Taking Statistics (More) Seriously:

The Measurement of Science, Technology and Innovation and its Future

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"What matters is not how one fashions things, but what one does with them; not the weapon, but the battle (...). The making and the using of the tool are different things" (O. Spengler, *Man and Technics: A Contribution to a Philosophy of Life*, 1932).

Taking Statistics (More) Seriously: The Measurement of Science, Technology and Innovation and its Future [1]

Introduction

Statistics on science, technology and innovation (STI) abound. Series on research and development (R&D) and human resources devoted to R&D as well as numbers on graduates go back to the 1960s, and new ones have appeared in the last two decades: papers and citations, technological inventions (patents), trade in high technology, technological balance of payments and (technological) innovation. In order to make sense of this multiplicity and diversity, scoreboards have appeared in recent years that organize the statistics according to a limited number of dimensions and compare nations among themselves. Scoreboards have multiplied in turn: international organizations, national and regional governments, industrial associations and consultants have entered the "industry" and produce scoreboards year after year.

There are two traditions concerned with the measurement of STI, and both emerged in the 1960-70s. One is **academic**. Among the most active researchers are certainly economists working in the econometrics tradition. Economists produce what they call "models" which link STI variables – mainly research and development (R&D) – to economic measures like economic growth and productivity. Another very productive academic specialty is bibliometrics. This specialty emerged at about the same time as the economic specialty did, but from historical and sociological issues rather than strictly economic ones, although management issues (evaluation of laboratories) and productivity (of scientists) issues reign in this literature, as they do in the field of economics.

[1] A first draft of this paper was prepared for a UNESCO Workshop on "New Dimensions of STI Indicators", Paris, 9-10 December 2010.

A second tradition is **institutional** (UNESCO, OECD, European Union, national governments and their statistical bureaus like the US National Science Foundation). It is concerned with indicators on the whole process of STI (or simply innovation), from invention to commercialization and diffusion. It usually makes use of its own statistics (from official surveys) but also contracts studies to academics and others in order to complete its picture of STI.

Given the quantity of available statistics, one could easily be led to believe that everything has been done and that the model (example) for initiating new series already exists: that of the "major" producers like the OECD. This paper argues the contrary. Numbers are perhaps numerous, but several dimensions of STI are still measured poorly or not at all.

This paper focuses on the institutional tradition and its indicators, and provides some discussion on the following four questions and issues:

1. The state of the art in indicators on STI: what indicators do we have, and what is the policy framework on which they rely?

2. How and why we got there: what are the factors (historical, political, methodological, etc.) that led to the current statistics and indicators.

3. What is missing: which dimensions and issues are poorly measured.

4. New avenues: identifying areas for developing new statistics and indicators.

In a forthcoming paper, Godin argues that if we take seriously the idea that we live in a "culture of science" or STI (a different concept from that of "scientific culture"), one has to understand culture broadly (Godin, 2011). A culture is not limited to activities related to communication or diffusion, as many understand scientific culture. There is not STI on one side and on the other its diffusion or culture as a receptacle. A culture of STI is a culture that includes first of all the activities and productions (output) of STI themselves. In this sense, a culture of STI is more or less developed depending on the existence and strength of a whole set of institutions, their activities, their productions and their effects on society. Only the consideration of this whole set allows one to understand STI. From an analytical point of view, STI is that sum of dimensions or sub-system which includes:

- Institutions (research).
- Productions (graduates, knowledge, technologies).
- Diffusion, use and users (education, communication and transfer).
- Impacts (effects on society, the economy and the individual).
- Environment/Climate (laws and regulations, economic conditions, institutions and social values).

This paper is devoted to a survey of the institutional statistics and indicators currently used to measure such a system or culture. The paper adopts a historical perspective, for it is the thesis of the author that understanding the past reveals our taken-for-granted assumptions and postulates and, consequently, the areas where one may look to develop and improve statistics. The first part is a brief summary of the emergence of statistics on STI from the mid-nineteenth century onward, in order to introduce the main issues or concepts behind the measurement, followed by an overview of available statistics according to the five dimensions listed above. The second part concentrates on the policy frameworks that explain the current state of statistics, and the past efforts of UNESCO to offer alternatives. The final part suggests some avenues for discussions.

The Culture of Numbers

Statistics on STI emerged in the mid-nineteenth century. [2] At the time, the statistics came from scientists themselves (not governments), and were concerned with measuring the number of “men of science” (scientists): their demography and geography (Table 1). The socio-political context explains the kind of statistics produced. It was a time when the

[2] For a detailed history, see Godin (2005a, 2005b, 2006, 2007).

progress of civilization, later called culture, and the contribution of “great men” to it, were central to many discussions. In fact, many thought that the lower social classes and “unfits” reproduced more than men of science did, representing a danger to the human race. This led to the idea of measuring the number of men of science a nation produces (Francis Galton; Alphonse de Candolle).

Soon, the idea came to some of using the numbers as an indicator of how a nation supports science. In fact, one of the first widespread uses of statistics would be to contribute to the advancement of science and to improve the social conditions of scientists. Scientists complained that they received too little recognition for their work: low salaries, few prizes. The number of men of science came to serve as indicator of the social condition of these scientists (James McKeen Cattell) and of the culture of science: a low number of men of science in a society was seen as indicative of insufficient public support to the scientific profession, and to a low culture of science.

Table 1.
Historical Development
of Statistics on Science

(19^{th} - 20^{th} Centuries)

Stages	**Source**	**Main statistics**
Emergence (1869-circa 1930)	Scientists (Galton, de Candolle, Cattell)	Number of scientists
Institutionalization (1920-circa 1970)	Governments and national statistical offices (pioneering role of the United States)	Monetary expenditures (and rates of return)
Internationalization (1960 and after)	International organizations (UNESCO, OECD, European Commission)	Technological innovation (indicators and international comparisons)

From the mid-twentieth century onward, the statistics being collected changed completely. Thereafter, the main producers of statistics were governments and their statistical bureaus, and the most cherished statistics changed from the number of scientists to the money spent on R&D activities. Again, the socioeconomic context explains the situation. First, efficiency has been on the agenda of most organizations since the beginning of the century, so managing or "controlling" expenses has become a priority. It was precisely in this context that a "national budget on research" would be constructed. This would soon be followed by statistics on production (output) from investments in research activities. Second, and in a more positive sense, governments sought to contribute to the development of science, and needed quantifiable objectives.

The end result of this historical development is a set of statistics, which I analyze here according to the five dimensions listed above (p. 5). As mentioned above, I concentrate on institutional or official statistics. In point of fact, it is official numbers that generally define our measurement of STI. The financial resources governments invest in collecting statistics, as well as the recurring production of these statistics, help to ensure that the official statistics (rather than those of academics) are the statistics spontaneously used to discuss STI. Governments automatically bring legitimacy to the numbers they produce.

Institutions

While the early measurement were concerned with counting the number of individuals (scientists) in STI and their characteristics, current statistics focuses on institutions, with few concerns with the individuals as a category. To officials, STI rests first of all on institutions devoted to the production of research **activities** (for a specific nation, this is only partly true, since one could theoretically buy or absorb all its scientific knowledge from outside sources). Accordingly, the identification, listing and counting of these institutions was one of the first tasks to which statisticians devoted themselves decades ago, and collecting such data was considered, in the 1950s and 1960s, to be the first step toward a sound science policy. Cattell's work in the early twentieth century began by producing directories or lists of individuals, universities and scientific societies, and was continued by the US National Research Council from the 1920s onward, then by the US National Science Foundation beginning in the 1950s (lists of industrial laboratories).

Early in their existence, UNESCO and the OECD also collected and published lists of international organizations, starting from the 1960s.

With time, institutions have become a mere unit for surveying. Today, it is virtually impossible to obtain a complete list of STI institutions for a given country, or even just the number of such institutions. In the case of industrial laboratories for example, data are kept secret for confidentiality reasons. It has become customary instead to classify institutions according to the economic sector to which they belong, and to produce aggregate numbers by sector: industry, government, university, non-profit (and foreign). Institutions are no longer visible in statistics. Like the individuals, the institutions have dissapear. Statistics have become "depersonalized".

What remains of statistics on institutions is a sectoral aggregate developed for policy purposes. That statistics is the "national science (or research) budget", or **Gross Domestic Expenditures on Research and Development** (GERD). It is the sum of the monetary expenditures devoted to research activities in the above four economic sectors. GERD is a measure of what has come to be known as input: the resources (financial and human) invested in research activities.

Without doubt, GERD has become the measure *par excellence* of STI: the more resources are invested in research activities, the more a nation is said to be STI-oriented. While until the 1950s it was the number of scientists that measured a civilization or a culture, now it is GERD. For example, the GERD/GDP ratio is used to compare nations with regard to their efforts toward developing STI. This ratio serves as an objective for policy. In general, a ratio of 3% of a nation's economic resources devoted to research activities is said to be the optimal level of national investments in STI, and this has been the goal pursued by governments since the early 1960s.

However, over the last fifteen years, **innovation** has become the most cherished indicator. While often talked of in terms of output, there is in fact no statistics on innovative production or output in official surveys (like numbers of innovations) except quantification of qualitative answers. The indicators on innovation are rather measures of innovative activities of organizations, like numbers on such questions as "do you innovate" (yes or no). Like the statistics on R&D, those on innovation have their own biases. Only certain types of innovation (technological, organizational and marketing) in certain economic sectors (firms) are measured.

Innovation is both inventing and adopting something new. The OECD Oslo manual limits innovation to firms, including adoption. Adoption or diffusion ("the spread of innovation") and transfer ("linkages and flows") are discussed from a supply-point of view (how a firm acquire knowledge and technology from others), with other users like end users as a residual. What is relevant too is to know who users are, including individuals as professionals and their use of knowledge; how a user like a developed country gets to know (foreign) new inventions; what mechanisms it has to this end; what supporting infrastructures, etc. Clearly, many countries would have more 'relevant' numbers if one counts the users and put emphasis on what countries adopt and use (from foreign sources for example) as well as what they invent and commercialize.

Production

One does not assess or evaluate the state of STI simply by counting the institutions and the resources that they devote to research or innovation activities. Activities lead to productions or outputs, so says the traditional model (Input → Research activities → Output), and it is these outputs that ultimately motivate the establishment and funding of STI institutions. What are the productions that are measured and that have come to define STI?

The institutions devoted to STI produce different kinds of output. Some are purely scientific (knowledge), others are technological (inventions), still others are human (graduates). Over time, technological output has taken central place over scientific output in the measurements. Certainly, since the beginning of the 20th century bibliometrics has devoted itself to measuring scientific knowledge (the number of **papers**), and a whole “industry” of researchers has become active in this type of study. But to most “statisticians”, above all official statisticians, what matters most is useful knowledge or knowledge put to use or **technology** (like ICT, biotechnology, nanotechnology). A look at the annual series of indicators produced by governments and international organizations, and at the methodological manuals available to national statisticians for measuring STI, bears witness to this understanding: STI is understood first of all as a system or culture of technology (Table 2).

Table 2.

OECD Methodological Documents

(Year = first edition)

Manuals
*The Measurement of Scientific and Technical Activities: Proposed Standard Practice for Surveys of Research and Developmen*t, (Frascati manual) (1962).

Proposed Standard Practice for the Collection and Interpretation of Data on the Technological Balance of Payments (1990).

Proposed Guidelines for Collecting and Interpreting Technological Innovation Data (Oslo manual) (1992)

Data on Patents and Their Utilization as Science and Technology Indicators (1994).

Manual on the Measurement of Human Resources in Science and Technology (Canberra manual) (1995).

Measuring Productivity (2001).

Handbooks
OECD Handbook on Economic Globalisation Indicators (2005).

Guides
Guide to Measuring the Information Society (2005).

Frameworks
A Framework for Biotechnology Statistics (2005).
Framework for Nanotechnology Indicators and Statistics (2008)
A Conceptual and Methodological Framework for Emerging Technologies Indicators (Forthcoming)

Others
Bibliometric Indicators and Analysis of Research Systems: Methods and Examples (1997).

How do we explain this? Behind STI and its measurement is economics, which in governments' hands has become a doctrine or cult. One measures the quantifiable, the tangible, and what is economically efficient: money spent on R&D, technological inventions (patents), trade in high-technology products, technological balance of payments, technological innovation, and productivity – all economic measures.

Despite this purely economic focus, one different statistics on production has remained central to official statistics for over a century: the number of **graduates**. From the very beginning of statistics on STI, the measurement of human resources and manpower was a central statistics. It started with measuring the number of "men of science", as discussed above, and professionals involved in R&D activities, then the number of graduates – and their migrations. Today, it is the whole population whose level of education has become a central statistics. More recently, many organizations have also got involved in measuring student achievement (OECD's PISA surveys). To some, these statistics are a measure of a scientific or literate society. However, to others peoples are "human capital" and they are measured because they contribute to economic growth or development. Whatever the meaning of the statistics, one thing is sure: the reasons for producing the statistics have changed over time and reflect the context of its uses.

Diffusion and Use

In such a context, it is surprising that few if any of the official measurements are devoted to the diffusion and use of STI. If STI is to be useful, it has to be diffused and used through society and the economy. Productions themselves are not enough. One must ask, "is STI used, and to what extent?" However, even UNESCO, to which the transfer of scientific knowledge has always been central to policy (see below), has never developed indicators on the diffusion of STI. With regard to the OECD, systematic measurements of diffusion and use are quite recent, and are limited to **information and communication technologies** (ICT).

Nevertheless, there exist some proxies for statistics on diffusion among current statistics. The indicator on the technological balance of payments is to a certain extent a measure of diffusion or exchanges of technologies, as is trade in high technology products. **Collaborations** of different types, including globalization of industries and co-authored papers, are a measure of sharing STI. Similarly for the series of indicators on **education**. In fact, the school is certainly the basic "medium" for diffusing STI. For decades, nations have thus measured the "literacy" of their populations in terms of enrollment and diplomas. Yet, and overall, statistics on the use, diffusion and transfer of STI are few. Recent developments have not improved the situation. Statisticians have now jumped to measuring the impacts of STI but have left the routes (namely the uses) through which the impacts manifest themselves a black-box.

The reasons for this situation are multiple. Certainly, a major reason is ideological. For decades, policy on science has relied on a rhetoric of promises: fruits follow automatically from basic research and its funding. Similarly for technology: once technologies are there, they will (or should) automatically be used and lead to progress. One forgets that nothing is automatic in fact. There are costs, time lags, and resistance. Everything requires effort.

Impacts

As with diffusion and use, the impacts or effects of STI are central to a society. Unused, STI remains isolated from society; similarly STI with no impact is "wasted". However, with regard to the diversity of productions arising from STI and to their uses, the impacts are currently poorly measured. In recent years many projects have appeared, but these are still in the preliminary stage.

The range of impacts of STI on society is very broad: scientific (citations), economic (growth and productivity), social, cultural, political, environmental, health, etc. (Godin and Doré, 2005). Such a wide spectrum was at the center of the first conceptual framework for the study of STI and policy. From the 1920s onward, and for thirty years, US sociologist William F. Ogburn studied science and technology and its effects on society. Ogburn was interested in explaining what he called cultural lags, or maladjustments between technology and society (Godin, 2010).

Ogburn had few followers. The measurement of STI soon turned economic. Of all the impacts of science on society, the cherished one, and that for which there exists an ongoing series of measurements, is economic growth and productivity. Econometric studies abound on linking R&D to **economic growth and productivity**, and policy documents use the results of these studies regularly. One use is for public organizations to put statistics on STI side by side with those on productivity in scoreboards of indicators, implicitly suggesting a relationship between the two columns. However, neither the economist's mathematics nor the official use of it is convincing: 1) econometrics is an economist' "game" and few people take it seriously; 2) (official lists of) productivity indicators are visual (and rhetorical) tools.

The reasons for the economic focus of statistics on impacts are many. Methodological limitations are certainly important. There are problems of causality and attribution in the measurement of impacts. However, this is not the whole story. Don't we have (imperfect) measures of economic impact (productivity)? Aren't the limitations as important in measuring the impact of STI on economic productivity as they would be in measuring the impacts of STI on the family? We come back to the economic doctrine, then. The obsession with economics truly defines our measurements: STI (and statistics) is economically oriented.

Certainly, one finds some of statistics on impacts in the scientific literature. **Citations** are a measure of scientific impact: the number of times a paper is cited is witness to its use by and effects on the scientific community. However, this statistics is intrinsic to science. It says nothing about the impact of science on society. Another statistics has taken on increased importance in the last decade: **scientific literacy** (knowledge of scientific facts). The US National Science Foundation and the European Commission have included a chapter on "scientific culture" in their regular series of indicators on science since the 1990s. The literature on the Public Understanding of Science has also produced a series of studies and measurements, often commissioned by governments, on many dimensions relating to the communication of science to the public, and the relation between the public and scientists. This literature also dealt with an important aspect of the culture of science – an aspect too often relegated to environment or context – the social values held by individuals concerning science (i.e.: **interests and attitudes**). However, debates abound on the real significance and relevance of the indicators.

Environment

Like productivity measures, statistics on the conditions or environment of STI are relatively few and “biased”. The practice of official statisticians is usually to add to the statistical series on STI a subclass on **economic conditions and factors** enabling STI. This includes measures like economic climate, competition and regulation (fiscal policy).

The main problem with such series of statistics is, like that on impacts, the missing evidence of a link between economic conditions and STI. The two series of statistics are put on separate column side by side with a presumption of causality. The measures are rather ideological: a plea for the free market economy. As example, in the innovation surveys policies are measured as “hampering factor” to the innovative firm. The other limitation is the economic focus of the measures: few are concerned with the cultural and social conditions enabling STI.

A Cultural Representation

What is the result of all this? A specific representation of STI:

- A focus on (research) activities rather than use and impacts.
- An economic-oriented representation rather than social/cultural.
- An interest in technology rather than science.
- A concern with issues of industrial countries (productivity, competitiveness).

- An emphasis on firms rather than people.

As suggested on several occasions above, there are many factors explaining the current state of indicators: methodological (attribution problem), ideological (rhetoric on promises; cult of the economy). In this section, I concentrate on the role of conceptual frameworks used in STI policy. To the stages of statistics described above (Table 1) there correspond a series of conceptual frameworks which owe their existence to policy objectives and which have considerably influenced the kind of statistics developed. Over the twentieth century, at least eight conceptual frameworks have been developed for the study of STI and have been used for policy purposes (Godin, 2009; 2010). These frameworks can be organized around three generations (Table 3; for a correspondence between Tables 1 and 3, see Appendix).

Table 3.
Major Conceptual Frameworks
used in STI Policy

First generation
- Cultural Lags
- Linear model of innovation

Second generation
- Accounting
- Economic Growth
- Industrial competitiveness

Third generation
- Knowledge-Based Economy
- Information Economy (or Society)
- National Innovation System

The first conceptual framework developed for analyzing STI was that on cultural lags, from American sociologist William F. Ogburn in the 1920-30s. According to Ogburn's story, society is experiencing an exponential growth of technological inventions but is insufficiently adjusted or adapted. There are lags between the material culture and the adaptive culture. Therefore, there is a need for society to adjust in order to reduce these lags. Society has to innovate in what he called "social inventions", or mechanisms to maximize the benefits of technology. He also identified a need for society to forecast and plan for the social effects of technology.

The framework on cultural lags has been very influential. It has served as basic narrative to *Recent Social Trends* (1933) and *Technology and National Policy* (1937), two major policy documents in the United States, the first on social indicators and the second on technological forecasting, a specialty Ogburn in fact launched. It was also used during the debate on technological unemployment in the 1930s in the United States. Lastly, the framework on lags was the first of a series of conceptual frameworks concerned with innovation as a sequential process. It is in fact to this framework that we owe the idea of "time lags" (between invention and its commercialization) and the later idea of technological gaps.

However, the best-known of the sequential frameworks in STI is what came to be called the "linear model of innovation". The story behind the framework is rather simple. It suggests that innovation follows a linear sequence: basic research → applied research → development. In one sense, the model is trivially true, in that it is hard to disseminate knowledge that has not been created. The problem is that the academic lobby has successfully claimed a monopoly on the creation of new knowledge, and that policy-makers have been persuaded to confuse the necessary with the sufficient condition that investment in basic research would by itself inevitably lead to successful applications. Be that as it may, the framework fed policy analyses by way of taxonomies and classifications of research and, above all, it is the framework against which most forthcoming ones were to compare themselves.

The frameworks on cultural lags and on the linear model of innovation came from academics. The next generation of frameworks owes a great deal to governments and international organizations, above all the OECD, whose work is witness to national priorities and policies. From its very beginning, science policy was defined according to the anticipated benefits of STI. Because STI brings benefits, so the story goes, there is a need to manage STI, and management requires data. To contribute to this end, the OECD produced a methodological manual for national statisticians, the Frascati manual (OECD, 1962), aimed at conducting and standardizing surveys of R&D. The manual offered a statistical answer and an accounting framework to three policy questions or issues of the time: the allocation of resources to science, the balance between choices or priorities, and the efficiency of research.

One basic statistics among the statistics collected with the manual and its framework was a figure on the "national science budget", or GERD. The statistics served two purposes. One was controlling the public expense on science, the growth of which was too high according to some budget bureaus. The other purpose, more positive, was setting targets for the support and development of STI, and this was used by policy departments. It gave rise to the GERD/GDP ratio as a measure of the intensity or efforts of a country or economic sector.

Among the benefits believed to accrue from STI, two have been particularly studied in the literature and at the OECD: economic growth (through productivity) and competitiveness. These gave rise to two frameworks. The framework on economic growth and productivity embodies a very simple (and again linear) story: research leads to economic growth and productivity. Consequently, the more investment, the more growth. The issue of productivity in STI has a long history. It emerged among scientists themselves in the nineteenth century (Galton, Cattell) and got into neoclassical economics and econometrics in the 1930s (the production function).

However, it was governments and their statistical bureaus that really developed indicators after World War II. Economic growth and productivity have been studied at the OECD since the very early years of science policy in the 1960s. These got increased attention in the early 1990s, following the Technology and Economy Programme (TEP), and then in the 2000s with the Growth project, where an explicit framework – the New Economy – was used to explain differences in productivity between member countries. The United

States had the characteristics of a new economy, which means above all that it was innovative and it made more extensive and better use of new technologies, particularly information and communication technologies.

The other benefit (and framework) of the economic type that was central to the OECD was industrial competitiveness. The story behind the framework on competitiveness is that STI has become a factor of leadership among countries. Like economic growth and productivity, industrial competitiveness has been discussed at the OECD from very early on. This led to a major study published at the end of the 1960s on technological gaps between countries, particularly between European countries and the United States. Technological gaps were considered signals that Europe was not performing well. The study developed a methodology for ranking countries based on multiple statistical indicators. Then, in the 1980s, the issue of industrial competitiveness gave rise to the concept of high technology and the role of new technologies in international trade. High technology came to be seen as a major factor contributing to international trade, and a symbol of an "advanced economy". Statistics measuring the performances of countries with regard to the technological intensity of their industries were constructed and further developed to measure how countries maintain or improve their position in world trade. Then a framework on globalization was suggested in the 1990s, as was a methodological manual for measuring globalization. Globalization was said to be a source of competitiveness for firms and countries, and gained widespread popularity in policy.

We now come to a third generation of conceptual frameworks. These arose through a synergy or co-production among academics, governments and international organizations. The OECD, with the collaboration of "evolutionary" economists as consultants, adopted new frameworks for policy-making. The frameworks were generally constructed as alternatives to the linear model. One of these frameworks is the National Innovation System. The framework suggests that the research system's ultimate goal is (technological) innovation, and that it is part of a larger system composed of sectors like government, university and industry and their environment. Briefly stated, research and innovation do not come from the university sector alone, so the story goes. The framework emphasizes the relationships between the components or sectors, as the "cause" that explains the performance of innovation systems.

This framework was developed by researchers like C. Freeman, R. Nelson and B.-A. Lundvall in the early 1990s (the latter contributing directly to its implementation at OECD). However, a "system approach" in science policy existed at the OECD in the 1960s, although the organization did not use the term National Innovation System as such. From the very early beginning of the OECD, policies were encouraged promoting greater relationships among the components of the research system at five levels: between economic sectors (like university and industry), between types of research (basic and applied), between government departments, between countries, and between the research system and the economic environment. The Frascati manual itself was specifically framed in a system approach. It recommended computing and aggregating the R&D expenditures of the sectors composing a research system into the GERD indicator, but also suggested constructing a matrix for measuring the flows of research funds between the sectors (sources of funds and research performers). During all these conceptual efforts, the industrial sector and the firm still held central place in the innovation system. By then, the Oslo manual on measuring innovation had become the emblem of this framework at the OECD.

The other recent framework is that on the knowledge-based economy or society. The origins of the concept of a knowledge economy come from economist Fritz Machlup in the early 1960s, and the concept re-emerged at the OECD in the 1990s as an alternative, or competitor, to that on the National Innovation System. The latter was believed by many to be more or less relevant to policy-makers. The work at the organization was entrusted to the French economist Dominique Foray. The story on the knowledge-based economy suggests that societies and economies rely more and more on knowledge, hence the need to support knowledge in all its forms: tangible and intangible, formal and tacit. The framework suggests that one examine (and measure) the production, diffusion and use of knowledge as the three main dimensions of the knowledge economy.

In reality, the concept of knowledge is a fuzzy idea, and the above three dimensions are very difficult to measure. More often than not, the concept is an umbrella-concept, that is, it synthesizes policy issues and collects existing statistics concerned with STI under a new label. A look at the statistics collected in measuring the concept is witness to this fact: available statistics – available because there are very few new statistics on the knowledge-base economy – are more often than not simply shifted to new categories.

The last framework in the third generation is that on the information economy or information society. The framework on the information economy was one of the key concepts invented in the 1960-70s to explain structural changes in the modern economy. It has given rise to many theories on society, conceptual frameworks for policy, and statistics for measurement. The story behind the framework suggests that information, particularly information and communication technologies (ICT), is the main driver of growth. Like knowledge, information is a difficult concept. For example, it took three decades at the OECD to develop a methodological manual or guide to measuring the information economy.

The above frameworks build on each other. The policy discourse relies on a cluster of interrelated concepts and frameworks that feed on each other. One such cluster is composed of information economy and knowledge-based economy, coupled with new economy. Information and communication technologies are everywhere: it explains the knowledge-based economy, as well as globalization, the new economy and, of course, the information economy. Another cluster consists of frameworks of the second generation: accounting, growth and productivity and industrial competitiveness, all three framed in an input-output semantics.

Alternative Representations

The dominant representation of STI has not gone unchallenged. In fact, at the same time as the now-official representation of STI was being constructed in the 1960s, others were suggesting different approaches. The issue was partly a matter of whose vision would define STI.

We owe to UNESCO the development of a more inclusive definition of STI. The fact that UNESCO was devoted early on to educational and cultural development as much as economic development explains its interest in a broader concept. Also, the fact that the organization was dominated by scientists, not economists or economic-minded consultants as was the case at OECD, was an influential factor in defining STI differently. Certainly very early on the OECD was developing projects to broaden its measurements, but the organization never put these ideas into practice until the 1990s.

1. Scientific and Technological Potential (1969)

The first UNESCO attempt to broaden the definition of STI and, therefore to offer a different representation, was the concept of "scientific and technological potential" accompanied by a manual on methodology for surveying such potential. According to the UNESCO, "the national scientific and technological potential (STP) comprises the whole of the organized resources a country has at its sovereign disposal for the purposes of discovery, invention and technological innovation, and for the study of national and international problems that science and its applications involve" (UNESCO, 1969a: 20; 30-32), namely:

- human resources
- financial resources
- physical resources
- information centers and services
- research programs
- decision centers

In UNESCO's view, a survey of scientific and technological potential should cover the social and human sciences as well as the natural sciences, and include a survey of the natural resources of the country. Briefly stated, UNESCO's view of a system or culture of STI and its measurement was not limited to R&D activities, but included a larger set of activities. To UNESCO, "such activities play an essential part in the scientific and technological development of a nation. Their omission from the survey corresponds 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" (UNESCO, 1969a: 21). The obstacle was perceived to be bigger in the case of developing countries because of their reliance on knowledge produced elsewhere, that is, on knowledge transfer:

> 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 other hand, serve to bring the results of R&D into the service of the economy and the society as a whole (Bochet, 1974: 1).
>
> 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 (Bochet, 1977: 5)?

2. Related Scientific Activities (1984)

The manual on scientific and technological potential surveys, updated in 1980, came from a Policy Division. The scope of such a survey was very broad, probably too broad. So UNESCO's Division of Statistics turned to a more limited set of activities: scientific and technological services, or "related scientific activities" as they came to be called.

UNESCO and its consultants regularly challenged the definition of science centered on R&D, insisting on adding related scientific activities. The official argument they 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 (Gostkowski, 1986: 2).

Interest in related scientific activities was the consequence of UNESCO's 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. The document was concerned with the standardization of data between Western and Eastern Europe, and with the necessity of measuring related scientific activities: 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" (UNESCO, 1969b: i). The document led to a guide and a manual on science and technology statistics, both published in 1984.

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 technology under the heading "science". Furthermore, 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. To UNESCO, related scientific activities were defined as (Bochet, 1974):

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;

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.

As such, related scientific activities included information and documentation, standardization, museums, topography, prospecting, etc. From UNESCO's efforts to measure related scientific activities came a guide on (but limited to) scientific and technical information and documentation, drafted in 1982, tested in seven countries and published in a provisional version in 1984. The guide defined scientific and technical information and documentation as "the collection, processing, storage and analysis of quantitative data concerning information activities (…)" (UNESCO, 1984: 5). To UNESCO, the principal items to be measured were the institutions and individuals performing these activities, the amount of financial resources and physical facilities available, and the quantity of users.

In the end, the program to include Eastern Europe failed. Equally, UNESCO never collected data on related scientific activities, including information and documentation. Why? The reasons are many. First, UNESCO itself came to concentrate 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. R&D was perceived as a higher order of activity. 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 counting related scientific activities among countries was generally motivated by political considerations, such as the need to present a more impressive science and technology performance. 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 (UNESCO, 1986: 6).

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. A meeting of experts on the methodology of collecting data 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 the 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.

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.

3. Scientific and Technological Activities

Related scientific activities was part of a broader concept, adopted some years before by Member countries. In its efforts to extend STI 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 (UNESCO, 1966b: 3). 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 (UNESCO, 1966a: 3):

> 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 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" (UNESCO, 1966a: 4). "Worldwide" standards were consequently suggested as early as 1969 (UNESCO, 1969b). The UNESCO manual dealt with the necessity of measuring related scientific activities, as discussed above, but also with another concept, that of "scientific and technological activities".

The concept of "scientific and technological activities" was the third and last effort of UNESCO to broaden the definition and measurement of a culture of STI, and would become the basis of UNESCO's philosophy of measurement:

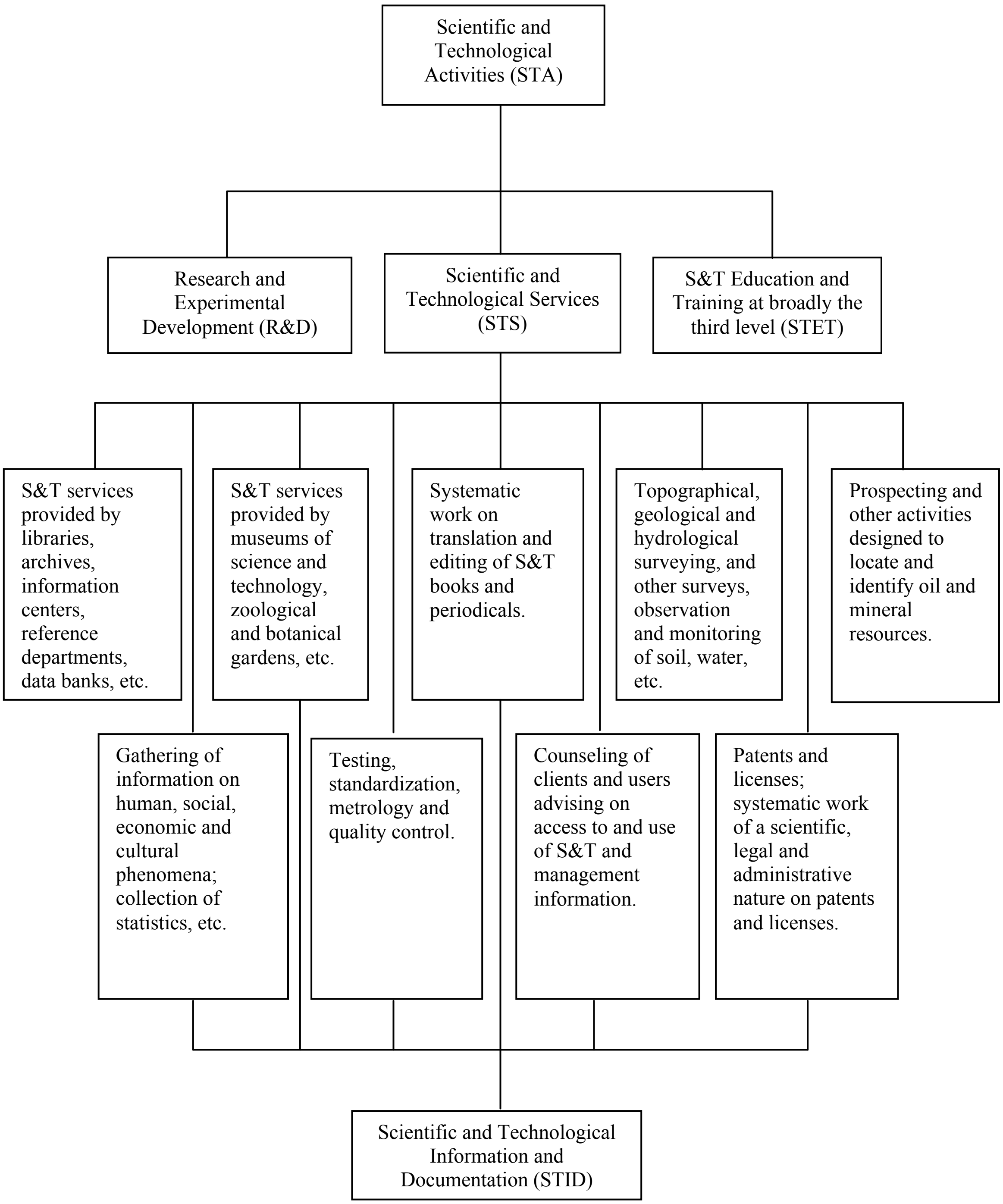
> Broadening of the scope of science statistics is particularly appropriate to the conditions of most of the developing countries which are normally engaged in more general scientific and technological activities, rather than R&D solely (OECD, 1969c: 9). In developing countries proportionally more resources are devoted to scientific activities related to the transfer of technology and the utilization of known techniques than to R&D per se (UNESCO, 1972: 14).

According to the UNESCO recommendation, adopted by member countries in 1978, 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) (UNESCO, 1978). However, 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".

Nevertheless, a few years after the UNESCO recommendation, the OECD appropriated the concept of scientific and technical activities in a new chapter added to the 1981 edition of the Frascati manual. 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 was discussed as such in an introductory chapter.

Figure 1.

S&T Activities (UNESCO)



However, the purpose was not to measure scientific and technical activities but "to distinguish R&D, which is being measured, from S&T education and training and scientific and technical services which are not" (OECD, 1981: 15). It had correspondingly few consequences on the standard definition of science and its measurement.

However, one decision has had a huge impact. The same edition of the Frascati manual that introduced the concept of scientific and technical activities also introduced that of innovation. Of all non-R&D activities and related scientific activities, innovation is the only one in the history of OECD statistics on science that was given a certain autonomy, and a status equivalent to R&D: in 1992, the OECD Member countries adopted a manual devoted specifically to the measurement of innovation – the Oslo manual (OECD, 1992). Since then, innovation has been the real benchmark for assessing a culture of science.

Is a New Vision Possible?

In the light of UNESCO's efforts on concepts and statistics, the OECD member countries refused to follow the organization as this would have meant departing from their practices, because, as reported by the OECD Secretariat in its responses to an *ad hoc* review group on statistics, "les pays de l'OCDE *perdraient le contrôle complet* qu'ils détiennent actuellement sur leurs normes et méthodes" (OECD, 1977: 16):

> 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 (OECD, 1977: 18).

The time may be ripe now for a new vision. Two options are available to UNESCO. One is jumping on catchwords and fads like measuring innovation or ICT or globalization, producing scoreboards and rankings, and imitating current statistics, just because the frameworks and the statistical series already exist for developed countries. The other option is developing a new vision more responsive to the goal of the organization, a vision which:

- Responds to Member countries' needs.
- Is policy-relevant to these countries.

Recommendations

1. Need of a conceptual and policy framework relevant to developing countries (not based on OECD concepts only). A framework identifies the problems and needs to be addressed in STI; it suggests policy avenues; and it recommends statistics to support the policy-makers. Currently, several countries produce (doubtful) statistics – often in answer to UNESCO's initiative (questionnaire) only. Increasing the policy relevance of statistics in the light of an APPROPRIATE CONCEPTUAL FRAMEWORK to Member countries' issues may provide the incentive to the national governments to develop statistical activities on a more regular basis.

2. Need to revise the supply-based view of studies and statistics of STI and add a user-based view. To date most, if not all, thoughts on STI are concerned with the originator or performer of R&D and the innovator as inventor who commercializes its invention. However, most Member countries use already existing STI as much as (or more than) they produce new STI. More efforts should be devoted to studying and measuring users of STI, not only institutional but including the individuals too, and innovators as adopters (and adapters). The following recommendations offer a user-view, as a complement to the dominant supply-view.

3. Revise the main concept used for measurement. To meet the two recommendations above, it is suggested to revise the main concept underlying the collection of statistics at UNESCO since 1978 – Science and Technological Activities (STA)**.** It is suggested to use Science, Technology and Innovation (STI), as composed of (in priority order)**:**

- People (old STET)
- Infrastructure (old STS)
- Diffusion (new category)
- Innovation (new category)
- R&D (same as before)

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Appendix

Statistics and their Conceptual Frameworks

Stages	**Main statistics**	**Objectives**	**Policy Frameworks**	**Statistics**
Emergence (1869-circa 1930)	Number of scientists	Eugenics		Men of science
		Advancement of science		*Ibidem*
Institutionalization (1920-circa 1970)	Monetary expenditures on R&D (and rates of return)	Management and policy	Cultural lags	
			Linear model of innovation	Money (FR, AR, D)
			Accounting	Input-Ouput
Internationalization (1960 and after)	Technological innovation (indicators and international comparisons)	Competitiveness	Economic growth	Productivity (MFP), inventions (patents)
			Competition and globalization	TBP, HT, licenses, collaborations
			Knowledge Economy	Scoreboards (of indicators)
			Information Economy	ICT
			National System of Innovation	Innovation