The Who, What, Why and How of S&T Measurement

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Statistics are generally qualified as objective, that is, as reporting facts. It is for this reason that statistics are also presented as an essential instrument for public policy. Statistics allow an enlightening of political choices by informing, and allow decisions to be objectivized by depersonalizing them.[1]

The sociology of science has long questioned this assertion. Statistics are socially constructed. By this, we mean that they imply choices that depend on various considerations which have nothing to do with mathematical science, choices that colour the results obtained.[2]

These choices can be divided into four categories. At the initial level, 1) the phenomenon to be measured (what), and 2) the instrument of measurement (how) require decisions that depend respectively on relevance and feasibility. These decisions in turn depend on 3) the objective of the measurement (why), and 4) the person doing the measuring (who). Briefly, statistics is a function of an agenda, one more often implicit than explicit.

We are interested here in official (government) statistics on science and innovation, statistics that are now 70 years old. It was basically in the 1930s, and initially in the Anglo-Saxon world (United States, Great Britain, Canada),[3] that the first statistics on R&D (research and development) made their appearance.[4] Their subsequent development and their dissemination through all western countries owes much to the OECD, which standardized an ensemble of methodological choices within a manual now known as the Frascati manual.

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[1] Porter, T. M., *Trust in Numbers: The Pursuit of Objectivity in Science and Public Life*, Princeton: Princeton University Press, 1995.
[2] Best, J., *Damned Lies and Statistics: Untangling Numbers From the Media, Politicians and Activists*, Berkeley: University of California Press, 2001.
[3] Not including the communist world.

With regard to official statistics, two types of agenda seem respectively to have governed the ministries and the statistical organizations during this period. The development of scientific and innovative activities, and the support for these activities, was the primary *leitmotif* of governments that got interested in measurement very early on. It is interesting to contrast in this context the ends for which R&D statistics are used, notably by their producers, for purposes relating to other statistics. Economic and social statistics generally serve to suggest the amplitude of a problem: unemployment is too high, inflation is skyrocketing, poverty is growing, etc. So governments must act. When it comes to science and innovation, on the other hand, we generally deplore it when performance is not high enough: R&D is insufficient, we don't have adequately qualified manpower, etc. While it is the big numbers that serve to justify government action in the social and economic spheres, it is the small numbers which, almost universally, dictate interventions when it comes to science and innovation.

The agenda of the official statistical organizations is different, and less visible, but no less present. Basically, the goal of the statistical organizations is not to correct situations, but simply to measure them. In this their chosen task, however, they convey at least three "interests". Firstly, an orientation (or ideology) that is fundamentally economic influences the official measurement of science and innovation. Not only do they measure activities by the monetary resources invested in them, but the principal indicators of results that have been developed concentrate on the economic aspects of science and innovation. Next, statistics is more oriented toward the requirements of public policy than toward those of knowledge: it seeks to be useful and to respond to the issues of the State. Finally, the instruments used for measurement are shaped by conceptual and methodological choices that unquestionably influence our understanding of science and innovation.

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[4] Godin, B., The Number Makers: Fifty Years of Official Statistics on Science and Technology, *Minerva*, 40 (4) 2002: 375-397.

This paper takes a critical look at statistics relating to science and to innovation by attempting to answer the following four questions:[5]

- who constructs statistics?
- why?
- what is being measured?
- how?

A Monopoly of the State

Anyone wishing to talk about science and innovation today in quantitative terms has no choice but to resort to official statistics, especially if they wish to discuss science on the international level. If there is one fundamental characteristic of statistics on science and innovation, it is that they are measured more in the departments of governments and their agencies than in universities. It is true that the academics are at the root of the development of several concepts and preliminary measurement exercises, while at the same time they work as consultants to the ministries and statistical organizations, but governments now have a monopoly on the production of statistics on science and innovation, a monopoly that is also reflected in the fact that academics lap up official statistics to fuel their research projects. This monopoly can be basically explained by the fact that governments are the only ones with sufficient financial resources to undertake surveys, particularly repeated surveys that allow to accumulate chronological series in order to follow trends in science and innovation.

The available financial resources, but also the instrument used for measurement, explain the State's monopoly on science and innovation statistics. Basically, the only legitimate measurement instrument for governments is the survey questionnaire. Governments send out questionnaires to businesses, for example, in order to collect information on expenses and personnel in R&D. In general, any statistics that do not come from such surveys are

[5] Godin, B., *Measurement and Statistics in the History of Science and Technology – 1930-2000*, London: Routledge, in press.

discredited by the national statistical organizations: measuring the production of knowledge by counting scientific papers (known as bibliometrics) or measuring invention by counting patents. The arguments used in refusing these tools are that statistics produced are neither reliable nor standardized. More honestly, it is that this information and the associated data banks come from a source external to the national statistical office, a source it does not control: universities in the case of statistics on papers, and intellectual property offices (and these are even public!) in the case of patents.

This control of the instrument (the survey questionnaire) and of official statistical sources was solidified and crystallized in a standardization manual defined and ratified by the OECD countries: the Frascati manual.[6] The manual defines the basic concepts intended to measure R&D via the survey, and suggests rules for the variables (or questions) to be developed, in order to ensure comparability of data among countries. Conceived in 1963, the manual is now in its sixth edition.

The manual has allowed State statisticians to possess a common understanding of R&D, the concept of which, it must be admitted, nevertheless remains relatively vague when one attempts to measure it. It has also provided us with (relatively) comparable data among countries. But it also helped the State to monopolize the measurement of science and innovation.

If we wish to extend this thinking further, to know who is at the root of the measurement of science and innovation, we must look even further afield, and name one country in particular that has had a major influence in the past 50 years: the United States. It was basically in the United States in the 1930s that the first measurements of R&D in the Western World were performed. And when, 20 years later (in 1951), the National Science Foundation (NSF) was set up to finance basic research in the United States, the government also entrusted it, under the impetus of the Bureau of Budget (BoB), which

[6] OECD, *The Measurement of Scientific and Technical Activities: Proposed Standard Practice for Surveys of Research and Experimental Development*, Paris, 2002.

wanted to control expenses, with the job of measuring scientific and technical activities.[7] Over the course of ten or so years of annual surveys, the NSF would develop experience that was relatively unique, as well as methodological thinking that served as the basis for the preparation of the Frascati manual. The appearance of the series *Science Indicators* starting in 1972, pulling together various indicators between a single set of covers, would be another initiative of the NSF imitated in a certain number of countries and by international organizations.

It should be noted, however, that while both the NSF and its statistical analyses were resolutely oriented toward basic research, it was economists who would considerably influence subsequent events, and who constitute the third determining source of current methodologies, after the statistical bureaus and the United States. The current statistics on science and innovation, and the analyses based on them, are a reflection of the active participation of economists in the work of the statistical organizations. Anyone interested in measuring the outputs issuing from science and innovation activities must be content with statistics on patents, on the technological balance of payments or on trade in high-technology products. There also exist abundant studies that try to link R&D and productivity statistically. But when it comes to measuring other dimensions (environment, wellness, health, culture), the official statistics are silent. This is surprising given the "paradigm shift" in science policy in the 1980s.

Political Goals and Uses of Statistics

Two period are generally distinguished in the history of science policy. The first, which extends approximately from the 1950s to the 1970s, is concerned with the interest of governments in developing scientific and technological activities via their financing (policy for science). The period that would follow, however, would be transformed more by social, that is, political (military, space), and economic (industry) considerations, and would seek, with relative success, to orient scientific development for specific purposes

[7] Godin, B., The Emergence of Science and Technology Indicators: Why Did Governments Supplement Statistics with Indicators?, *Research Policy*, 32 (4), April 2003: 679-691.

(science for policy).[8] To both periods correspond parallel discussions and uses of statistics.

During the first period, statistics were used, and by their own producers as well, to boost the candidacy of science and technology among the ranks of government budget priorities. The NSF, for example, was an ardent defender of the need to invest in basic research. This research had, at least according to V. Bush, essential virtues for progress, but it was statistics which allowed to transcend mere rhetoric. The figures showed that basic research was lagging to the benefit of applied research, that shortages of researchers were already appearing, and that the United States was on the verge of being overtaken by the USSR.[9]

Far from being a thing of the past, such a use of statistics was even reinforced by another starting in the 1980s: the use of statistics to construct what we call conceptual frameworks used to map out science policy. At the heart of these analyses, we find the imperatives of economic progress. Most of the recent writings from the OECD relating to or interpolating science policy – national system of innovation, knowledge-based economy, competitiveness, globalization, new economy – seek to demonstrate, and with great difficulty we might add, the (cor)relation between R&D (or information technologies) and productivity.

This type of studies is just one of the numerous uses of statistics today. Three broad types of uses of statistics can be identified: theoretical, practical, and political/symbolic. The first use of statistics, that which the university researchers perform for example, is aimed at understanding phenomena relating to science and innovation. The OECD's conceptual frameworks also form part of this type of use. They provide governments

[8] OECD (1971), *Science, Growth, and Society: A New Perspective*, Paris.
[9] Godin, B., Measuring Science: Is There Basic Research Without Statistics?, *Social Science Information*, 42 (1) Mars 2003: 57-90.

with a way of comprehending science and science policy, accompanied by empirical and comparative elements. In this instance, statistics nourishes conceptual thinking.[10]

A second use of statistics, in its relationships with public policy, is of the practical type. Here, statistics is used directly for decision-making. So when European governments set themselves the objective of achieving a level of R&D expense equivalent to 3% of GDP by 2010, or when Canada sets itself the goal of achieving fifth ranking among OECD countries according to the same indicator, it is statistics which is directly dictating the objective.[11]

This type of use is relatively rare in the recent history of statistics, however. In general, statistics, at least official statistics, arrive too late to enlighten political choices, not to mention the fact that they are frequently too aggregated. In addition, science policy is not based on any coercive legislation or regulations that make the use of statistics imperative, unlike other areas such as delimiting electoral boundaries, which is based on population statistics. At best, official statistics on science and innovation must content itself with a role that is contextual in nature: to assist in sketching a very macro picture of science and innovation trends, a picture that we generally find in the introductory chapters of policy documents.

One type of use of statistics more widespread in the history of the science policy of the past 40 years is its symbolic and/or political use. History is full of cases where statistics rapidly becomes political. These usually involve convincing people that more must be invested in science and innovation activities using statistics as the argument, or posting better performances than what the figures actually show.

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[10] Godin, B. The Knowledge-Based Economy: Conceptual Framework or Buzzword?, *Science, Technology and Human Values*, in publication.
[11] Sheehan, J., and A. Wycoff, *Targeting R&D: Economic and Policy Implications of Increasing R&D Spending*, STI Working Paper, 2003, DSTI/DOC (2003) 8.

In recent history, Canada has provided us with the most eloquent example of a political use of statistics.[12] Basically, Quebec had been complaining since the beginning of the 1980s of a significant gap between Ontario and Quebec when it came to federal investment in science and technology. Ontario received almost 60% of the federal government largesse, compared to just 14% for Quebec. Under the (probable) influence of its supervisory ministry (Industry Canada), Statistics Canada developed the idea of producing its statistics in such a way as to reduce the gap between the two provinces. They removed from the statistics the share of federal expenditures allotted to the National Capital Region (NCR), a region that straddles the two provinces, and where – in its Ontario portion – the federal laboratories are concentrated. This statistical artifice had the effect of reducing the gap between Ontario and Quebec to just 8%. Furthermore, Quebec suddenly found itself with a ratio of R&D to GDP higher than Ontario's, an occurrence unprecedented in history.

Analysis of the OECD's writings allows us to observe a case where statistics were used for symbolic purposes. We owe to the OECD, and to its comparative statistics, the generalized practice countries have of comparing themselves with other countries. Ever since its very first statistical analyses in the 1960s-70s, the OECD classified countries as compared to others based on the principal indicator from the Frascati manual: the GERD (Gross Domestic R&D Expenditure) and GERD/GDP.[13] Inevitably, such classifications provoked emulation among countries that sought to compare themselves to the most successful, these latter thus becoming the symbol of excellence, and through that fact, the *de facto* standard. The countries that excel are generally very quick to announce their performance rankings for political and symbolic reasons, and those in last place are very eager to see their national authorities use the statistics to bolster their cause. At the time, Europe envied (or was jealous of) the American performance, and the United States' GERD/GDP ratio rapidly became the standard for statistical comparison.[14]

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[12] Godin, B., La distribution des ressources fédérales et la construction statistique d'un territoire: la Région de la Capitale Nationale (RCN), *Revue canadienne de science politique*, 33 (2), 2000: 333-358.
[13] Godin, B., The Most Cherished Indicator: Gross Domestic Expenditures on R&D, *Science and Public Policy*, in publication.
[14] Godin, B., Technological Gaps: An Important Episode in the Construction of S&T Statistics, *Technology in Society*, 24, 2002: 387-413.

Conventions, Nothing but Conventions

The measurement of science and innovation is marked by substantial difficulties that have nothing to do with the mathematics of measurement (in fact, there is no mathematics, symbolism or formula in OECD manuals). The principal problems essentially involve the definition of concepts to be measured. What is science? What is research? What is innovation? The answers to these questions depend on an empirical reality, to be sure, but only in part, since our understanding of these concepts is also rooted in the way we have been measuring them for the past 40 years. And when it comes to measurement, choices are made that reveal this habituation.

The official measurement of science and innovation measures its object in a very particular manner. To begin with, most of the current measures concern only the natural sciences, the medical sciences and engineering. The social sciences and humanities are rarely considered statistically. The debate as to whether these disciplines truly constitute sciences is a very old one. Official statistics responds in the affirmative, at least in its standards, but does not always consider them in the reality of its surveys.

Official statistics measures science using the concept of research. Research, as we now measure it, is referred to by the name, and acronym, "R&D". We are forced to admit, however, that the statistics so named speak of many other things than what we define as research. The "D" is for development, an activity undertaken essentially by businesses, and which constitutes the major portion of R&D (approximately 70%).

Here again, one very specific type of R&D alone constitutes the subject of the surveys. To be considered for the purposes of statistics, R&D has to be institutional, that is, it must be undertaken in one of the following sectors: industry, university, government laboratory or non-profit organization (NPO). But above all, R&D is measured well only if it is situated in a specific location known as the laboratory. R&D conducted in a decentralized manner or performed irregularly (i.e.: non-systematically) is badly captured by the measurement instrument. OECD standards even prohibits such measurement. For a long time, and yet today, R&D undertaken within small and medium-sized enterprises (SMEs), R&D in the social sciences and R&D conducted within service businesses has been undercounted because of these conventions.

Innovation underwent measurement problems just as significant. There are basically two ways to define innovation. 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 of these activities: a new product, a new process or a new service (here we speak of an innovation). Official statistics has chosen to measure innovation as an activity.[15] The reasons for this decision are many, but the logic of the statistical organizations, that of measuring activities, has been decisive – especially when the sources for the measurement of innovation as a result (output) are not based on the survey questionnaire.

The malleability of the concept of innovation does not stop there. An innovative firm is not just a firm that performs innovative activities or that invents new products or services. It is also a business that adopts new technologies simply to improve its performance and its productivity. This is an important dimension of what it is to be "technologically advanced", and it leads some to question once again statistics on high technology that rely essentially on the measurement of R&D without considering either the state of a firm' equipment, or the R&D incorporated in goods purchased by a firm.

Defining concepts is only one aspect of choosing the object to be measured. This object must then be classified according to dimensions that give some sense to the statistics. We have mentioned that R&D is measured, classified and broken down for each of the institutional sectors: business, government laboratories, universities and NPOs. Statistics on these sectors are generally presented and analyzed according to what we call

[15] OECD/Eurostat, *Proposed Guidelines for Collecting and Interpreting Technological Innovation Data* (Oslo Manual), Paris, 1997; Godin, B., *The Rise of Innovation Surveys: Measuring a Fuzzy Concept*, communication presented to the international conference in honour of K. Pavitt "What We Know About Innovation", 13-15 November 2003, SPRU, University of Sussex, Brighton (UK).

classifications. Each sector is attributed a classification by the Frascati manual, a classification borrowed from among existing ones, notably those of UNESCO. We associate with businesses a classification of R&D by industrial sector (ISIC); with ministries, a classification according to the socio-economic objectives of the State's interventions, a classification inspired by budget documents (NABS); and with universities, a classification by discipline (of the CLARDER type).

Only afterward did it become obvious that it was difficult to link statistics so designed to each other. Every sector had its own classification, and it was impossible, for example, to link government efforts in a given sector and their impact on the corresponding industry. And this was even more true, since the classifications divide up R&D into categories that do not really correspond to reality: university research, for example, is more and more multidisciplinary than disciplinary; research within firms is oriented toward products, which are multiple even within the same industry, and which are not restricted to the industrial category in question.

The classification of R&D into basic/applied is a matter of the same logic, that being to draw upon existing classifications. This dichotomy, which has long existed and which has served university researchers for several decades, was renewed within statistics starting from the first edition of the Frascati manual.[16] Very early on, however, numerous countries ceased to collect information on this dimension of research. Essentially, classifying research projects according to these categories is frequently arbitrary. Myriad solutions have been suggested over the past 30 years – among them adding a category of research called oriented or strategic between the two, as had been recommended in the Frascati manual – but none really gained the consensus of State statisticians.

Briefly, while the State appropriated control over the measurement of science and innovation, it left to others the task of defining the manner in which it would present its statistics. The statistics on science and innovation renew historic choices which often take on the allure of dichotomies. If the measurement of science and of innovation

[16] Godin, B., Measuring Science: Is There Basic Research Without Statistics?, *op. cit*.

abounds with dichotomies, it is because the choices to measure such an object, and in such or such a fashion, leads to exclusions and therefore, to oppositions: natural sciences versus social sciences, R&D versus so-called related scientific activities, technological innovation versus organizational or social innovation, basic research versus applied research.

The Unspoken Aspects of Measurement

The measurement of science and innovation continued its development for some time before acquiring its own tools. The first statistics drew upon existing data sources, such as directories of industrial laboratories. So what were constructed were proxies for measuring phenomena. For example, innovation had long been measured using R&D, even though the former covers a much greater range of activities. Then came the specifically dedicated survey: a survey on R&D initially, then in the 1990s, one on innovation. Finally, standards were developed at the international level to harmonize data collection methodologies among countries. The last innovation to date is the "scoreboard", bringing together in a single document an ensemble of indicators drawn from various sources and intended to compare countries among themselves on multiple dimensions of science and innovation.[17]

It should be noted, however, that all during these developments, a bias was guiding the measurement efforts. After 60 years of statistical work, we still measure the inputs, or the resources allocated to scientific and technological activities, but very seldom the outputs and the impacts, that is, the results issuing from science and innovation. Basically, it is relatively easy to count the amounts invested in activities. That has been the logic of the State – and of economists. The challenges lie elsewhere – but are not insoluble – when it comes to measuring results that sometimes remain intangible, not to mention the fact that they often manifest themselves only in the very long term.

[17] These documents are rarely produced by national statistical offices, but more frequently by international organizations, like the OECD, or by regional organizations.

Nevertheless, over the past decades, statistics has been considerably improved. But it would be wrong to pretend, for that reason, that we measure the phenomena we study perfectly. Recently, for example, a very troubling fact has come to light in the analysis of survey results. It has become apparent that the figures obtained on investments in R&D differ, sometimes quite appreciably, depending on whether they come from a survey on R&D or from a survey on innovation.[18] A blatant case where the instrument used has a direct impact on the results obtained.

Statistics on science and innovation remain marked by significant methodological limitations, the first of which, as we have noted, is the question of the concepts to be measured. This fact is admitted by statisticians, who do not, however, see the limitations of their own statistics when criticizing data sources other than those from national statistical organizations. Thus the attentive reader will observe that attached to the statistics tables are methodological notes. These are intended to qualify the data: their quality, their scope, etc.

The methodological notes are not always very detailed, however. Most often, they take the form of standardized notes or appear in separate documents, which does not invite a particularly critical reading of the data. And basically, the users generally have a tendency not to consider these notes (such is the case with policy documents) and the producers to minimize them, arguing that it is trends alone that count.[19] This is how statistics gain their autonomy and their legitimacy. They circulate without either

[18] OECD, *Assess Whether There Are Changes Needed as a Result of the Comparison of R&D Data Collected in R&D and in Innovations Surveys*, 2001, DSTI/EAS/STP/NESTI (2001) 14/PART3; D. Francoz, *Measuring R&D in R&D and Innovation Surveys: Analysis of Causes of Divergence in Nine OECD Countries*, 2000, DSTI/EAS/STP/NESTI (2000) 26; D. Francoz, *Achieving Reliable Results From Innovation Surveys: Methodological Lessons Learned From Experience in OECD member countries*, Communication presented to the Conference on Innovation and Enterprise Creation: Statistics and Indicators, Sophia Antipolis, 23-24 November 2000. See also, for Italy and Germany: G. Sirilli, *Old and New Paradigms in the Measurement of R&D*, 1999, DSTI/EAS/STP/NESTI (99) 13; C. Grenzmann, *Differences in the Results of the R&D Survey and Innovation Survey: Remark on the State of the Inquiry*, 2000, DSTI/EAS/STP/NESTI/RD (2000) 24.

[19] B. Godin, *Metadata: How Footnotes Make for Doubtful Numbers*, Project on the History and Sociology of Science and Technology Statistics, Montreal, 2002: http://www.inrs-ucs.uquebec.ca/inc/CV/godin/metadata.pdf.

qualification or precaution. So we come to take them for the reality, and to forget that a statistic is always constructed.

Conclusion

Governments and their organizations innovated when, 70 years ago, they began to measure science and innovation. A community of university researchers, initially composed of economists, was thus developed which used these statistics and then set about producing some statistics itself (although in a different manner), and also participated in the efforts of the statistical organizations.

The links weaving statistics and politics together are many. They range from understanding phenomena in which we desire to intervene (theoretical), to the evaluation of government actions (practical), not to mention the promotion of national efforts (symbolic). If official statistics plays an important role on the latter point, it is nevertheless not alone when we look at the two other functions. Qualitative analysis is everywhere in the first case, and detailed administrative statistics in the second.

It remains that official statistics contributes to public policy, via crystallization of the concepts that it serves. It is official statistics which gave rise to the recent "buzzwords" that underlie scientific policy: high technology, information society, knowledge-based economy, new economy. Without statistics, the discussions on these ideas would likely have been far less influential.