), its recommendations have often been ignored by national statistical bodies.

Once again, OECD attributes the difficulty of measuring university R&D to technical constraints. The first of these is related to university accounting systems: "Accounting systems in Higher Education institutions do not, in general, give information broken down according to [R&D incomes and expenditures]. This is mainly because such information, apart from being quite difficult to compile, is of limited interest to Higher Education institutions' accountants." (OECD, 1989: 23) The nature of university work also raises serious difficulties for the measurement of university research. First, since research is intimately connected with teaching, "it is difficult to define where the education and training activities of Higher Education staff and their students end and R&D activities begin, and *vice versa*." (OECD, 1989: 24) Next, professors have very flexible work schedules: "more R&D is carried out in the university vacation periods than during the teaching terms. In addition, R&D does not necessarily take place within the constraints of recognized working hours. It may be carried out in the researchers' homes, at week-ends or in the evenings. This means that they have more flexibility and freedom in terms of working hours than their counterparts in other sectors." (OECD, 1989: 12) This line of argumentation is reiterated by national statistical organizations, as in the following quote from Statistics Canada:

> There are [...] particularly serious problems in surveying R&D activities in the Higher Education sector. One is that R&D is not necessarily an organized institutional activity but more of a personal activity of members of the institutions. [....] However, faculty members are expected to perform research as part of their normal duties and neither they, nor their institutions, have any cause to identify the resources devoted to this activity (largely their own time) (Statistics Canada, 1997).

Governments do conduct fairly straightforward studies of industrial and governmental R&D, but the above difficulties have led many to develop rather indirect – and much criticized (Irvine, Martin and Isard, 1990) – means of measuring investment in university research (OECD, 1997b). The OECD manual maintains that governments may nonetheless overcome these difficulties, insofar as they are willing to carry out surveys of university research (OECD, 1989: 34-35).[1] But this is precisely the problem: such surveys are not carried out. "[C]ountries have, over time, approached the problem of identifying and measuring R&D in different ways – influenced by, among other things, the time and financial resources available to carry out the data collection exercise, and also by the *importance* with which the national authorities rate Higher Education R&D, compared to R&D in other sectors of the economy." (OECD, 1989: 13)[2] This statement goes well beyond the methodological difficulties: in terms of measurement, governments are more concerned politically with firms and innovation than with university research.

The administrative needs of science policy

Vannevar Bush was eager to suggest, in the 1940s, that applied research necessarily depends upon basic research. It was the conclusion of his famous report *Science: The Endless Frontier* which led to the creation of the National Science Foundation (NSF), and became the standard model referred to in matters of Western science policy during the past several decades (Bush, 1945). The report recognized a very specific role for government in the realm of science and technology: the role of *funding* research, especially *basic* research conducted in universities. From this perspective it was basic research, and basic research only, that would ultimately create jobs, produce advances in health care and ensure the protection of citizens (through military technology).

When science policy began to emerge towards the end of the second world war, it did not therefore set out to guide or control research and scientists, but rather to ensure that the latter possessed the monetary ressources for producing knowledge – hence the emphasis that was placed on the measurement of inputs: where are the main *loci* of scientific activities, which expertises and disciplines are involved, and how much money is required (Shapley, 1959: 8 and 13).

The scope of science and technology policies – and thus of science and technology measurement – was therefore concerned with the national effort (GERD) and thus with the sectors that fund and execute research, such as universities, governments and firms, rather than with the researcher as individual or with his or her research activities. These sectors represent, in fact, those of the system of national accounts (Stirner, 1959) – with the exception of the university sector which is not yet distinguished as a separate entity in the system. At the same time, the categories and classifications defining each of these sectors were (and still are) used to present statistics: disciplines in the case of universities, industrial sectors in the case of firms, and socio-economic objectives in the case of government R&D. These classifications are widely recognized to be outdated, but to change them would require considerable work and consensus.

The ideology of the autonomous researcher

In addition to the methodological difficulties and the needs of science policy, the state of science and technology measurement until the 1990s can be explained, we submit, by the presence of a particular assumption or belief, let us call it the ideology of the autonomous researcher. The ideology suggests to governments not to intervene in scientific matters: peers decide of the value and merit of research. Consequently, there is no need for governments to worry about the evaluation and measurement of science and scientists, and to track the output of research.

The measurement of outputs and impacts has long been considered unnecessary, since these were perceived as the necessary, but implicit, consequences of research, as Bush has argued. It is scientists, in fact, who began portraying science as a source of progress during the 18th century, for instance, with the purpose of convincing governments to finance their work. Their discourse was determined by two arguments: 1) science inculcates intellectual virtues like objectivity, logic and rationality in individuals (Turner, 1980); 2) science drives socio-economic progress (Stewart, 1992; Golinski, 1992). Later, that is throughout the present century, scientists also advanced a parallel discourse on research freedom with which they frequently challenged the State *(Science and Freedom,* 1995; Polanyi, 1962; Weber, 1919). Consequently, by the end of the second world war researchers had succeeded in obtaining funding contingent upon promises rather than results (Turner, 1990; Guston and Keniston, 1994; Braun, 1993). This success went hand in hand with the fact that universities have for many centuries been autonomous institutions.

Over the course of the twentieth century, the public discourse of scientists was supported by economists in its efforts to persuade governments of the importance of funding research. The economist views science as a pure public good: science gives rise to benefits that, contrary to private goods, are not appropriable by the producer, and generates results and impacts that are difficult to measure and control (Nelson, 1959; Arrow, 1962). In conjunction with this idea, the economic understanding of science and technology was guided by what is known as the linear model where basic research gives rise to applied research which in turn generates innovation (Schumpeter, 1934; Forrest, 1991; Saren, 1984; Kline, 1985).[3] Governments must therefore invest where industry does not – in university basic research.

The importance of academic freedom in universities is such that it constitutes a central category of the measurement of science and technology: basic research is defined as "work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, *without any particular application or use in view.*" (OECD, 1993: 68)[4] Thus defined, basic research is essentially characterized by curiosity.[5]

These three factors – methodological, administrative and ideological – have had three consequences for the measurement of science and technology: 1) many countries refuse to carry out surveys of university *inputs*; 2) most do not systematically measure the *outputs* of research [6]; and 3) no measurements are made of researchers' *activities* which, for the present time, remain something of a black box left to the sociologists and historians of science to study. Only indirect measurements of the nature of scientific activities are ever available, such as measuring collaborative research activities by monetary investment.

In sum, neither the activities of individuals nor the goods produced (output) – whether in the university sector or elsewhere – are ever systematically measured. This is the general picture of science and technology measurement throughout the West. It is a situation influenced by the OECD, an institution whose importance has grown as governments have put in jeopardy their capacity of reflection on science policy.

Statistical internationalism

The history of measurement and statistics has shown how the latter first emerged among individual nation states and later became standardized at the international level (Brian, 1989). Science and technology often follow the same pattern (Latour, 1987; Schaffer, 1992; Johnston, 1996), as well as statistics (Kula, 1986: 114-119). However, measurement of science and technology is a different matter. Current methods for measuring science and technology are, for the most part, the product of an international organization, namely, the OECD – inspired largely by the National Science Foundation. In 1963, the OECD published the Frascati Manual (OECD, 1993) which provided member countries with recommendations on how to collect and organize R&D data in a manner that would allow international comparisons.

This work of standardization began in the mid 1950s, *at about the same time* [7] that a few countries like the United-States and Great Britain launched the first surveys into science and technology. Why did the OECD, following the lead of its predecessor, the OEEC,[8] target science and technology and, more specifically, science and technology measurement? Indeed, science and technology are mentioned as a mean to economic development in article 2 of the founding 1960 Convention, for example. Our hypothesis is that this focus upon science and technology enabled the OECD to define the (economic) terms of an important new challenge that had hardly begun to be mastered by governments. This particular focus also allowed it to reinforce its primary mission of promoting economic development (via science and technology).

It may be tempting to justify OECD intervention in matters of science and technology by the necessity to reduce and control spending. C. Freeman, wrote, for example, that « it is in any case self-evident that the present rate of expansion cannot continue continually (…). A choice must be made » (Freeman and Young, *op.cit.:* 15). Then, he added that statistics are the proper means to that end. Similarly, in the historical note in the appendix to the latest edition of the Frascati Manual we find the following statement: "Encouraged by the rapid growth of the amount of national resources devoted to research and experimental development (R&D), most OECD Member countries began to collect statistical data in this field around 1960." (OECD, 1993: 127) This statement, which was highly qualified in the first edition, demands interpretation. The 1963 Frascati Manual linked five goals with the conducting of measurement: information, follow-up, comparison, management and evaluation (OECD, 1963: 9-11). In more recent OECD documents, mention is also made of the need for indicators that permit a better *understanding* of the relationship between science and the economy (OECD, 1992: 317ss).

In fact, the notion of control may include several meanings that are not always clear in the literature on social statistics. The first meaning, associated with Michel Foucault, refers to the *disciplining, policing and regulating* of individuals (Rose, 1988; Miller and Rose, 1990; Miller and O'Leary, 1987). This is a strong definition of control, but a definition which is also presented in less radical form in the literature. Indeed, a second definition refers to how classifications and measurements inadvertently shape individuals by suggesting new ways in which to behave and think about themselves (Hacking, 1995) or, at the very least, how categories create ways of *describing* and acting upon human beings (Goodman, 1978; Desrosières, 1993). We submit that a third and more general sense of control refers to the means by which statistics enable governments to *intervene* in the social sphere, though not necessarily for the purpose of control.

In our opinion, to assess the history of scientific measurement in terms of a need to control <u>spending</u> would be to rationalize the past in light of the present. At the beginning of the 1960s, all governments believed in the importance of investing in science and technology (OCDE, 1965).[9] Economic decline was not yet in sight, and it was during this period, moreover, that the OECD began producing abundant literature calling on nations to establish science policy and invest in scientific activity. As of 1964, the organization produced dozens of studies on national science and technology policies in as many countries (Appendix 1), as well as an important three-volume study, *The Research System*, published between 1972 and 1974. It also produced, from 1963 onwards, numerous documents assessing science and technology policy and its objectives (Appendix 2).

This work continued uninterrupted into the 1980s and 1990s. The OECD launched a regular series of analyses of science and technology in public policy-making: *Science and Technology Policy Outlook* (1985, 1988, 1991, 1994), followed by *Science, Technology, and Industry Outlook* (1996, 1998). It founded the *STI Bulletin*, a journal on science and technology. As of 1988, it began publishing statistical *compendia* of science and technology in which were presented the results of governmental surveys on R&D (Appendix 3).[10] Finally, the OECD has produced five methodology manuals (Appendix 4): the Oslo Manual (1997), the Canberra Manual (1995), the patents manual (1994), the BPT manual (1990), the Frascati Manual (1963) and its supplement on higher education (1989). The Frascati Manual has undergone repeated and careful updating and is now in its fifth edition.

The control of spending was not, therefore, the *leitmotif* behind governments and OECD sponsored measurement. Neither was the control (choice) of the <u>objects</u> of research its goal – at least not until the 1980s. Rather, measurement became necessary for supporting and demonstrating the OECD's **(socio)economic mission** and for determining, consequently, the institutions (universities, industries, government laboratories) in which the State should invest. At this time, governments needed to know precisely which investments would foster scientific development and how to maximize their economic impacts. Economists had begun to show an interest in science and were publishing data evincing the importance of science to economic progress (Kendrick, 1956; Solow, 1957; Griliches, 1958; Denison, 1964).

In its appropriation of the field of science measurement, the OECD enabled itself to define science policy and measurement in terms that were essentially economic. Indeed, all OECD science policy documents underscore the economic benefits of science and technology (there is one exception: the Brooks report, published in 1971. Indeed, *Science, Growth and Society* was more concerned with the social than the economic benefits of science. However, this should be considered more as an *ad hoc* deviation in the OECD's approach to science and technology policy. New publications would not be resumed until the beginning of the 1980s).

The OECD, however, is attracted to science and technology for more than economic reasons. Science has much in common with a central feature of the organization's stated mission: **cooperation** between States. [11] Indeed, the OECD has repeatedly pointed out that "science is international by its very nature" (OECD, 1962: 2). And indeed it is, in the two following senses: 1) science is international *per se:* laws of nature apply in Europe and in America as they do to heaven and earth, as Newton wrote in the *Principia*; 2) science is an activity that takes place among scientists of different countries, the very Republic of Science envisioned in the 17th century. Science was therefore to serve as a prestigious barometer of collaboration between OECD member States.

But why were national governments so obedient in following OECD recommendations during this period? The obvious answer is that it is the member countries themselves who define the terms of debate, who produce and approve the relevant OECD literature. Another reason is that national governments needed to compare themselves: statistics help to display national performances and to justify (more) expenses (a country compares itself to others). But there were also several circumstantial factors which fostered loyalty to the organization.

Firstly, the OECD of the 1960s enjoyed an excellent reputation which attracted ample funding.[12] It therefore possessed the symbolic capital and financial means to develop its standardised methodological tools.[13] Secondly, member countries had few departments of science and technology and little expertise in science policy. Such departments only began appearing in the late 1960s and early 1970s, and the OECD model provided member States with practical solutions to the problems of scientific and technological measurement.[14] The model gained further legitimacy by virtue of its American origin (National Science Foundation) during a period when the United States was synonymous with prestige. Finally, there was a general consensus with respect to the categories subject to measurement:[15] basic research was carefully distinguished from applied research (and the university was identified with the former and industry with the latter), and the measurement of inputs was favored over the measurement of outputs.

Such a consensus had a long pedigree. Indeed, the ascription of superiority to theory over practice was a hallmark of the ancient Greeks (contemplation) which has influenced philosophy up until this century (Arendt, 1958; Lobkowicz, 1967). Scientific discourse later perpetuated this belief by way of two dichotomies: science versus technology and basic research versus applied research (Kline, 1995; Toulmin, 1988; Layton, 1974; Weinbert, 1970). Finally, beginning in the 1950s, this hierarchy was incorporated into "science policies" as governments followed the recommendations of the Bush report in viewing basic research, rather than applied research and development, as the source of innovation (Smith, 1990; Sarewitz, 1996; Averch, 1985; Stokes, 1997; Kleinman, 1995; Barfield, 1997).

Consensus notwithstanding, several modifications to the OECD classification system have regularly been advanced. Some governments, for example, have suggested introducing "strategic" research in between the categories of basic and applied research (Godin, 2000a). However, "the lack of an agreed approach to [the] separate identification [of strategic research] in Member countries prevents a recommendation at this stage" (OECD, 1993: 69).

Despite important attempts at harmonization, it would be incorrect to assume that member countries adhere to the Frascati Manual instructions with equal commitment. Each country has its own accounting system which does not always lend itself to straightforward collection and presentation of data as recommended by the manual. In Japan, research personnel is measured in terms of actual individuals rather than in terms of "full-time equivalence"; whereas in the United

States it consists only of those individuals assigned to separately budgeted R&D. In Canada, R&D is classified according to who funds the research, rather than who executes it as recommended by the OECD. Some countries, moreover, refuse to adopt various types of measurements. Canada, for instance, refuses to measure basic research as well as high technology industries (Baldwin and Gellathy, 1998). On the whole, however, the manual serves the mutual interests of an international community.

Numbers that make up a system

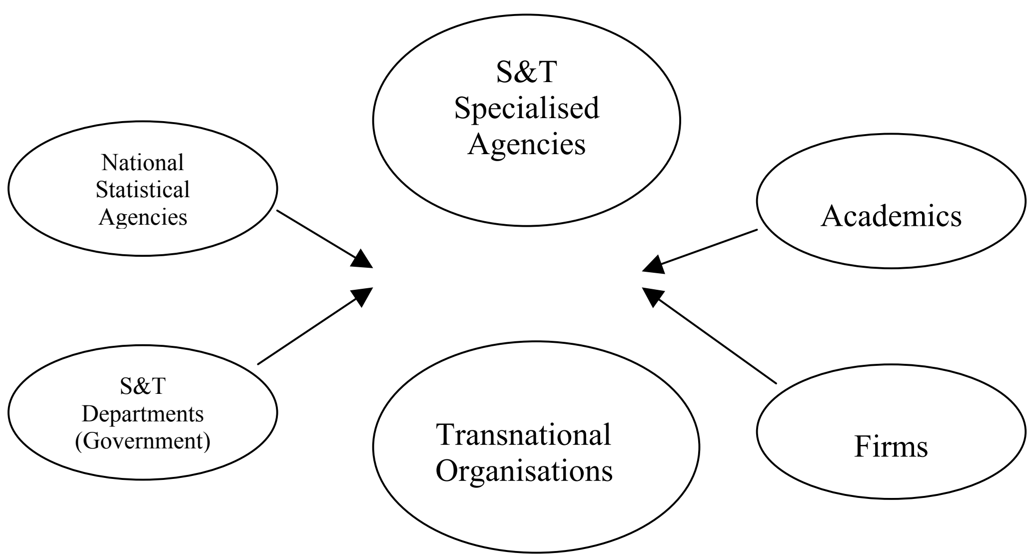
Some authors have identified a central issue in the history of official statistics: that of centralization versus decentralization of measurement activity (Desrosières, 1993; Beaud and Prévost, 1997). This debate has not so affected the field of science and technology measurement. There have certainly been periods of tension between producers and consumers of data, and between different producers but, in the main, government departments and statistics agencies have coexisted in relative harmony – sometimes to the point of cohabitation, as in Canada (Godin, 2000b).

The measurement of science and technology is the result of a system composed of multiple actors, and is characterized by a relatively clear-cut division of labor. This division tends to have the effect of "opposing" government departments against autonomous producers of statistics, rather than against their own national statistics agencies with whom they share objectives.

From the start, the measurement system comprised six categories of producers (see figure 2): 1) trans-national organizations like the OECD, UNESCO and the European Union; 2) national statistics agencies; 3) government departments; 4) organizations specializing in the study of science and technology;[16] 5) university researchers;[17] and 6) private firms.[18]

These actors play specific yet complementary roles in science and technology measurement. National statistical agencies and government departments specialize in the production of data based on input measurements obtained in surveys. As we have seen, their commitment is inspired by the OECD and by the historical need to develop informed investments in science and technology. At the opposite end of the spectrum are university researchers and private firms who specialize in output measurement using databases originally constructed for bibliographic purposes. Contrary to national statistical agencies and government departments, their business is often the production of statistics rather than raw data. Their entry into the field of science measurement roughly coincided with that of national governments and the OECD, but with a different aim in mind: university researchers were attracted by the implications of these empirical measurement tools for an emerging sociology of science (Price, 1961, 1963).

Figure 2.
The Organization of the Science Measurement System



Concerned with:	Concerned with:
input	output
surveys	databases
raw data	statistics

Finally, a third group, composed of specialized agencies and inter-governmental organizations, play an intermediary role between the aforementioned organizations. They buy, commission or simply use the information produced from various sources and organizations (with the exception of the NSF which conducts its own surveys) which they then analyze and organize into summary documents. I call the institutions in this group “clearing houses”.

Clearing housess play an important role within the functions usually associated with statistics agencies in that they are concerned with the organization of information. This activity is especially important because the two other types of producers are usually too motivated by their own methodologies to pay attention to what the other is doing. Thus, as per OECD works, government organizations measure mostly inputs and, since they conduct their own surveys to that end, their work tends to be concerned only with information that they themselves produce, i.e. raw data which for the most part is distinct from statistics proper (Holton, 1978; Gilbert and Woolgar, 1974). The few government organizations that have attempted output measurement – for example, Statistics Canada’s experiment in bibliometrics during the 1980s (Walker, 1988; MacAulay, 1985) – now refuse to repeat the experience. University researchers, on the other hand, rarely work with public micro-data on R&D, partly because of the difficulties involved in ensuring confidentiality. They rely instead upon private secondary databases which, furthermore, allows them to transcend the study of both input data and factual information. The measurement of outputs (publications), which has given rise to the new field of bibliometrics, allows them to go beyond inputs in that their commitment is to discover laws (Price’s law of exponential development (Price, 1951; 1956), Lotka’s law (Lotka, 1926)), to construct indicators (the impact factor (Garfield, 1972), the specialization index (Godin, Gingras and Davignon, 1997)), and to analyze scientific networks (using co-citation analysis (Small and Griffith, 1974)).

National statistical organizations are not alone in debating the value of bibliometrics. The field has yet to win the acceptance of the university community itself *(Science,* 1993; 1991) and of university researchers interested in the sociology of science (Edge, 1979; Woolgar, 1991). The field has nevertheless developed into a research specialization that is drawn upon by numerous organisations in conducting evaluations of research.

In sum, science and technology measurement system is characterized by a polarization of viewpoints and methodologies not unlike that which, during the nineteenth century, opposed Quetelet against rival statisticians. Quetelet wanted to identify the social constants and laws that lay behind the figures (facts) amassed by the State (Porter, 1986: 41). In such a context, clearing houses of the third group serve as a bridge between the two major types of producers. Using information from various sources, their goal is to draw up a complete cartography of science and technology by way of the publication of *compendia* or repertoires of statistical indicators. Most of these are published every two years, and are in their 14th edition in the case of the NSF *(Science and Engineering Indicators,* 2000), the 6th in that of Eurostat (the Statistical Office of the European Union) *(Recherche and développement: Statistiques annuelles,* 1998), the 5th in that of the OST *(Science and Technologie: Indicateurs,* 2000), the 3rd in that of UNESCO *(Rapport mondial sur la science,* 1998) and the 2nd in the case of the European Union *(European Report on Science and Technology Indicators,* 1997).

Notwithstanding the presence of these clearing houses, the overall structure of science and technology measurement is entirely founded upon a principle of division or dichotomisation. Sociology has shown that this principle, often called “boundary-work”, is an important technique in the work of social construction (Gieryn, 1983; Gieryn, 1999; Dolby, 1982; Laudan, 1996; Taylor, 1996). Science and technology is riddled with such divisions: science/technology, basic research/applied research, science/society, university/industry, producer/user, scientist/amateur, science/pseudo-science. The measurement system is itself characterized by a two-fold division.

First, a conceptual division whereby the data on science and technology are distributed in accordance with the “input/output” model. Second, an institutional division in which each side of this conceptual dichotomy corresponds to a type of actor and methodology: on one side are the national statistics organizations and government departments that refuse to take measures of university’ outputs into account for example, on the other are the university researchers and private firms that do.

Beyond these constructs, let us mention one final dichotomy, in itself a reflection of bureaucratic jurisdictions, and one which clearing houses also strive to transcend: that of Education versus R&D. As a rule, statistics on education are rarely found alongside statistics on science and technology. They are produced either by a separate section within statistical organizations or by departments distinct from those concerned with science and technology. The systematic integration of education and R&D statistics appears mainly in comprehensive documents produced by clearing houses.

Conclusion

Historians of statistics have to this day shown no interest in the statistics of science and technology. In contention with the existing literature, we have described how the measurement of science and technology is part and parcel of an integrated system. We have also shown how the statistics on science and technology emerged simultaneously at the international and national levels. And finally, we have submitted that the measurement of science and technology developed from the outset in opposition to the idea of control. Since it was believed at the time that scientists (university scientists, at least) should be free of constraints, governments have never “measured” the scientists themselves.

However, the situation looks as it is likely to change (OECD, 1992) as governments focus attention upon performance measures. One objective is to determine the specific areas in which research ought to be conducted, such as research fields and performing sectors. Another is to better "control" the results generated by this work. Two types of measurements have been developed to meet these objectives. First, the counting of university innovation activities (Sherman, 1994) as a means of measuring the commercialization of knowledge and the socio-economic relevance of research. Second, the measurement of university collaboration with socioeconomic users, the hypothesis being that increased collaboration translates into an increased probability of impact. This type of measurement serves only as a proxy of impact measurement however, impact which itself remains difficult if not impossible to measure.

These new measurements are directly related to the aims of the last fifteen years of science policy. During the 1980s, science policy has gone from being a policy on science to being one in which science must be made to serve socio-economic ends (Gibbons and al., 1994; Godin and Trépanier, 1995). It is no longer a matter of funding scientific activity for its own sake, but rather one of funding whatever contributes to economic progress and social improvement. This is well illustrated by the fact that the Frascati Manual (1963) excluded innovation in the measure of research, while the recent Oslo Manual (1997) is entirely devoted to the measurement of innovation.

It would be a mistake to imagine, however, that governments alone are involved in these measurements. They are also the subject of academic interest, at least among those members of the scientific community who are interested in the measurement of science and technology. The concept of National Innovation Systems designed to understand scientific systems in all their interactions and complexity – a notion of which the OECD is an ardent advocate (OECD, 1997c, 1999; *STI Review,* 1994) – can only come to fruition if researchers possess the necessary tools with which to understand science in all its dimensions.

In any event, impact measurement is laden with considerable difficulties. The socio-economic impacts of science and technology are diffuse, and are usually only apparent in the long-term.

They are also mostly manifest at the macro level: any link with the micro level would, methodologically speaking, be difficult to establish. In sum, the state of impact measurement is comparable to the state of input measurement at the beginning of the 1960s. It remains to be seen whether the present willingness of governments to measure outputs and impacts will translate into efforts and investments similar to those which led to both the Frascati Manual and to the subsequent surveys that are annually conducted by statistics organizations and government departments.

Notes

1 The manual recommends the use of full-time equivalence (FTE) as a solution to many of the measurement difficulties.

2 Our emphasis.

3 The genealogy of this idea began with J. Schumpeter (*Theory of Economic Development,* 1912) who distinguished between invention and innovation. Economists then later developed was is now known as the linear model.

4 Our emphasis.

5 This classification has been the object of numerous debates: NSF, 1979, 1989; Hensley, 1989; Stokes, 1997.

6 Although we have dealt mainly with university output, the same situation prevails concerning the measurement of industrial output. Besides patents, well known not to measure innovation exhaustively, and despite the many calls for better measures of innovation, the recently published OECD manual on industrial innovation (the Oslo Manual) takes the measure of innovation as a process only, not as product (output). While the manual defines two methods to measure innovation, the subject-approach and the object-approach, it opts for the latter and is concerned with measuring inputs, not the volume of outputs.

7 OECD started measuring R&D few years only after the United States, but preceded them as regards the construction of indicators.

8 It was the Committee for Applied Research of the European Productivity Agency of the OEEC that initiated these discussions in 1957.

9 See for example the report of the first conference of science ministers (OECD, 1965).

10 Since 1967 the OECD has published a document entitled "International Survey of the Resources Devoted to R&D by OECD Member Countries."

11 The first science policy document deals entirely with cooperation (OEEC, 1960), and the following all included a chapter on the subject.

12 Founded in 1961, the OECD replaced the OEEC which was itself created in 1948 to coordinate the american Marshall Plan for the reconstruction of Europe.

13 This is also the case today for the European Union which, together with the OECD, conceived and elaborated the recent Oslo and Canberra manuals.

14 In Canada, for example, the first research and development surveys were initiated by the Department of Reconstruction and Supply and by the National Research Council (NRC). Statistics Canada

followed suit only in 1963 with the Frascati Manual.

15 Article 6 of the 1960 Convention identifies consensus as an operative principle of OECD decision-making.

16 National Science Foundation (NSF), Observatory of Science and Technology (OST), Observatoire néerlandais de la science and de la technologie (NOWT), National Institute of Science and Technology Policy (NISTEP) of Japan.

17 The Science Policy Research Unit (SPRU) at the University of Sussex in the United Kingdom, the *Centre de sociologie de l'innovation* (CSI) at the École des mines in Paris, the Centre for Science and Technology Studies at the University of Leiden (Netherlands), and the Observatory of Science and Technology (OST) in Quebec.

18 Institute of Scientific Information (ISI), Computer Horizon Inc. (CHI).

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Appendix 1
Documents Regarding *National Science and Technology Policies* (OECD)

- National Science and Technology Policies– Sweden 1964
- National Science and Technology Policies– Belgium 1966
- National Science and Technology Policies– Greece 1966
- National Science and Technology Policies– France 1966
- National Science and Technology Policies– United Kingdom and Germany 1967
- National Science and Technology Policies– Japan 1967
- National Science and Technology Policies– Unites States 1968
- National Science and Technology Policies– Canada 1969
- National Science and Technology Policies– Italy 1969
- National Science and Technology Policies– Norway 1970
- National Science and Technology Policies– Spain 1971
- National Science and Technology Policies– Austria 1971
- National Science and Technology Policies– Swiss 1971
- National Science and Technology Policies– Netherlands 1973
- National Science and Technology Policies– Island 1973
- National Science and Technology Policies– Ireland 1974
- National Science and Technology Policies– Yougoslavie 1976
- National Science and Technology Policies– Australia 1977
- National Science and Technology Policies– Island 1983
- National Science and Technology Policies– Greece 1984
- National Science and Technology Policies– Norway 1985
- National Science and Technology Policies– Australia 1986
- National Science and Technology Policies– Portugal 1986
- National Science and Technology Policies– Sweden 1987
- National Science and Technology Policies– Finland 1987
- National Science and Technology Policies– Netherlands 1987
- National Science and Technology Policies– Austria 1988
- National Science and Technology Policies– Denmark 1988
- National Science and Technology Policies– Swiss 1989
- National Science and Technology Policies– Italy 1992
- National Science and Technology Policies– Tchécoslovaquie 1992
- National Science and Technology Policies– Portugal 1993
- National Science and Technology Policies– Mexico 1994
- National Science and Technology Policies– Turkey 1995
- National Science and Technology Policies– Poland 1995
- National Science and Technology Policies– Korea 1996

Appendix 2
Major Science Policy Documents (OECD)

- International Cooperation in Scientific and Technical Research (1960: OECE)
- Science and the Policies of Government (1963)
- Science, Economic Growth and Government Policy (1963)
- First Ministerial Meeting (1963):
  Ministers Talk About Science (1965)
- Second Ministerial Meeting (1966):
  1. Fundamental Research and the Policies of Governments
  2. Government and the Allocation of Resources to Science
  3. Government and Technical Innovation
  4. The Social Sciences and the Politics of Governments
- Third Ministerial Meeting (1968):
  Gaps in Technology in Members Countries (1970)
- Science, Growth and Society (1971)
- Technical Change and Economic Policy (1980)
- Science and Technology Policy for the 1980s (1981)
- New Technologies in the 1990s: a Socio-economic Strategy (1988)
- Technology in a Changing World (1991)
- Technology, Productivity and Job Creation: the OECD Job Strategy (1996)

Appendix 3.

Repertoires of Statistics (OCDE)

- Main Science and Technology Indicators (1988 and ss.)
- Science and Technology Indicators (1984, 1986, 1989)
- Basic science and Technology Statistics (1991, 1997, 2000)
- Research and Development Expenditure in Industry (1995, 1996, 1997, 1999)
- Science, Technology and Industry Scoreboard of Indicators (1995, 1997, 1999)

Appendix 4.
Manuals from the
Measurement of Scientific and Technological Activities Series
(OECD)

- Proposed Standard Practice for Surveys of Research and Experimental Development. (Frascati Manual, 1963)
- Proposed Standard Method of Compiling and Interpreting Technology Balance of Payments Data. (TBP Manual, 1990)
- The Measurement of Scientific and Technological Activities. Using Patent Data as Science and Technology Indicators (Patent Manual, 1994)
- The Measurement of Scientific and Technological Activities. Manual on the Measurement of Human Resources. (Canberra Manual, 1995)
- Proposed Guidelines for Collecting and Interpreting Technological Innovation Data. (Oslo Manual, 1997)