THE MAKING OF SCIENCE, TECHNOLOGY AND INNOVATION POLICY: CONCEPTUAL FRAMEWORKS AS NARRATIVES, 1945-2005

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In memoriam Jean-Jacques Salomon

INTRODUCTION

In recent years, policy analysts have studied policy as a process of argumentation[1]. Gone are the analyses of politics based on rational choice and instrumental rationality, as well as the study of policy cycles (agenda-setting → policy formulation → adoption → implementation → evaluation), at least among critical authors. Policy-making is conceptual construction, from its very first step – the problem to be addressed – to the last – action.

Policy-makers construct their problem through conceptual frameworks that structure policy action. As E. Goffman suggested, frameworks (or frames) are principles of organization "which govern the subjective meaning we assign to social events", principles that transform fragmentary information into a structured and meaningful whole[2]. More recently, D. Schon put it as follows: a frame is a "way of selecting, organizing, interpreting, making sense of reality", and "provides guideposts for knowing, analyzing, persuading and acting"[3].

Generally, a frame "[1] constructs the situation, [2] defines what is problematic about it, and [3] suggests what courses of action are

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1 G. Majone (1989), *Evidence, Argument, and Persuasion in the Policy Process*, New Haven: Yale University Press; D. Stone (1988) [2002], *Policy Paradox: The Art of Political Decision Making*, New York: Norton & Co; D. Stone (1989), Causal Stories and the Formation of Policy Agendas, *Political Science Quarterly*, 104 (2), p. 281-300; F. Fischer and J. Forester (eds.) (1993), *The Argumentative Turn in Policy Analysis and Planning*, Durham: Duke University Press; F. Fischer (2003), *Reframing Public Policy: Discursive Politics and Deliberative Practices*, Oxford: Oxford University Press.

2 E. Goffman (1974), *Frame Analysis: An Essay on the Organization of Experience*, Cambridge (Mass.): MIT Press, p. 10.

3 M. Rein and D. Schon (1993), Reframing Policy Discourse, in F. Fischer and J. Forester (eds.), The Argumentative Turn in Policy Analysis and Planning, *op. cit.*, p. 145-166, p. 146. See also: M. Rein and D. Schon (1991), Frame-Reflective Policy Discourse, in P. Wagner et al. (eds.), *Social Sciences and Modern States*, Cambridge: Cambridge University Press, p. 262-332.

appropriate. It provides conceptual coherence, a direction for action, a basis for persuasion, and a framework for the collection and analysis of data"[4]. For the purposes of this book, I define a conceptual framework as an argument or discourse that acts as an organizing principle to give meaning to a socioeconomic situation and answers to a series of analytical and policy questions. Ideally, a conceptual framework:

1. Identifies a problem, its origins and the issues involved;
2. Suggests an explanation of the current situation;
3. Offers evidence, often in terms of statistics and indicators;
4. Recommends policies and courses of action.

Policy frameworks are often constructed as narratives or stories that give meaning to situations[5]. This is not peculiar to policy. Narratives are present everywhere. They are an integral part of the discipline of history, where there is a long-running debate on the role of narratives in the discipline[6]. Narratives are also present in ordinary life, as Goffman has studied, as well as in science: think of theories on the origins of the universe[7], or the origins of life and humans[8]. Economic

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4 M. Rein and D. Schon (1993), Reframing Policy Discourse, *op. cit*., p. 153. Fischer identifies the three steps as follows: defining the problem situation, identifying policy intervention, anticipating outcomes. See F. Fischer (2003), Reframing Public Policy, *op. cit*., p. 168.

5 T. J. Kaplan (1986), The Narrative Structure of Policy Analysis, *Journal of Policy Analysis and Management*, 5 (4), p. 761-778.

6 H. White (1973), Metahistory: the Historical Imagination in Nineteenth-Century Europe, Baltimore: Johns Hopkins University Press; P. Ricoeur (1983), Temps et récit I: L'intrigue et le récit historique, Paris, Seuil.

7 S. Hawking (1988), A Brief History of Time: From the Big Bang to Black Holes, Toronto: Bantam Dell Pub Group; H. Kragh (1996), Cosmology and Controversy: the Historical Development of Two Theories of the Universe, Princeton: Princeton University Press.

8 P.J. Bowler (1984), *Evolution: the History of an Idea*, Berkeley: University of California Press; P. J. Bowler (1989), *The Invention of Progress: the Victorians and the Past*, Oxford: Basil Blackwell.

theory is also full of narratives[9], as is sociology. In the latter case, for example, you can think of the discipline as being composed of narratives on modernity[10]. Finally, narratives are present in matters concerning technology. D. Nye, for example, has documented how people appropriated technology in nineteenth century America for community creation, identity and self-representation[11]. M. Hard and A. Jamison have looked at the intellectuals' appropriation of technology in this century, as discourses on modernity[12].

This book looks at conceptual frameworks in science studies and science policy, and at the narratives involved. It is based on work conducted over the last ten years on science policy and on statistics about science, technology and innovation (see www.csiic.ca). This introductory chapter offers an overview of the book. It offers a brief *tour d'horizon* of the frameworks developed over the twentieth century and discusses the logic, or rhetoric, of narratives. This chapter is a summary and a guide to the main arguments of the book. The rest of the book goes deeper into each of the conceptual frameworks.

The book is organized in two parts. The first looks at the emergence of conceptual frameworks in science policy and documents how they contributed to the gradual emergence of an economic doctrine. The second part studies more recent frameworks and the new rhetoric, if any, involved. The book uses an intergovernmental organization as

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9 D. N. McCloskey (1990), *If You're So Smart: The Narrative of Economic Expertise*, Chicago: University of Chicago Press.

10 P. Wagner (1994), A Sociology of Modernity: Liberty and Discipline, London: Routledge.

11 D. E. Nye (2003), America as Second Creation: Technology and Narratives of New Beginnings, Cambridge (Mass.): MIT Press; D. E. Nye (1997), Narratives and Space: Technology and the Construction of American Culture, New York: Columbia University Press. See also: J. F. Kasson (1977), Civilizing the Machine: Technology and Republican Values in America, 1776-1900, New York: Penguin.

12 M. Hard and A. Jamison (1998), *Intellectual Appropriation of Technology: Discourses on Modernity*, Cambridge (Mass.): MIT Press.

example – the Organization for Economic and Co-Operation Development (OECD) – and emphasizes the role of statistics in science policy. As a matter of fact, for decades the OECD has been an influential think-tank for its member countries in matters of policy, and one of its main tasks is collecting statistics as evidence for the views promoted.

FRAMEWORKS AS NARRATIVES

Science policy is about 60 years old. The first modern arguments for science policy came from V. Bush, followed by the US President's Scientific Research Board[13]. The (OECD) came next: from the 1960s, the organization started publishing policy documents that have had a major influence in member countries[14]. The policies suggested over the years, at both the national and international levels, relied on conceptual frameworks that furnished a rationale for action.

Over the twentieth century, at least eight conceptual frameworks have been developed in the study of science, technology and innovation, and have been used for policy purposes. These frameworks can be organized around three generations (Table 1). The first conceptual framework was that on cultural lags, from American sociologist William F. Ogburn in the 1920-30s[15]. According to Ogburn's story, society is experiencing an exponential growth of inventions but is insufficiently adapted. There are lags between the material culture and the adaptive culture. Therefore, there is need for society to adjust

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13 V. Bush (1945), *Science: The Endless Frontier*, North Stratford: Ayer Co. Publishers, 1995; US President's Scientific Research Board (1947), *Science and Public Policy*, New York: Arno Press, 1980.

14 One early and major document was: OECD (1963), *Science and the Policies of Government*, Paris: OECD.

15 This framework is not discussed in this book. See: B. Godin (2009), *The Invention of Innovation: William F. Ogburn and the Use of Invention*, Project on the Intellectual History of Innovation, Montreal: INRS, Forthcoming.

in order to reduce the lags. Society has to innovate in what he called social inventions, or mechanisms to maximize the benefits of technology. There is also a need for society to forecast and plan for the social effects of technology.

Table 1. Major Conceptual Frameworks Used in Science Policy

First generation

Cultural Lags
Linear model of innovation

Second generation

Accounting
Economic Growth
Industrial competitiveness

Third generation

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

The framework on 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. It was also used during the debate on technological unemployment in the 1930s. 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 idea of technological gaps.

The best-known of the sequential frameworks is what came to be called the "linear model of innovation". The precise source of the linear model remains nebulous, as its origin has only recently been documented (chapter 1). Authors who used, improved or criticized the model in the last fifty years rarely acknowledged or cited any original source. The model was usually taken for granted. According to others, however, it comes directly from V. Bush's *Science: The Endless Frontier* (1945). To still others, the model does not exist, but among its opponents. It is a straw man. In fact, however, the linear model does exist, and comes from economic historian W. Rupert Maclaurin at MIT in the 1940s.

Few people, including bureaucrats, really believed in this framework. 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 necessarily 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 was the framework most others compared to.

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. This latter organization is an influential think-tank for its member countries. It is not an advocacy think-tank looking for media exposure and defending partisan or ideological ideas[16], but rather a research-oriented think tank that feeds concepts to national policy-makers for better understanding of issues in science, technology and innovation policies. Other organizations that have acted as think tanks in the short history of science, technology and innovation policy are the US National Bureau of Economic Research (NBER), the US RAND Corporation and the British Science Policy Research Unit (SPRU). However, the OECD has a

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[16] D. E. Abelson (2002), Do Think Tanks Matter? Assessing the Impact of Public Policy Institutes, Montreal: McGill-Queens.

specific role as the source of ideas for national policy-makers. As with most think tanks, and like management gurus, the organization simplifies policy analysis through the use of metaphors and imagery [17], but as an international organization, it brings immediate (although sometimes relative) legitimacy to discourses and frameworks, partly because the member countries themselves define the agenda of the organization. In this sense, the OECD frameworks are witnesses to national priorities and policies.

From its very beginning, science policy was defined according to the anticipated benefits of science. Because science brings benefits, so the story goes, there is a need to manage science, and management requires data. To contribute to this end, the OECD produced a methodological manual for national statisticians, the Frascati manual (1962), aimed at conducting and standardizing surveys of research and development (chapter 2). 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 was a figure on the "national science budget", or Gross Domestic Expenditures on R&D (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 science, technology and innovation, 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 science, technology and innovation, two have been particularly studied at the OECD: economic growth (through productivity) and competitiveness. These

[17] D. Stone (1996), Second-Hand Dealers in Ideas, in D. Stone (ed.), *Capturing the Political Imagination: Think Tanks and the Policy Process,* London: Frank Cross, p. 136-151.

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. This story is often framed within an input-output semantics: inputs → research activities → outputs (→ outcomes) (chapter 3). The accounting framework discussed above is precisely framed into such a semantics. The origins of the framework on economic growth and productivity can be traced back to the economic literature on technological unemployment in the 1930s, in which "technological change" was equated with changes in factors of production (input) and measured via changes in productivity (output). This equation is now known as the "production function". Used extensively by economists in the mid-1950s and subsequently to study science, technology and innovation and its relationship to the economy, the economists' framework immediately offered official policy-makers a useful conceptual framework. This was due to the fact that the framework was perfectly aligned with the policy discussions at the time on the "efficiency" (productivity) of the science system.

Certainly, the issue of productivity in science has a long history[18]. It emerged among scientists themselves (Table 2). In the nineteenth century, the British statistician Francis Galton, followed in the twentieth century by James McKeen Cattell, the US psychologist and editor of *Science* for fifty years, started respectively computing the number of children scientists had and the number of scientists a nation (or state) produced. The numbers were called measures of productivity, or productiveness. Subsequently, productivity came to mean the scientific production of the scientists, above all the number of scientific papers they published. From the 1920-30s onward,

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[18] B. Godin, (2009), The Value of Science: Changing Conceptions of Scientific Productivity, 1869-*circa* 1970, *Social Science Information*, 4, Forthcoming; B. Godin (2007), From Eugenics to Scientometrics: Galton, Cattell and Men of Science, *Social Studies of Science*, 37 (5): 691-728; B. Godin (2006), On the Origins of Bibliometrics, *Scientometrics*, 68 (1): 109-133.

historians and psychologists were early producers of numbers on productivity defined as such. However, it was governments and their statistical bureaus that really developed this meaning after World War II. Finally, productivity in science matters came to examine not only the scientists and the science system, but the effects of science on the economy, above all economic productivity.

Table 2. Evolving Conceptions of Productivity in Science

Productivity as Reproduction

Key authors: F. Galton, J. M. Cattell
Issue: civilization, then advancement of science
Statistics: great men; men of science

Productivity as Output

Key authors: organizations (and their consultants: C. Freeman)
Issue: efficiency
Statistics: money spent on R&D

Productivity as Outcome

Key authors: economists (D. Weintraub, R. Solow)
Issue: economic growth
Statistics: productivity

Economic growth and productivity have been studied at the OECD since the very early years of science policy. They 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 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 (chapter 4).

The other benefit of an economic type that was studied at the OECD was industrial competitiveness[19]. The story behind the framework is that science and technology have 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 (chapter 5). 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 suggestted 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 science, technology and innovation policy (chapter 6).

We now come to a third generation of conceptual frameworks. These arose through a synergy among academics, governments and international organizations. The OECD, with the collaboration of economists as consultants, developed new frameworks for policy-making. The frameworks were generally constructed as alternatives to the linear model. One of the first such frameworks was the National Innovation System (chapter 7). The framework suggests that the research system's ultimate goal is innovation, and that it is part of

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19 B. Godin (2002), Technological Gaps: An Important Episode in the Construction of Science and Technology Statistics, *Technology in Society*, 24, p. 387-413.

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.

Most authors agree that this framework was developed by researchers like C. Freeman, R. Nelson and B.-A. Lundvall. In fact, however, the "system approach" in science policy owes its existence rather to the OECD and its very early works beginning 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 to greater relationships among the component 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. As we mentioned above, the manual computed and aggregated 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).

Then in the 1990s the OECD launched a research program on National Innovation Systems, with B.-A. Lundvall as Deputy Director. Many studies were published in the same spirit as that of the early system approach. Certainly there were more sources of innovation studied, more types of relationships were examined, and a different role was assigned to government. However, 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[20].

The other new framework is that on the knowledge-based economy or society (chapter 8). 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 we 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 concept, and these 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 science, technology and innovation under a new label. A look at the statistics collected in measuring the concept is witness to this fact: existing statistics are simply shifted to new categories.

The last framework in the third generation is that on the information economy or information society (chapter 9). 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.

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[20] B. Godin (2002), *The Rise of Innovation Surveys: Measuring a Fuzzy Concept*, Project on the History and Sociology of Statistics on Science, Technology and Innovation, Montreal: INRS.

This preoccupation with information has a long history. The growth and management of scientific publications was the very first step toward the construction of the concept of the information economy. Through time, the concept evolved from an understanding of information as knowledge, to information as commodity or industrial activity, then information as technology.

Like knowledge, information is a difficult concept. For example, it took three decades to develop a methodological manual, or guide to measuring the information economy, at the OECD. What helped finally was politics. First, internal politics, like the efforts of the Working Party (on measuring the information society) done to raise its own visibility within the OECD. Second, ministers' interests as manifested during summits and conferences. Ultimately it seems that the emergence of a political issue often leads to its measurement. Measurement in turn helps crystallize concepts and issues.

The framework on the information economy relies on other frameworks. In fact, most frameworks build on other frameworks. The OECD policy discourse relies on a cluster of frameworks that feed on each other. One such cluster is composed of third-generation frameworks: information economy and knowledge-based economy, coupled with new economy. Another cluster consists of those of the second generation: accounting, growth and productivity and industrial competitiveness, all three framed into an input-output semantics. Furthermore, this second generation, particularly the stories involved, feeds the third generation, giving the whole discourse a continuity and a coherent rationale. Metaphors often help here. A metaphor has important organizational properties: it is prescriptive and normative in that it generates a vision, and it unifies elements of reality because of its fluidity and flexibility (polysemy). A metaphor is both constructive (of meaning) and productive (of action). Briefly stated, it is both intellectually and socially useful. A metaphor serves a variety of worldviews. This is the role played by the information 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. A network of interrelated concepts and frameworks thus feed each other.

THE LOGIC (RHETORIC?) OF NARRATIVES

I have suggested that conceptual frameworks in science, technology and innovation policies are usually constructed in the form of a story or narrative[21]. A narrative gives meaning to science, technology and innovation, and to policy actions. It helps put science, technology and innovation on the political agenda. A typical narrative goes like this:

1. Premise: science, technology and innovation are good for you and for society.
2. Something new is happening in society (CHANGE) and it is quite different from the past.
3. Let's call this change … (NEW NAME).
4. The new phenomenon or event will generate big effects, rewards/returns.
5. Let's collect STATISTICS as evidence.
6. It is essential that policies be developed.
7. Let's imagine a FRAMEWORK to this end.

Let's look at each step. A major premise or assumption lies behind each framework, namely that science, technology and innovation are good for you and for society. This is a premise no official narrative has ever questioned. For example, no one would imagine, and in fact there was never a framework developed that opposed or suggested getting rid of new technologies and their bad consequences. New science and new technologies are to be placed under control, but

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[21] I use the term narrative here as including any of the following, which a literary critic would probably distinguish: argument, plot, storyline, story, tale.

never eliminated. As US sociologist William F. Ogburn once put it: “the control of invention (…) is generally interpreted as meaning their promotion not their denial”[22].

A narrative on science, technology and innovation starts with suggesting that something new is happening in the economy, that an important change is underway. This change is then contrasted to the past. Certainly, continuity is usually mentioned, with “arguments from qualification”, like “there is a new situation, *but* it is different only from a perspective of scale or form”; “things are changing, *however* it is only a matter of intensity or acceleration”[23]. The narrative generally suggests that it is difficult to draw a boundary between the current era and the past. But this specification, or qualification, is rapidly forgotten. Indeed, the newness is less that of a change in society or economy than a change in the interest of policy-makers and politicians. Be that as it may, dichotomies reign: the future will be different from the past. Change is what counts here: its nature, its size, its rate.

This is exactly what characterizes the framework on the knowledge-based economy. According to the OECD, knowledge and its production, diffusion and use is what defines today’s society. Certainly, knowledge has always been present and important in past economies and societies, but today it is more influential than ever: “although knowledge has always been a central component in economic development, the fact that the economy is strongly dependent on the production, distribution and use of knowledge is now being emphasized”[24]. How can the organization develop such a

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[22] W. F. Ogburn and N. M. Nimkoff (1940), *Sociology*, Boston: Houghton Mifflin, p. 916.

[23] This rhetorical move is similar to the “argument from limitations”, as discussed in B. Godin (2005), *Measurement and Statistics on Science and Technology: 1920 to the Present*, Chapter 9, London: Routledge.

[24] OECD (1996), *Science, Technology and Industry Outlook: Part V, Special Theme: The Knowledge-Based Economy*, DSTI/IND/STP (96) 5, p. 5. For similar narratives from academics, see D. Foray (2004), *The*

vision? With a very broad concept of knowledge, one that embraces things previously separated or put aside in previous analyses – R&D, intangibles, learning – measuring them and adding the numbers together. The effect of the concept is to attract the attention of as many policy-makers (and experts) as possible in the field of science, technology and innovation policies.

Naming and classification are central features of conceptual frameworks. They offer labels that are easily memorized. As catchwords, labels are often "mere labeling without yielding anything but the label", as H. Blumer suggested decades ago[25]. Be that as it may, these labels gain the attention of many people, which helps them to reproduce or diffuse. Such is the role of names or terms given to frameworks, like knowledge-based economy or information society. Such is also the role of concepts like networks, clusters, social capital, as well as technological systems and its affiliates[26], and many others like the Triple-Helix and the New Production of Knowledge (Mode1/Mode2)[27].

Economics of Knowledge, Cambridge (Mass.); MIT Press; N. Stehr (2005), *Knowledge Politics*, Boulder (London): Paradigm Publishers.

24 H. Blumer (1930), Science Without Concepts, reprinted in H. Blumer (1969), *Symbolic Interactionism: Perspective and Method*, Berkeley: University of California Press, p. 153-170. On the fuzziness of concepts, see also: W. B. Gallie (1956), Essentially Contested Concepts, *Proceedings of the Aristotelian Society*, p. 167-198

25 H. Blumer (1930), Science Without Concepts, reprinted in H. Blumer (1969), *Symbolic Interactionism: Perspective and Method*, Berkeley: University of California Press, p. 153-170. On the fuzziness of concepts, see also: W. B. Gallie (1956), Essentially Contested Concepts, *Proceedings of the Aristotelian Society*, p. 167-198.

26 Technological regime, technological guideposts, technological or techno-economic paradigms, techno-economic networks.

27 For more labels, see J. R. Beniger (1986), *The Control Revolution: Technological and Economic Origins of the Information Society*, Cambridge (Mass.): Harvard University Press. For critical analyses of academic frameworks, see: B. Godin (1998), Writing Performative History: The New "New Atlantis", *Social Studies of Science*, 28 (3), p. 465-483; T. Shinn (2002), The Triple Helix and New Production of Knowledge: Prepackaged Thinking in Science and Technology, *Social*

The conceptual framework on the National Innovation System is a recent example of labelling. As we mentioned above, a system approach has always characterized the OECD work on science, technology and innovation since the 1960s. Then, in the early 1990s, a label came to be applied to such an approach – National Innovation System – and a research program developed. Certainly, as we have suggested, differences exist between the early system approach and the latter. Nevertheless, the National Innovation System brought an explicit framework to the field of science, technology and innovation policy, putting the firm at the center of the system, whereas the early system approach was instead concerned with the central role of governments and policies in the system. Only historical myopia leads some to think that the framework is new.

A similar rhetorical move (renaming something old for political purposes) also occurred with the concept of "high technology"[28]. In the mid-1980s, the term high technology began to be used concurrently with, or in place of, the terms research intensity and technology intensity. Nothing had really changed with regard to the definition of the concept (by way of statistics), or at least not yet. But a valued and prestigious label (high) was now assigned to it. Technology trade had now gained strategic importance in the

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Studies of Science, 32 (4), p. 599-614; R. Miettinen (2002), *National Innovation System: Scientific Concept or Political Rhetoric?*, Helsinki: Edita. Some labels, like postmodern science, strategic science, or co-produced science, had much less fortune than the more popular ones discussed. See respectively: S. Funtowicz and J. Ravetz (1999), Post-Normal Science – an Insight Now Maturing, Futures, 31(7), p. 641-646; A. Rip (2002), Regional Innovation System and the Advent of Strategic Science, Journal of Technology Transfer, 27 (1), p. 123-131; M. Callon (1999), The Role of Lay People in the Production and Dissemination of Scientific Knowledge, 4 (1), p. 81-94. These three examples are cited in C. Freeman and L. Soete (2007), *Developing Science, Technology and Innovation Indicators: What We Can Learn from the Past*, UNU-MERIT, Working Paper Series, Maastricht, p. 11 (footnote 6).

28 B. Godin (2008), The Moral Economy of High Technology Indicators, in H. Hirsch-Kreinsen and D. Jacobson (eds.), *Innovation in Low Tech Firms and Industries*, Edward Elgar.

economic and political context of the time: research or technology-intensive industries were expanding more rapidly than other industries in international trade, so went the story and its numbers, and these industries were believed be an important policy option for economic progress. High technology would thereafter be the label for these industries, and would become a well-known and much-used label in the field of science, technology, and innovation policy.

As narrative, a conceptual framework generally suggests that the new phenomenon or event will generate big rewards/returns, as well as leadership potential for those at the forefront. It also suggests that if no action is taken, bad consequences could follow. Crisis stands on the horizon! Usually, the narrative is either in the form of hype, hyperbole or utopia, suggesting that enormous outcomes are looming, or in the form of dramatization, with metaphors on disease, defeat and decline, such as that there is too little investment in science, technology and innovation, which imperils economic performance.

One then arrives at the next element of a narrative: statistics. Briefly stated, a narrative suggests that it is necessary to know more about the change – in order to get more from it. More research is needed, particularly statistical work. In the case of frameworks, statistics helped to strengthen the narrative. How does narrative work here? Over the years, the OECD has developed a "formula" in three steps, and the framework on economic growth and productivity is the best evidence to document the strategy. First, the organization looks at academic work and synthesizes the results. These results generally concern specific national economies, and have to be placed in a comparative perspective with other countries. Second, the OECD internationalizes the numbers, more often than not based on the American experience (in fact, the frameworks used at the OECD are regularly those suggested by the United States delegation. This is where the value-added of the OECD lies: internationalizing statistics. The organization is rarely an innovator in the matter of theories and concepts. Generally, the organization has needed exemplars or models that it then standardizes and conventionalizes, generalizes and diffuses. This is the case for its methodological manuals, produced as standards to be used by member countries for the collection of national data. However, collecting national statistics and placing them in an international frame is the task of the OECD.

As a third step, the organization identifies best practices/performers using indicators, rankings and benchmarking[29]. Coming first, or pride of first place, is what drives the exercises in measurement and its statistical comparisons. The results are published in what the OECD calls scoreboards, among others.

Other tools or devices used as evidence in narratives are visual aids like boxes, tables, figures and graphs. Visual devices are essential, since numbers often do not or cannot demonstrate the results conclusively, like the OECD's early work on technological gaps, and the more recent work on the new economy, on globalization and on the knowledge-based economy. In this latter case, for example, the OECD could measure only part of the phenomenon – the production of knowledge, not its diffusion and use (except for information and communication technologies) – because of a lack of data. Equally, the OECD had difficulties "proving" the emergence of a new economy in other countries: "Ten years or so from now, it should be easier to assess, for instance, the impacts on growth deriving from information and communication technologies, other new technologies and changes in firm organization"[30]. But at the time, such an assessment was impossible. Nevertheless, the organization concluded that more science, technology and innovation policies should be developed to bring economies closer to a new economy.

Pictorial devices generally help persuade the reader of the seriousness and empiricism of the organization, despite the limitations of the data. The physical space these devices occupy is sometimes even greater than that given to the text itself, as was the case for the project

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

[30] OECD (2001), Drivers of Growth: Information Technology, Innovation and Entrepreneurship, Paris: OECD, p. 119.

on economic growth and productivity (new economy). It is worth recalling here that as early as 1919 the US economist W. C. Mitchell suggested presenting narratives to policy-makers with statistics precisely as such[31]:

> Secure a quantitative statement of the critical elements in an official's problem, draw it up in concise form, illuminate the tables with a chart or two, bind the memorandum in an attractive cover tied with a neat bow-knot (…). The data must be simple enough to be sent by telegraph and compiled overnight.

Apart from visual devices, an important strategy is black-boxing the limitations of statistics[32]. This is done by using footnotes, appendices or separate manuals (like the so-called metadata), where the limitations are discussed, but without effect on the core of the text and its conclusions. The "argument from limitations" (the form of which is like "the data are incomplete, *but* this does not affect the results") is also a recurrent tool of the strategy.

Let's conclude this section by mentioning that one of the major factors responsible for the success (use) of official statistics is their regularity. Individual researchers rarely have the resources to produce surveys year after year that would enable the measurement of trends. They certainly contribute in the very early development stages: they originate new statistics and methodologies. But they do not have the resources to conduct the surveys themselves, and many shift rapidly to another object of study, or become simple users of statistics produced by officials. Only governments and their statistical bureaus have sufficient resources to conduct annual surveys and produce

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[31] W. C. Mitchell (1919), Statistics and Government, *Journal of the American Statistical Association*, 125, March, p. 223-235.

[32] B. Godin (2005), Measurement and Statistics on Science and Technology, Chapter 9, *op. cit*.

regular statistics. This gives them a relative monopoly and allows them to impose their vision (statistical) of science.

THE POLICY (POLITICAL?) PROCESS

A narrative generally ends with policy recommendations. In order to benefit from a new context, a series of policy objectives is defined, obstacles and conditions are identified, and targets suggested. The policy recommendations conclude the narrative. They, more often than not, are lists of fads, recurring from year to year, like increasing the industrial share of R&D in the national budget, improving the relevance of public research, need for structural adjustment (through adoption of new technologies). To these, the organization adds a little something new in every periodic publication or review, generally specific to a new technology or to a public issue. Over history, the most popular and regular policy formulas were magic ratios like the GERD/GDP ratio of 3% suggested as early as the 1960s, and a basic/applied research ratio of 10-20% basic research, first suggested by the French statistician Condorcet[33].

In general, the development of frameworks at the OECD proceeds as follows. Work proposals come either from the Secretariat (in collaboration with committees composed of national delegates) or from the ministers (often under the influence of a specific country). Studies are then conducted by the Secretariat, with a view to presentation to a ministerial conference. The conference, in turn, generally under the advice of the OECD officials themselves, asks for more work. This is how projects extend and build on previous ones. To contribute to its work as a think tank, the OECD develops the following activities:

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33 On basic research, see: B. Godin (2003), Measuring Science: Is There Basic Research Without Statistics?, *Social Science Information*, 42 (1): 57-90.

- Organizing conferences and workshops to discuss policy issues.
- Setting up specific committees and working groups composed of national delegates.
- Sharing workload with member countries.
- Inviting or hiring national bureaucrats and researchers to join the organization.

The work is motivated by several factors, two of which deserve mention. Linked as it is to the political process, the OECD has to feed ministers regularly for their meetings. An easy way to do this is to turn readily-available academic fads into keywords (or buzzwords), then into "synthetic, attractive and readily understandable" narratives[34] in order to catch the attention of policy-makers. Buzzwords and slogans help sell ideas: they are short, simple, and easy to remember.

A second factor explaining the OECD strategy is the publication process, or the rush to publish. As think tank, the OECD publishes biannual, yearly and biennial reports, among them those for ministers' conferences, where time frames are very tight. Publication drives policy: there is a need for a new issue at every conference, and in every new publications of the organization, such as *Science, Technology and Industry Scoreboard* or *Science, Technology and Industry Outlook*, both published every two years. Umbrella concepts like that on the knowledge-based economy are thus very fertile for producing documents. They synthesize what is already available, what comes from day-to-day work conducted in other contexts and, above all, what is fashionable, often at the price of original work.

Academics are regularly enrolled in these activities. They are consulted or invited to participate in various OECD forums to "enlighten" bureaucrats and share ideas, as researchers from SPRU

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[34] OECD (1998), Possible Meeting of the CSTP at Ministerial Level: Statistical Compendium, DSTI/EAS/STP/NESTI (98) 8, p. 3.

did in the 1970s-80s. They are also employed as deputy directors by the organization, like D. Foray to work on the knowledge-based economy, or B. A. Lundvall on the national innovation system. In the end, academics are “accomplices”. Many of them use the same labels and narratives in their papers, and few of them develop fundamental criticisms of the frameworks.

PART I

CHAPTER ONE

THE LINEAR MODEL OF INNOVATION: THE HISTORICAL CONSTRUCTION OF AN ANALYTICAL FRAMEWORK

One of the first conceptual frameworks developed for understanding science, technology, and innovation, and its relation to the economy has been the "linear model of innovation". The model postulates that innovation starts with basic research, then adds applied research and development, and ends with production and diffusion:

Basic research → Applied research → Development → (Production and) Diffusion

The model has been very influential. Academic organizations, as a lobby for research funds[1], and economists, as expert advisors to policy-makers[2], have disseminated the framework, or the understanding based thereon, widely, and have justified government support to science using this framework. As a consequence, science policies carried a linear conception of innovation for many decades[3], as did ademics studying science and technology. Very few people

[1] National Science Foundation (1957), *Basic Research: A National Resource*, Washington: National Science Foundation.

[2] R. R. Nelson (1959), The Simple Economics of Basic Scientific Research, *Journal of Political Economy*, 67: 297-306.

[3] D. C. Mowery (1983), Economic Theory and Government Technology Policy, *Policy Sciences*, 16, p. 27-43.

defend such an understanding of innovation anymore: "Everyone knows that the linear model of innovation is dead", claimed N. Rosenberg[4] and others. But is this really the case?

In order to answer this question, one must first trace the history of the framework to the present. The precise source of the linear model of innovation remains nebulous, having never been documented. Several authors who have used, improved or criticized the model in the last fifty years have rarely acknowledged or cited any original source. The model was usually taken for granted. According to others, however, it comes directly from, or is advocated clearly in V. Bush's *Science: The Endless Frontier* (1945)[5]. One would be hard pressed, however, to find anything but a rudiment of this model in Bush's manifesto. Bush talked about causal links between science (namely basic research) and socio-economic progress, but nowhere did he develop a full-length argument based on a sequential process broken down into its elements, or one that suggests a mechanism whereby science translates into socioeconomic benefits.

In this chapter, I trace the history of the model, suggesting that it developed in three (overlapping) stages. The first, from the beginning of the twentieth century to *circa* 1945, was concerned with the first two terms, basic research and applied research. This period was

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4 N. Rosenberg (1994), *Exploring the Black Box: Technology, Economics, and History*, New York: Cambridge University Press, p. 139.

5 J. Irvine and B. R. Martin (1984), *Foresight in Science: Picking the Winners*, London: Frances Pinter, p. 15; C. Freeman (1996), The Greening of Technology and Models of Innovation, *Technological Forecasting and Social Change*, 53, p. 27-39; D. A. Hounshell (1996), The Evolution of Research in the United States, in R. S. Rosenbloom and W. J. Spencer (eds.), *Engines of Innovation: US Industrial Research at the End of an Era*, Boston: Harvard Business School, p. 43; D. C. Mowery (1997), The Bush Report after Fifty Years – Blueprint or Relic?, in C. E. Barfield (ed.), *Science for the 21st Century: The Bush Report Revisited*, Washington: AEI Press, p. 34; D. E. Stokes (1997), *Pasteur's Quadrant: Basic Science and Technological Innovation*, Washington: Brookings Institution, p. 10; P. Mirowski and E.-M. Sent (2002), *Science Bought and Sold: Essays in the Economics of Science*, Chicago: University of Chicago Press, p. 21-22.

characterized by the ideal of pure science, and people began developing a case for a causal link between basic research and applied research. This is the rhetoric in which Bush participated. Bush borrowed his arguments directly from his predecessors, among them industrialists and the US National Research Council. The second stage, lasting from 1934 to *circa* 1960, added a third term to the discussion, namely development, and created the standard three-stage model of innovation: Basic research → Applied research → Development. Analytical as well as statistical reasons were responsible for this addition. Analysis of this stage constitutes the core of this chapter. The last stage, starting in the 1950s, extended the model to non-R&D (not research and development-related) activities like production and diffusion. Business schools as well as economists were responsible for this extension of the model.

The main thesis of this chapter is that the linear model owes little to Bush. It is rather a theoretical construction of industrialists, consultants and business schools, seconded by economists. The paper also argues that the long survival of the model, despite regular criticisms, is due to statistics. Having become entrenched with the help of statistical categories for counting resources and allocating money to science, technology, and innovation, and standardized under the auspices of the OECD and its methodological manuals, the linear model functioned as a "social fact". Rival models, because of their lack of statistical foundations, could not easily become substitutes.

This chapter is divided into four parts. The first discusses the core of the linear model and its source, that is, the political rhetoric, or ideal of pure science, that made applied research dependent on basic research. The second part discusses the first real step toward the construction of the model by looking at the category and the activity called "development" and its place in industrial research. The third part documents the crystallization of the standard three-stage model via statistics. It argues that statistics has been one of the main factors explaining why the model gained strength and is still alive, despite criticisms, alternatives and a proclaimed death. The last part documents how economists extended the standard model to include innovation.

The chapter focuses on the United States, although it draws on material from other countries in cases where individuals from those countries contributed to the construction of the model or to the understanding of the issue. Two factors explain this focus. First, American authors were the first to formalize the linear model of innovation and to discuss it explicitly in terms of a sequential model. Second, the United States was the first country where the statistics behind the model began to be systematically collected. Although limited, this focus allows one to balance D. Edgerton's recent thesis that the linear model does not exist: "the linear model is very hard to find anywhere, except in some descriptions of what it is supposed to have been", claims Edgerton (p. 32)[6]. To Edgerton, the model does not exist in Bush's writings, and here Edgerton and the present author agree, but neither does it exist elsewhere. As this chapter implies, only if one looks at the term itself can one supports Edgerton's thesis. The model, whatever its name, has been THE mechanism used for explaining innovation in the literature on technological change and innovation since the late 1940s.

A POLITICAL RHETORIC

From the ancient Greeks to the present, intellectual and practical work have always been seen as opposites. The ancients developed a hierarchy of the world in which *theoria* was valued over practice.

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[6] D. Edgerton (2004), The Linear Model did not Exist, in K. Grandin, N. Worms, and S. Widmalm (eds.), *The Science-Industry Nexus: History, Policy, Implications*, Sagamore Beach: Science History Publications, p. 31-57.

This hierarchy rested on a network of dichotomies that were deeply rooted in social practice and intellectual thought[7].

A similar hierarchy existed in the discourse of scientists: the superiority of pure over applied research. The concept of pure research originated in 1648, according to I. B. Cohen[8]. It was a term used by philosophers to distinguish between science or "natural philosophy", which was motivated by the study of abstract concepts, and the mixed "disciplines" or subjects, like mixed mathematics, that were concerned with concrete concepts[9]. The term came into regular use at the end of the nineteenth century, and was usually accompanied by the contrasting concept of applied research.

The ideology of pure science has been widely documented in the literature, and will not be discussed here[10]. Suffice it to say that pure science was opposed to applied science on the basis of motive (knowledge for its own sake). The dichotomy was a rhetorical resource used by scientists, engineers and industrialists for defining, demarking and controlling their profession (excluding amateurs), for financial support (to scientists), for raising the status of a discipline (as engineers did), and for attracting scientists (as industrialists did). It was also a rhetoric, particularly present in Great Britain, that referred to the ideal of the freedom of science from interference from

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7 H. Arendt (1958), *The Human Condition*, Chicago: Chicago University Press; G. E. R. Lloyd (1966), *Polarity and Analogy: Two Types of Argumentation in Early Greek Thought*, Cambridge: Cambridge University Press; N. Lobkowicz (1967), *Theory and Practice: History of a Concept From Aristotle to Marx,* London: University of Notre Dame.

8 I. B. Cohen (1948), *Science Servant of Men*, Boston: Little, Brown and Co., p. 56.

9 R. Kline (1995), Construing Technology as Applied Science: Public Rhetoric of Scientists and Engineers in the United States, 1880-1945, *Isis*, 86: 194-221.

10 G. H. Daniels (1967), The Pure-Science Ideal and Democratic Culture, *Science*, 156, p. 1699-1705; E. T. Layton (1976), American Ideologies of Science and Engineering, *Technology and Culture*, 17 (4), p. 688-700; D. A. Hounshell (1980), Edison and the Pure Science Ideal in 19^{th} Century America, *Science*, 207: 612-617.

the State, with an eye to the counter-reference and negative experiences in Nazi Germany and to some extent in the Soviet Union[11].

Although generally presented as opposing terms, however, basic and applied research were at the same time being discussed as cooperating: basic research was the seed from which applied research grew: "to have the applications of a science, H. A. Rowland argued, the science itself must exist"[12]. Certainly, the relationship was one-way (from basic to applied research), but it gave rise to a whole rhetoric in the early twentieth century, one supported by the industrialists, among others.

Industrial research underwent expansion after World War I. Several big firms became convinced of the necessity of investing in research,

and began building laboratories for the purpose of conducting research[13]. Governments accompanied them in these efforts. In Great

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11 Congress for Cultural Freedom (1955), *Science and Freedom*, London: Martin Secker & Warburg.

12 H. A. Rowland (1902), A Plea for Pure Science, in *The Physical Papers of Henry Augustus Rowland*, Baltimore: Johns Hopkins University Press, p. 593-613, p. 594; N. Reingold and A. P. Molella (1991), Theorists and Ingenious Mechanics: Joseph Henry Defines Science, in N. Reingold (ed.), *Science: American Style*, New Brunswick: Rutgers University Press, p. 127-155.

13 On the emergence of industrial research, see: National Research Council (1941), *Research: A National Resource (II): Industrial Research*, National Resources Planning Board, Washington: USGPO; G. Wise (1985), *W. R. Whitney, General Electric, and the Origins of US Industrial Research*, New York: Columbia University Press; L. S. Reich (1985), *The Making of American Industrial Research: Science and Business at GE and Bell, 1876-1926*, New York: Cambridge University Press; D. A. Houndshell and J. K. Smith (1988), *Science and Corporate Strategy: Du Pont R&D, 1902-1980*, New York: Cambridge University Press; A. Heerding (1986), *The History of N. V. Philips' Gloeilampenfabriken*, New York: Cambridge University Press; J. Schopman (1989), Industrious Science: Semiconductor Research at the N. V. Philips' Gloeilampenfabriken, 1930-1957, *Historical Studies in Physical and Biological Sciences*, 19 (1), p. 137-172; M. B. W. Graham and B. H. Pruitt (1991), *R&D for Industry: A Century of Technical Innovation at*

Britain, for example, the Department of Scientific and Industrial Research aided and funded industries in their efforts to create industrial research organizations[14]. In the United States, it was the newly created National Research Council of the National Academy of Science that gave itself the task of promoting industrial research. The close links between the National Research Council and industry go back to the preparations for war (1916). Industrialists were called upon for the World War I research efforts coordinated by the National Research Council. After the war, the National Research

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Alcoa, New York: Cambridge University Press; J. K. Smith (1990), The Scientific Tradition in American Industrial Research, *Technology and Culture*, 31 (1), p. 121-131; M. A. Dennis (1987), Accounting for Research: New Histories of Corporate Laboratories and the Social History of American Science, *Social Studies of Science*, 17, p. 479-518; D. Mowery (1984), Firm Structure, Government Policy, and the Organization of Industrial Research: Great Britain and the United States, 1900-1950, *Business History Review*, p. 504-531; G. Meyer-Thurow (1982), The Industrialization of Invention: A Case Study from the German Chemical Industry, *ISIS*, 73, p. 363-381; T. Shinn (1980), The Genesis of French Industrial Research, 1880-1940, *Social Science Information*, 19 (3), p. 607-640. For statistical analyses, see: D. C. Mowery and N. Rosenberg (1989), The US Research System Before 1945, in D. C. Mowery and N. Rosenberg, *Technology and the Pursuit of Economic Growth*, New York: Cambridge University Press; D. C. Mowery (1983), Industrial Research and Firm Size: Survival, and Growth in American Manufacturing, 1921-1946: An Assessment, *Journal of Economic History*, 63 (4), p. 953-980; D. E. H. Edgerton and S. M. Horrocks (1994), British Industrial Research and Development Before 1945, *Economic History Review*, 67 (2), p. 213-238; S. M. Horrocks (1999), The Nature and Extent of British Industrial Research and Development, 1945-1970, *ReFresh*, 29, Autumn, p. 5-9; D. C. Mowery (1986), Industrial Research, 1900-1950, in B. Elbaum and W. Lazonick (eds.), *The Decline of the British Economy*, Oxford: Clarendon Press; D. E. H. Edgerton (1993), British Research and Development After 1945: A Re-Interpretation, *Science and Technology Policy*, April, p. 10-16; D. E. H. Edgerton (1987), Science and Technology in British Business History, *Business History*, 29 (4), p. 84-103; M. Sanderson (1972), Research and the Firm in British Industry, 1919-1939, *Science Studies*, 2, p. 107-151.

14 Committee on Industry and Trade (1927), *Factors in Industrial and Commercial Efficiency*, Part I, chapter 4, London: Majesty's Stationery Office; D. E. H. Edgerton and S. M. Horrocks (1994), British Industrial R&D Before 1945, *op. cit.*, p. 215-216.

Council, "impressed by the great importance of promoting the application of science to industry (…), took up the question of the organization of industrial research, (…) and inaugurated an Industrial Research Division to consider the best methods of achieving such organization (…)"[15]. "In the 1920s, the division had been a hotbed of activity, preaching to corporations the benefits of funding their own research"[16]. The division conducted special studies on industrial research, arranged visits to industrial research laboratories for executives, organized conferences on industrial research, helped set up the Industrial Research Institute – an organization that still exists today[17] – and compiled a biennial repertory of laboratories from 1920 to the mid 1950s[18].

In Europe as well as in North America, industrialists reproduced the nineteenth-century discourses of scientists on the utility of science: pure research was "of incalculable value to all the industries"[19]. The *Reprint and Circular Series* of the National Research Council in the late 1910s and 1920s was witness to this rhetoric by industrialists. J. J. Carty, vice-president, ATT, was a typical purveyor of the rhetoric. In 1924, speaking before the US Chamber of Commerce, he proclaimed, "The future of American business and commerce and

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15 A. L. Barrows, The Relationship of the NRC to Industrial Research, in National Research Council (1941), Research: A National Resource II: Industrial Research, *op. cit*. p. 367.

16 G. P. Zachary (1997), *Endless Frontier: Vannevar Bush, Engineer of the American Century*, Cambridge (Mass.): MIT Press, 1999, p. 81.

17 The Institute was launched in 1938 as the National Industrial Research Laboratories Institute, renamed the next year as the Industrial Research Institute. It became an independent organization in 1945.

18 See A. L. Barrows (1941), The Relationship of the NRC to Industrial Research, *op. cit*; R. C. Cochrane (1978), *The National Academy of Sciences: The First Hundred Years 1863-1963*, Washington: National Academy of Sciences, p. 227-228, 288-291, 288-316; National Research Council (1933), *A History of the National Research Council, 1919-1933*, Reprint and Circular Series of the National Research Council, No. 106, Washington, p. 44-48.

19 J. J. Carty (1916), The Relation of Pure Science to Industrial Research, *Reprint and Circular Series*, No. 14, National Research Council, p. 8.

industry is dependent upon the progress of science"[20]. To Carty, science was composed of two kinds: pure and applied. To him, the pure scientists were "the advance guard of civilization. By their discoveries, they furnish to the engineer and the industrial chemist and other workers in applied science the raw material to be elaborated into manifold agencies for the amelioration of mankind, for the advancement of our business, the improvement of our industries, and the extension of our commerce"[21].

Carty explicitly refused to debate the contested terms "pure" and "applied" research: "the two researches are conducted in exactly the same manner"[22]. To Carty, the distinction was one of motive. He wanted to direct "attention to certain important relations between purely scientific research and industrial research which are not yet sufficiently understood"[23]. In an article published in *Science*[24], Carty developed the first full-length rationale for public support to pure research. To the industrialist, "pure" science was "the seed of future great inventions which will increase the comfort and convenience and alleviate the sufferings of mankind"[25]. But because the "practical benefits, though certain, are usually indirect, intangible or remote", Carty thought that the "natural home of pure science and of pure scientific research is to be found in the university"[26], where each master scientist "should be provided with all of the resources and facilities and assistants that he can effectively employ, so that the range of his genius will in no way be restricted for the want of anything which money can provide. Every reasonable and even

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20 J. J. Carty (1924), Science and Business, *Reprint and Circular Series*, No. 24, National Research Council, p. 1.

21 *Ibid.*, p. 1-2.

22 *Ibid.*, p. 7.

23 *Ibid.*, p. 1.

24 J. J. Carty (1916), The Relation of Pure Science to Industrial Research, *op. cit*.

25 *Ibid.*, p. 8.

26 *Ibid.*, p. 8 and 9.

generous provision should be made for all workers in pure science"[27]. But "where are the universities to obtain the money necessary for the carrying out of a grand scheme of scientific research? It should come from those generous and public-spirited men" [philanthropists and, much later, the State] and "from the industries"[28]. This rationale is not very far from that offered by W. von Humboldt, founder of the modern university, in his memorandum of 1809[29].

V. Bush followed this rhetoric with his blueprint for science policy, titled *Science: The Endless Frontier*[30]. He suggested the creation of a National Research Foundation that would publicly support basic research on a regular basis. The rhetoric behind the Bush report was entirely focused on the socioeconomic benefits of science: "Advances in science when put to practical use mean more jobs, higher wages, shorter hours, more abundant crops, more leisure for recreation, for study, for learning how to live the deadening drudgery which has been the burden of the common man for past ages. Advances in science will also bring higher standards of living, will lead to the prevention or cure of diseases, will promote conservation of our limited resources, and will assure means of defense against aggression"[31]. "Without scientific progress no amount of achievement in other directions can insure our health, prosperity, and security as a nation in the modern world"[32].

But what is the mechanism by which science translates into socio-economic progress? Bush distinguished between basic research, or

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27 *Ibid.*, p. 12.

28 *Ibid.*, p. 14-15.

29 W. von Humboldt (1809), On the Spirit and the Organizational Framework of Intellectual Institutions in Berlin, *Minerva*, 8, 1970, p. 242-250.

30 V. Bush (1945), *Science: The Endless Frontier*, North Stratford: Ayer Co., 1995.

31 *Ibid.*, p. 10.

32 *Ibid.*, p. 11.

research "performed without thought of practical ends" and resulting "in general knowledge and an understanding of nature and its laws", and applied research[33]. To Bush, however, the two types of research were or should be understood in relation to each other: "the further progress of industrial development would eventually stagnate if basic research were long neglected"[34]. Basic research is the "means of answering a large number of important practical problems"[35]. But how:[36]

> Basic research (…) creates the fund from which the practical applications of knowledge must be drawn. New products and new processes do not appear full-grown. They are founded on new principles and new conceptions, which in turn are painstakingly develop by research in the purest realms of science. Today, it is truer than ever that basic research is the pacemaker of technological progress.

This was the furthest Bush went in explaining the links between science and society. It is clear that Bush was dealing with the Basic research → Applied Research part of the linear model of innovation. Certainly, in the appendix to the Bush report, the Bowman committee used a taxonomy of research composed of pure research/background research/applied research and development, and argued that "the development of important new industries depends primarily on a continuing vigorous progress of pure science"[37]. But the taxonomy was never used as a sequential model to explain socio-economic progress. It served only to estimate the discrepancy between the funds spent on pure research and those spent on applied research.

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33 *Ibid.*, p. 18.
34 *Ibid.*
35 *Ibid*.
36 *Ibid*., p. 19.
37 *Ibid.*, p. 81.

Bush succeeded in putting the ideal of pure science on officials' lips and influencing the emerging science policy[38]. But he suggested no more than a causal link between basic research and its applications, and the rhetoric had been developed and discussed at length before him. Nowhere did Bush suggest a model, unless one calls a one-way relationship between two variables a model. Rather, we owe the development of such a model to industrialists, consultants and business schools.

An Industrial Perspective

The early public discourses of industrialists on science, among them those of US National Research Council members, were aimed at persuading firms to get involved in research. For this reason, they talked mainly of science or research, without always discussing the particulars of science in industry. But within firms, the reality was different: there was little basic research, some applied research, and a lot of development. It was not long before the organization of research reflected this fact.

Development (or the "D" in R&D) is a term that came from industry[39]. In the early 1920s, many large firms had "departments of applied science, or, as they are sometimes called, departments of development and research"[40]. It was not long before every manager was using the expression "research and development", recognizing the fact that the development of new products and processes was as important as research, if not the primary task of industrial

38 B. Godin (2003), Measuring Science: Is There Basic Research without Statistics?, *Social Science Information*, 42 (1), p. 57-90.

39 B. Godin (2006), Research and Development: How the "D" got into R&D, *Science and Public Policy*, 33 (1), p. 59-76.

40 J. J. Carty (1924), Science and Business, *op. cit*. p. 4.

laboratories. In the 1930s, several annual reports of companies brought both terms together[41].

To industrialists, in fact, development was more often than not an integral part of (applied) research or engineering[42]. "Many laboratories are engaged in both industrial research and industrial development. These two classes of investigation commonly merge so that no sharp boundary can be traced between them. Indeed, the term research is frequently applied to work which is nothing else than development of industrial processes, methods, equipments, production or by-products"[43]. And the organization of research in firms reflected this interpretation. Until World War II, very few firms had separate departments for research on the one hand, and (product) development on the other[44]. Both activities were carried out in the same department, and it was the same kind of people (engineers) that carried out both types of tasks[45]. As noted by J. D. Bernal, the British scientist well known for his early social analysis of science and his advocacy for science planning rather than the freedom of science:

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41 For examples, see M. Holland and W. Spraragen (1933), *Research in Hard Times*, Division of Engineering and Industrial Research, National Research Council, Washington p. 9-11.

42 For an excellent discussion of the "confusion" between research and other activities, see: F. R. Bichowsky (1942), *Industrial Research*, New York: Chemical Publishing, chapters 3 and 7.

43 National Research Council (1920), Research Laboratories in Industrial Establishments of the United States of America, Bulletin of the NRC, vol. 1, part 2, March, p. 1-2.

44 After 1945, several large laboratories began having separate divisions for the two functions. See: F. R. Bichowsky (1942), Industrial Research, op. cit.; W. E. Zieber (1948), Organization Charts in Theory and Practice, in C. C. Furnas (ed.), Research in Industry: Its Organization and Management, Princeton: D. Van Nostrand, p. 71-89; C. E. K. Mees and J. A. Leermakers (1950), The Organization of Industrial Scientific Research, op. cit. p. 175-202.

45 G. Wise (1980), A New Role for Professional Scientists in Industry: Industrial Research at General Electric, 1900-1916, Technology and Culture, 21, p. 408-429; L. S. Reich (1983), Irving Langmuir and the Pursuit of Science and Technology in the Corporate Environment, Technology and Culture, 24, p. 199-221.

there is a “difficulty of distinguishing between scientists and technicians in industrial service. Many mechanical engineers, and still more electrical and chemical engineers, are necessarily in part scientists, but their work on the whole cannot be classified as scientific research as it mostly consists of translating into practical and economic terms already established scientific results”[46].

Development as an activity got more recognition and visibility when industrialists, consultants and academics in business schools started studying industrial research. In the 1940s and 1950s, these individuals began developing “models of innovation”. The models, usually illustrated with diagrams, portrayed research as a linear sequence or process starting with basic research, then moving on to applied research, and then development.

Already in 1920, in a book that would remain a classic for decades, C. E. K. Mees, director of the research laboratory at Eastman Kodak, described the development laboratory as a small-scale manufacturing department devoted to developing “a new process or product to the stage where it is ready for manufacture on a large scale”[47]. The work of this department was portrayed as a sequential process: development work is “founded upon pure research done in the scientific department, which undertakes the necessary practical research on new products or processes as long as they are on the laboratory scale, and then transfers the work to special development departments which form an intermediate stage between the laboratory and the manufacturing department”[48]. To the best of my knowledge,

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[46] J. D. Bernal (1939), The Social Function of Science, Cambridge (Mass.): MIT Press, 1973, p. 55.

[47] C. E. K. Mees (1920), The Organization of Industrial Scientific Research, New York: McGraw Hill, p. 79.

[48] *Ibid.*, p. 79. In the 1950 edition, the process of “technological advance” included the following steps: research, then development, the latter composed of three steps (establishment of small-scale use, pilot plant and models, adoption in manufacturing). C. E. K. Mees and J. A. Leermakers (1950), The Organization of Industrial Scientific Research, New York: McGraw-Hill, p. 4-5.

however, the first and most complete description of such a sequence came from To the best of my knowledge, however, the first discussion of such a model in the literature came in 1928 from Maurice Holland, Director of the Engineering and Industrial Research Division at the National Research Council[49]. To Holland, research is "the prime mover of industry", because it accelerates the development of industries by reducing what he called the “time lag” between discovery and production. As n argument to convince industries to invest in research, Holland portrayed the development of industries as a series of successive stages. He called his sequence the "research cycle". It consists of the following seven steps:

- pure science research
- applied research
- invention
- industrial research [development]
- industrial application
- standardization
- mass production

More than ten years later, R. Stevens, vice-president at Arthur D. Little, in a paper appearing in the US National Research Council report to the Resources Planning Board titled *Research: A National Resource*, made his own attempt “to classify the stages through which research travels on its way towards adoption of results by industry”[50]. By then, such sequences were the common understanding of the relations between research and industry, and

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[49] M. Holland (1928), Research, Science and Invention, in F.W. Wile, *A Century of Industrial Progress*, American Institute of the City of New York, New York: Doubleday, Doran and Co., p. 312-334.

[50] R. Stevens (1941), A Report on Industrial Research as a National Resource: Introduction, in National Research Council: A National Resource (II): Industrial Research, *op. cit*. p. 6-7.

would proliferate among industrialists' writings in the 1940s. For example, F. R. Bichowsky, in a lucid analysis of industrial research, distinguished several industrial activities and organized them into a "flow sheet chart": research, engineering (or development), and factory (or production)[51]. C. C. Furnas, in a classic analysis conducted for the Industrial Research Institute, proposed five activities and presented them as a flow diagram: exploratory research and fundamental research activities at a first level, followed by applied research, then development, then production[52].

These efforts would soon culminate in the well-known three-stage model: Basic research→ Applied research → Development. It is to official (i.e.: government) statistics that we owe this simpler (and now standardized) model.

A STATISTICAL CLASSIFICATION

Over the period 1920-1950, official statisticians developed a definition and a classification of research made up of three components – basic research/applied research/development. The story of these statistical categories is the key to understanding the crystallization of the linear model of innovation and its coming into widespread use: statistics solidified a model in progress into one taken for granted, a "social fact".

Although research had been measured since the early 1920s, the question "what is research?" was often left to the questionnaire respondent to decide. The first edition of the US National Research Council directory of industrial research laboratories, for example, reported using a "liberal interpretation" that let each firm decide which activities counted as research: "all laboratories have been included which have supplied information and which by a liberal

51 F. R. Bichowsky (1942), Industrial Research, *op. cit*. p. 81.

52 C. C. Furnas (1948), Research in Industry: Its Organization and Management, *op. cit*. p. 4.

interpretation do any research work"[53]. Consequently, any studies that used National Research Council numbers, like those by Holland and Spraragen[54] and by the US Work Project Administration[55] were of questionable quality: "the use of this information [National Research Council data] for statistical analysis has therefore presented several difficult problems and has necessarily placed some limitations on the accuracy of the tabulated material".[56] Again in 1941, in its study on industrial research conducted for the US National Resources Planning Board, the National Research Council used a similar practice: the task of defining the scope of activities to be included under research was left to the respondent[57]. In Canada as well, the first study by the Dominion Bureau of Statistics contained no definition of research[58].

The situation improved in the 1950s and 1960s thanks wholly to the US National Science Foundation and the OECD, and to their methodological conventions. In 1951, the National Science Foundation was mandated by law to measure scientific and technological activities in the country[59]. To that end, the organization developed a series of surveys on R&D based on precise definitions and categories. Research then came to be defined as "systematic, intensive study directed toward fuller knowledge of the subject

53 National Research Council (1920), *Research Laboratories in Industrial Establishments of the United States of America*, Bulletin of the National Research Council, vol. 1, part 2, March, p. 45.

54 M. Holland and W. Spraragen (1933), Research in Hard Times, *op. cit*.

55 G. Perazich and P. M. Field (1940), *Industrial Research and Changing Technology*, Work Projects Administration, National Research Project, report no. M-4, Philadelphia: Pennsylvania.

56 *Ibid*., p. 52.

57 National Research Council (1941), Research: A National Resource (II): Industrial Research, *op. cit*. p. 173.

58 Dominion Bureau of Statistics (1941), *Survey of Scientific and Industrial Laboratories in Canada*, Ottawa.

59 B. Godin (2003), The Emergence of S&T Indicators: Why Did Governments Supplement Statistics with Indicators?, *Research Policy*, 32 (4), p. 679-691.

studied and the systematic use of that knowledge for the production of useful materials, systems, methods, or processes"[60]. Industrialized countries followed the National Science Foundation definition when they adopted the OECD Frascati manual in 1963. The manual was designed to help countries in their measurement efforts, offering methodological conventions that theoretically allowed international comparisons. In line with the National Science Foundation's definition, the manual defined research as "creative work undertaken on a systematic basis to increase the stock of scientific and technical knowledge and to use this stock of knowledge to devise new applications"[61].

Before such definitions were arrived at, however, two practices prevailed. First, research was "defined" either by simply excluding routine activities or by supplying a list of activities designed solely to help respondents decide what to include in their responses to the questionnaires. Among these activities were basic and applied research, but also engineering, testing, prototypes, and design, which would later collectively come to be called development. No disaggregated data were available for calculating statistical breakdowns, however. In fact, "in these early efforts, the primary interest was not so much in the magnitude of the dollars going into scientific research and development, either in total or for particular agencies and programs, but in identifying the many places where research and development of some sort or other was going on (…)"[62].

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[60] National Science Foundation (1953), *Federal Funds for Science*, Washington, p. 3.

[61] OECD (1970), *The Measurement of Scientific and Technical Activities: Proposed Standard Practice for Surveys of Research and Experimental Development*, Paris, p. 8. The first edition (1962) contained no definition of research.

[62] W. H. Shapley (1959), Problems of Definition, Concept, and Interpretation of Research and Development Statistics, in National Science Foundation, *The Methodology of Statistics on R&D*, NSF 59-36, Washington.

Although no definition of research *per se* existed, people soon started "defining" research by way of categories. This was the second practice. The most basic taxonomy relied on the age-old dichotomy: pure vs. applied research. Three typical cases prevailed with regard to the measurement of these two categories. The first was an absence of statistics because of the difficulty of producing any numbers that met the terms of the taxonomy. Bernal, for example, was one of the first academics to conduct a national measurement of research in a western country, although he used available statistics and did not conduct his own survey. In *The Social Function of Science* (1939), Bernal did not break the research budget down by type of research or "character of work" — such statistics were not available. "The real difficulty (…) in economic assessment of science is to draw the line between expenditures on pure and on applied science", Bernal said[63]. He could only present total numbers, sometimes broken down by economic sector according to the System of National Accounts, but he could not figure out how much was allocated to basic research and how much to applied research.

The second case with regard to the pure vs. applied taxonomy was the use of proxies. In his well-known report, *Science: The Endless Frontier* (1945), Bush elected to use the term "basic research", and defined it as "research performed without thought of practical ends"[64]. He estimated that the nation invested nearly six times as much in applied research as in basic research[65]. The numbers were derived by equating college and university research with basic research, and equating industrial and government research with applied research. More precise numbers appeared in appendices, such as ratios of pure research in different sectors – 5% in industry, 15% in government, and 70% in colleges and universities[66] – but the sources and methodology behind these figures were absent from the report.

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63 J. D. Bernal (1939), The Social Function of Science, *op. cit.* p. 62.

64 V. Bush (1945), Science: The Endless Frontier, *op. cit*. p. 18.

65 *Ibid*., p. 20.

66 *Ibid*., p. 85.

The third case was skepticism about the utility of the taxonomy, to the point that authors rejected it outright. For example, *Research: A National Resource* (1938), one of the first measurements of science in government in America, explicitly refused to use any categories but research: "There is a disposition in many quarters to draw a distinction between pure, or fundamental, research and practical research (…). It did not seem wise in making this survey to draw this distinction"[67]. The reasons offered were that fundamental and applied research interact, and that both lead to practical and fundamental results. This was just the beginning of a long series of debates on the classification of research according to whether it is categorized as pure or applied[68].

We owe to the British scientist J. S. Huxley, a colleague of Bernal and a member of the "visible college" of socialist scientists, as G. Werskey called them[69], the introduction of new terms and the first formal taxonomy of research (see Table 1). The taxonomy had four categories: background, basic, ad hoc and development[70]. The first two categories defined pure research: background research is research "with no practical objective consciously in view", while basic research is "quite fundamental, but has some distant practical objective (…). Those two categories make up what is usually called pure science"[71]. To Huxley, ad hoc meant applied research, and development meant more or less what we still mean by the term today: "work needed to translate laboratory findings into full-scale commercial practice".

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67 National Resources Committee (1938), *Research: A National Resource*, Washington: USGPO, p. 6.

68 B. Godin (2003), Measuring Science: Is There Basic Research Without Statistics?, *op. cit*.

69 G. Werskey (1978), The Visible College: The Collective Biography of British Scientific Socialists of the 1930s, New York: Holt, Rinehart and Winston.

70 J. S. Huxley (1934), *Scientific Research and Social Needs*, London: Watts and Co.

71 *Ibid*., p. 253.

Despite having these definitions in mind, however, Huxley did not conduct any measurements. Nevertheless, Huxley's taxonomy had several influences. Bush borrowed the term "basic" from Huxley when talking of pure research. The concept of "oriented basic research", later adopted by the OECD, comes from Huxley's definition of basic research[72]. Above all, the taxonomy soon came to be widely used for measurement. We owe to the US President's Scientific Research Board the first such use.

Table 3. Taxonomies of Research

J. Huxley (1934)	background, basic, ad hoc, development
J. D. Bernal (1939)	pure (and fundamental), applied
V. Bush (1945)	basic, applied
Bowman (in Bush, 1945)	pure, background, applied and development
US President's Scientific Research Board (1947)	fundamental, background, applied, development
Canadian Department of Reconstruction and Supply (1947)	pure, background, applied, development, analysis & testing
R. N. Anthony	uncommitted, applied, development
US National Science Foundation (1953)	basic, applied, development
British Department for Scientific and Industrial Research (1958)	basic, applied and development, prototype
OECD (1962)	fundamental, applied, development

The US President's Scientific Research Board conducted the first real survey of resources devoted to "R&D" in 1947, marking the first time

72 OECD (1970), The Measurement of Scientific and Technical Activities: Proposed Standard Practice for Surveys of Research and Experimental Development, *op. cit*. p. 10.

that the term appeared in a statistical report, and using precise categories, although these did not make it "possible to arrive at precisely accurate research expenditures" because of the different definitions and accounting practices employed by institutions[73]. In the questionnaire it sent to government departments (other sectors like industry were estimated using existing sources of data), it included a taxonomy of research that was inspired directly by Huxley's four categories: fundamental, background, applied and development[74]. Using these definitions, the Board estimated that basic research accounted for about 4% of total research expenditure in the United States[75], and showed that university research expenditures were far lower than government or industry expenditures, that is, lower than applied research expenditures, which amounted to 90% of total research[76]. Despite the Board's precise definitions, however, development was not measured separately, but was rather included in applied research.

We owe to the Canadian Department of Reconstruction and Supply the first measurement of development *per se*[77]. In the survey it conducted in 1947 on government research, it distinguished research, defined as being composed of pure, background[78] and applied research (but without separating the three items "because of the close inter-relationships of the various types of research"), from

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[73] President's Scientific Research Board (PSRB) (1947), *Science and Public Policy*, Washington: USGPO, p. 73.

[74] *Ibid.*, p. 299-314.

[75] *Ibid.*, p. 12.

[76] *Ibid.*, p. 21.

[77] Department of Reconstruction and Supply (1947), *Research and Scientific Activity: Canadian Federal Expenditures 1938-1946*, Ottawa; Department of Reconstruction and Supply (1947), *Research and Scientific Activity: Canadian Federal Expenditures, 1946 and 1947*, Ottawa; Department of Reconstruction and Supply (1947), *Research and Scientific Activity: Provincial Government Expenditures: 1946-1947*, Ottawa.

[78] Here, the term background has changed meaning, as in Bush, and means collection and analysis of data.

development and analysis and testing. Development was defined as "all work required, after the initial research on laboratory (or comparable) level has been completed, in order to develop new methods and products to the point of practical application or commercial production".

The inclusion of development was (probably) motivated by the importance of military procurement in the government's budget for science (contracts to industry for developing war technologies). Indeed, most of the data in the report were broken down into military and non-military expenditures. Overall, the Department estimated that 40% of the $34 million spent on federal scientific activities went to research, 48% to development, and 12% into analysis and testing.

Although innovative with regard to the measurement of development in government research[79], Canada would not repeat such measurements for years, and never did measure development in industry before the advent of the OECD statistical recommendations in the Frascati manual (1962). It is rather to accountant R. N. Anthony of Harvard Business School that we owe the first, and an influential, series of systematic measurements of all of the terms in the taxonomy. By that time, however, the taxonomy was reduced to three terms, as it continues to this day: basic research, applied research, and development.

An important measurement issue before the 1950s concerned the demarcation of research and non-research activities. Anthony *et al.* identified two problems: there were too many variations on what constituted research, and too many differences among firms concerning which expenses to include in research[80]. Although routine

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79 The report of the US National Resources Committee on government research published in 1938 made no use of the category development. See National Ressources Committee (1938), Research: A National Resource, *op. cit*.

80 D. C. Dearborn, R. W. Kneznek and R. N. Anthony (1953), *Spending for Industrial Research, 1951-1952*, Division of Research, Graduate School of Business Administration, Harvard University, p. 91.

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

In the early 1950s, the US Department of Defense's Research and Development Board asked Anthony to conduct a survey of industrial research to enable the government to locate available resources in the event of war, that is, to "assist the military departments in locating possible contractors for research and development projects"[81]. Anthony had just conducted a survey of management controls in industrial research laboratories for the Office of Naval Research in collaboration with the corporate associates of the Harvard Business School[82], and was about to begin another survey to estimate the amounts spent on research. The Research and Development Board asked both the Harvard Business School and the Bureau of Labor Statistics to conduct a joint survey of industrial research. The two institutions coordinated their efforts and conducted three surveys. The results were published in 1953[83].

The Bureau of Labor Statistics report does not have detailed statistics on categories of research, but Anthony's report does. The survey included precise definitions that would have a major influence on the National Science Foundation, which was the official producer of

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81 Bureau of Labor Statistics (1953), *Scientific R&D in American Industry: A Study of Manpower and Costs*, Bulletin no. 1148, Washington, p. 1, 51-52.

82 R. N. Anthony and J. S. Day (1952), *Management Controls in Industrial Research Organizations*, Boston: Harvard University.

83 D. C. Dearborn, R. W. Kneznek and R. N. Anthony (1953), Spending for Industrial Research, 1951-1952, *op. cit*; US Department of Labor, Bureau of Labor Statistics, Department of Defense (1953), Scientific R&D in American Industry: A Study of Manpower and Costs, *op. cit*.

statistics on science and technology in the United States, and on the OECD. Anthony's taxonomy contained three items[84]:

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

Along with the definitions, Anthony specified precisely the activities that should be included in development (scale activity, pilot plants and design) and those that should be excluded (market research, legal work, technical services and production). The survey revealed that industry spent 8% of its research budget on basic research (or uncommitted research), 42% on new products (applied research) and 50% on product improvement (development)[85]. This was the first of a regular series of measurements of these three categories in the history of science statistics. It soon became the norm.

In the 1950s, the National Science Foundation started measuring research in the United States as part of its mandate to regularly evaluate national scientific activities. The Foundation extended Anthony's definitions to all sectors of the economy – industry, government, and university – and produced the first national numbers on research so broken down. It took about a decade, however, for standards to appear at the National Science Foundation. Until 1957, for example, development was merged with applied research in the case of government research, with no breakdown. Similarly, until 1959, statistics on development were neither presented nor discussed

[84] D. C. Dearborn, R. W. Kneznek and R. N. Anthony (1953), Spending for Industrial Research, 1951-1952, *op. cit*. p. 92.

[85] *Ibid*., p. 47.

in reports on industrial research. [86] But thereafter, the three components of research were separated, and a national total was calculated for each based on the following definitions:

- Basic or fundamental research: research projects which represent original investigation for the advancement of scientific knowledge and which do not have specific commercial objectives, although they may be in the fields of present or potential interest to the reporting company[87].
- Applied research: research projects which represent investigation directed to discovery of new scientific knowledge and which have specific commercial objectives with respect to either products or processes.
- Development: technical activity concerned with non-routine problems which are encountered in translating research findings or other general scientific knowledge into products or processes.

As Anthony had done, the National Science Foundation suggested three categories – with different labels. The main, and the important, difference has to do with the fact that Anthony's definitions center on output, while the National Science Foundation's emphasized aims or objectives. Nevertheless, the two taxonomies produced approximately the same statistical results. The NSF surveys showed once more the importance of development in the research budget: over 60% in the case of government research[88], and 76.9% for

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[86] The situation was similar in other countries. See, for example: Department of Scientific and Industrial Research (1958), *Estimates of Resources Devoted to Scientific and Engineering R&D in British Manufacturing Industry, 1955*, London.

[87] The last part of the definition was, and still is, used for the industrial survey only.

[88] National Science Foundation (1957), Federal Funds for Science: The Federal Research and Development Budget, Fiscal Years 1956, 1957, and 1958, NSF 57-24, Washington, p. 10.

industrial research[89]. For the nation as a whole, the numbers were 9.1% of the research budget for basic research, 22.6% for applied research and 68.3% for development[90].

Anthony's and the National Science Foundation's categories were developed for statistical purposes. However, the three categories also served to describe components or steps in the process of innovation, a description that culminated in the three-stage linear model: Basic research → Applied research → Development. Anthony talked of "a spectrum, with basic research at one end, with development activities closely related to production or sale of existing products at the other end, and with other types of research and development spread between these two extremes"[91]. The National Science Foundation, for its part, suggested that: "the technological sequence consists of basic research, applied research, and development", where "each of the successive stages depends upon the preceding"[92].

By the early 1960s, most countries had more or less similar definitions of research and its components[93]. Research had now come to be defined as R&D, composed of three types of activities[94]. The OECD gave itself the task of conventionalizing and standardizing the definition. In 1963, OECD member countries adopted a

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[89] National Science Foundation (1959), Science and Engineering in American Industry: Report on a 1956 Survey, NSF 59-50, Washington, p. 49.

[90] National Science Foundation (1962), Trends in Funds and Personnel for Research and Development, 1953-61, Reviews of Data on R&D, 33, April, NSF 62-9, p. 5.

[91] R. N. Anthony and J. S. Day (1952), Management Controls in Industrial Research Organizations, *op. cit*. p. 58-59.

[92] National Science Foundation (1952), *Second Annual Report of the NSF: Fiscal Year 1952*, Washington: USGPO, p. 11-12.

[93] J. C. Gerritsen (1961), *Government Expenditures on R&D in France and the United Kingdom*, EPA/AR/4209, Paris: OEEC; J. C. Gerritsen (1963), *Government Expenditures on R&D in the United States of America and Canada*, DAS/PD/63.23, Paris: OECD.

[94] B. Godin (2005), Research and Development: How the "D" got into R&D, *op. cit*.

methodological manual for conducting R&D surveys and producing statistics for indicators and policy targets, like the GERD/GDP ratio (Gross Expenditures on R&D divided by Gross Domestic Product). The Frascati manual included precise instructions for separating research from related scientific activities and non-research activities, and development from production. The manual, in line with the National Science Foundation's definitions, also recommended collecting and tabulating data according to the three components of research defined as follows[95]:

- Fundamental research: work undertaken primarily for the advancement of scientific knowledge, without a specific practical application in view.
- Applied research: work undertaken primarily for the advancement of scientific knowledge, with a specific practical aim in view.
- Development: the use of the results of fundamental and applied research directed to the introduction of useful materials, devices, products, systems, and processes, or the improvement of existing ones.

ECONOMISTS APPROPRIATE THE MODEL

Economists came into the field quite late. In the early 1960s, when the three components of R&D were already in place in official circles, economists were still debating terms like development and its inclusion in R&D – because it was seen as not inventive in character[96] – and looking for their own definitions and taxonomy of

95 OECD (1962), *The Measurement of Scientific and Technical Activities: Proposed Standard Practice for Surveys of Research and Development*, DAS/PD/62.47, p. 12.

96 S. Kuznets (1962), Inventive Activity: Problems of Definition and Measurement, in National Bureau of Economic Research, The Rate and Direction of Inventive Activity: Economic and Social Factors, *op. cit*, p. 35; J. Schmookler (1962), Comment on S. Kuznets' paper, in National

research[97]. They finally settled on the conventional taxonomy, using the standard three categories to analyze industrial research[98], and using numbers on R&D for measuring the contribution of science to economic progress. In fact, as R. R. Nelson reported in 1962, "the establishment of the NSF has been very important in focusing the attention of economists on R&D (organized inventive activity), and the statistical series the National Science Foundation has collected and published have given social scientists something to work with"[99].

Where some economists innovated was in extending the model to one more dimension: the steps necessary to bring the technology to commercial production, namely innovation (Table 4). Some authors often refer back to J. Schumpeter to model the process of innovation. Certainly, we owe to Schumpeter the distinction between invention, (initial) innovation, and (innovation by) imitation (or diffusion)[100].

Bureau of Economic Research, The Rate and Direction of Inventive Activity: Economic and Social Factors, *op. cit*. p. 45.

97 E. Ames (1961), Research, Invention, Development and Innovation, *American Economic Review*, 51 (3), p. 370-381; S. Kuznets (1962), Inventive Activity: Problems of Definition, in National Bureau of Economic Research, The Rate and Direction of Inventive Activity, *op. cit*. p. 19-43; J. Schmookler (1962), Comment on S. Kuznets' paper, in National Bureau of Economic Research, The Rate and Direction of Inventive Activity: Economic and Social Factors, *op. cit*. p. 43-51; J. Schmookler (1966), *Invention and Economic Growth,* Cambridge: Harvard University Press, p. 5-9.

98 For early uses of these categories and construction of tables of categories by economists, see: C. F. Carter and B. R. Williams (1957), *Industry and Technical Progress: Factors Governing the Speed of Application of Science*, London: Oxford University Press; F. M. Scherer (1959), The Investment Decision Phases in Modern Invention and Innovation, in F. M. Scherer et al. (eds.), *Patents and the Corporation*, Boston: J. J. Galvin; E. Ames (1961), Research, Invention, Development and Innovation, *op. cit*. p. 373; F. Machlup (1962), *The Production and Distribution of Knowledge in the United States,* Princeton: Princeton University Press, p. 178s.

99 R. R. Nelson (1962), Introduction, in National Bureau of Economic Research, The Rate and Direction of Inventive Activity, *op. cit*. p. 4.

100 J. Schumpeter (1912), *The Theory of Economic Development: An Inquiry into Profits, Capital, Credit, Interest, and the Business Cycle,* Cambridge:

While invention is an act of intellectual creativity – and "is without importance to economic analysis"[101] – innovation and diffusion are defined as economic decisions, because of their "closeness to economic use": a firm applying an invention or adopting it for the first time[102].

Table 4. Taxonomies of Innovation

Mees (1920)	Pure science, development, manufacturing
Holland (1928)	Pure science research, applied research, invention, industrial research [development], industrial application, standardization, mass production
Stevens (1941)	Fundamental research, applied research, test-tube or bench research, pilot plant, production (improvement, trouble shooting, technical control of process and quality)
Bichowsky (1942)	Research, engineering (or development), factory (or production)
Furnas (1948)	Exploratory and fundamental research, applied research, development, production
Maclaurin (1949)	Fundamental research, applied research, engineering development, production engineering, service engineering
Mees and Leermakers (1950)	Research, development (establishment of small-scale use, pilot plant and models, adoption in manufacturing)
Brozen (1951a)	Invention, innovation, imitation
Brozen (1951b)	Research, engineering development, production, service
Maclaurin (1953)	Pure science, invention, innovation, finance, acceptance
Ruttan (1959)	Invention, innovation, technological change

Harvard University Press, 1934; J. Schumpeter (1939), *Business Cycles: A Theoretical, Historical, and Statistical Analysis of the Capitalist Process*, New York: McGraw-Hill.

101 J. Schumpeter (1939), Business Cycles, *op. cit*. p. 85.

102 J. Schmookler (1962), Comment on S. Kuznets' paper, *op. cit*. p. 51.

Ames (1961)	Research, invention, development, innovation
Scherer (1965)	Invention, entrepreneurship, investment, development
Schmookler (1966)	Research, development, invention
Mansfield (1968)	Invention, innovation, diffusion
Myers and Marquis (1969)	Problem solving, solution, utilization, diffusion
Utterback (1974)	Generation of an idea, problem-solving or development, implementation and diffusion

Despite having brought forth the concept of innovation in economic theory, however, Schumpeter professed little dependence of innovation on invention, as several authors have commented[103]: "Innovation is possible without anything we should identify as invention and invention does not necessarily induce innovation"[104]. The formalization of Schumpeter's ideas into a sequential model arose due to interpreters of Schumpeter, particularly in the context of the technology-push/demand-pull debate[105].

The first sequential interpretations came from two American economists who used and improved on Schumpeter's categories in the early 1950s. Y. Brozen, from Northwestern University, suggested two models, one that used Schumpeter's three categories[106], and

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103 C. S. Solo (1951), Innovation in the Capitalist Process: A Critique of the Schumpeterian Theory, *Quarterly Journal of Economics*, LXV, August, p. 417-428; V. W. Ruttan (1959), Usher and Schumpeter on Invention, Innovation, and Technological Change, *Quarterly Journal of Economics*, 73, p. 596-606.

104 J. Schumpeter (1939), Business Cycles, *op. cit*. p., 84.

105 For schematic representations of the views in this debate, see: C. Freeman (1982), *The Economics of Industrial Innovation*, Cambridge: MIT Press, 1986, p. 211-214; R. Rothwell and W. Zegveld (1985), *Reindustrialization and Technology*, New York: Sharpe, p. 60-66.

106 Y. Brozen (1951), Invention, Innovation, and Imitation, *American Economic Journal*, May, p. 239-257.

another that explained the factors necessary "to capitalize on the discoveries of science": research, engineering development, production, service[107]. W. P. Maclaurin, an economist from MIT who got interested in technological change early on, was another academic who developed a sequential analysis of innovation. Maclaurin served as secretary of one of the committees that assisted V. Bush in the preparation of *Science: the Endless Frontier*. In 1947, he published a paper in *The Harvard Business Review* in which he defended Bush's proposal for a National Research Foundation[108]. He discussed the importance of fundamental research and its funding with the aid of a model broken down into "four distinct stages": fundamental research, applied research, engineering development, and production engineering. Then in 1953, Maclaurin devoted an entire paper to the process of technological change. Suggesting that "Schumpeter regarded the process of innovation as central to an understanding of economic growth", but that he "did not devote much attention to the role of science", Maclaurin "broke down the process of technological advance into elements that may eventually be more measurable". He identified five steps: pure science, invention, innovation, finance, and acceptance (or diffusion)[109].

We had to wait several years to see these propositions coalesce into a series of linear models of innovation. Certainly, in their pioneering work on innovation in the late 1950s, C. F. Carter and B. R. Williams from Britain would examine investment in technology, as a

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[107] Y. Brozen (1951), Research, Technology and Productivity, in L. R. Tripp (ed.), *Industrial Productivity*, Industrial Relations Research Association, Champaign: Illinois, p. 25-49.

[108] W. R. Maclaurin (1947), Federal Support for Scientific Research, *Harvard Business Review*, Spring, p. 385-396.

[109] W. R. Maclaurin (1953), The Sequence from Invention to Innovation and its Relation to Economic Growth, *Quarterly Journal of Economics*, 67 (1), p. 97-111. A few years before, Maclaurin suggested another model composed of five stages: fundamental research, applied research, engineering development, production engineering, and service engineering. See: W. R. Maclaurin (1949), *Invention and Innovation in the Radio Industry*, New York: Macmillan, p. xvii-xx.

“component in the *circuit* which links the pure scientist in his laboratory to the consumer seeking a better satisfaction of his needs”[110]. But the authors neither discussed nor suggested a formalized model of innovation until 1967[111]. Similarly, the influential conference on the rate and direction of inventive activity, organized in 1960 by the National Bureau of Economic Research and the Social Science Research Council, was concerned with another model than that of innovation *per se*: the production function, or input-output model[112]. If there is one study that deserves mention before the 1960s, it is that of V. W. Ruttan from the university of Minnesota. Ruttan gave himself the task of clarifying the terms used up to the present to discuss innovation, and suggested a synthesis of A. P. Usher’s steps in the invention process[113] and Schumpeter’s concept of innovation. From his analysis, Ruttan suggested the following sequence: Invention → Innovation → Technological Change[114].

Then a series of models of innovation appeared in the 1960s. E. Ames, although critical of the term innovation (“innovation has come to mean all things to all men, and the careful student should perhaps avoid it wherever possible, using instead some other term”), suggested a model composed of four stages that he discussed in terms of a “sequence of markets”: research, invention (applied research), development and innovation[115]. This model came directly from F.

110 C. F. Carter and B. R. Williams (1957), Industry and Technical Progress, *op. cit*.; C. F. Carter and B. R. Williams (1958), *Investment in Innovation*, London: Oxford University Press.

111 B. R. Williams (1967), *Technology, Investment and Growth*, London: Chapman and Hill.

112 See chapter 3 below.

113 A. P. Usher (1954), *A History of Mechanical Inventions*, Cambridge: Harvard University Press.

114 V. W. Ruttan (1959), Usher and Schumpeter on Invention, Innovation, and Technological Change, op. cit.

115 E. Ames (1961), Research, Invention, Development and Innovation, *op. cit*.

Machlup's early measurement of the knowledge society[116]. A few years later, economist J. Schmookler, who was well known for his analyses on the role of demand in invention, looked at what he called technology-producing activities as being composed of three components: research, development, and inventive activity[117]. In light of other economists' definitions, Schmookler was definitively dealing with invention rather than innovation, although he was concerned with the role of market forces (wants) in invention. At about the same time, F. M. Scherer, in a historical analysis of the Watt-Boulton engine, identified four ingredients or steps that define innovation: invention, entrepreneurship, investment and development[118]. E. Mansfield, for his part, distinguished invention from innovation and diffusion, and defined innovation as the (first) application of an invention and diffusion as its (first) use[119].

All of these individuals were developing models that defined innovation as a sequence from research or invention to commercialization and diffusion. Academics from management schools followed, and have been very influential in popularizing such models[120]. S. Myers and D. G. Marquis, in a study conducted for the National Science Foundation, defined the process of innovation as composed of five stages: recognition (of both technical feasibility and demand), idea formulation, problem solving, solution, utilization and

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116 F. Machlup (1962), *The Production and Distribution of Knowledge in the United States*, Princeton: Princeton University Press, p. 178s.

117 J. Schmookler (1966), Invention and Economic Growth, *op. cit.*, p. 7.

118 F. M. Scherer (1965), Invention and Innovation in the Watt-Boulton Steam Engine Venture, *Technology and Culture*, 6, p. 165-187.

119 E. Mansfield (1968), *The Economics of Technological Change*, New York: W. E. Norton, chapters 3 and 4.

120 For reviews, see: R. E. Roberts and C. A. Romine (1974), *Investment in Innovation*, Washington: National Science Foundation, p. 20-29; M. A. Saren (1984), A Classification and Review of Models of the Intra-Firm Innovation Process, *R&D Management*, 14 (1), p. 11-24; J. E. Forrest (1991), Models of the Process of Technological Innovation, *Technology Analysis and Strategic Management*, 3 (4), p. 439-452.

diffusion[121]. J. M. Utterback is another author often cited in the literature for his model of innovation, composed of the following three steps: generation of an idea, problem-solving or development, and implementation and diffusion[122].

It was these efforts from both economists and researchers in management schools that led to the addition of diffusion in the much-quoted linear model of innovation: Basic research → Applied research → Development → (Production and) Diffusion. Yet it is important to mention two areas of research that contributed to the focus on diffusion and its integration into theoretical models of innovation. The first was the sociological literature, particularly on the diffusion of invention. This tradition goes back to W. F. Ogburn and S. C. Gilfillan and their contributions to the US National Resources Committee's report on technology and its social impacts (1937). The "model" they suggested was one of the first descriptions of innovation as a social process, and was motivated by the authors' interest in social consequences of technology and diffusion lags. It included diffusion as a phase in the process, but also included the social impacts of invention, as the ultimate phase[123]. It was E. M.

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121 S. Myers and D. G. Marquis (1969), *Successful Industrial Innovations: A Study of Factors Underlying Innovation in Selected Firms*, NSF 69-17, Washington: National Science Foundation, p. 3-6.

122 J. M. Utterback (1974), Innovation in Industry and the Diffusion of Technology, *Science,* 183, p. 621.

123 Other contributions from Ogburn are: The Subcommittee on Technology of the National Resources Committee, presided by W. F. Ogburn, defined invention as a process composed of four phases "occurring in sequence": beginnings, development, diffusion, social influences. See *Technological Trends and National Policy* (1937), Subcommittee on Technology, National Resources Committee, Washington, p. vii. See also p. 6 and 10. A few years previously, in the President's report on social trends, Ogburn and Gilfillan defined invention as a series of stages as follows: idea, trial device (model or plan), demonstration, regular use, adoption. See W. F. Ogburn and S. C. Gilfillan (1933), The Influence of Invention and Discovery, in *Recent Social Trends in the United States*, Report of the President's Research Committee on Social Trends, New York: McGraw-Hill, Volume 1, p. 132. In the 1950 edition of *Social Change*, first

Rogers' classic book, however, that would be most influential on the literature. In *Diffusion of Innovations* (1962), Rogers depicted innovation as composed of four elements: innovation, communication (or diffusion), consequences on the social system, and consequences over time[124]. By the third edition (1983) of his book, however, Rogers had adopted the economic understanding of innovation. The process of innovation was now portrayed as composed of six main phases or sequential steps: needs/problems, research, development, commercialization, diffusion and adoption, and consequences[125].

The second influence with regard to diffusion was the theory of the product life cycle. Authors portrayed the life cycle of new products or technologies as having an S-shaped curve, and the process of technological development as consisting of three phases: innovation (product), maturation (process), and standardization[126].

By the early 1960s, then, the distinctions between and the sequence of invention[127], innovation and diffusion were already in place – and even qualified as "conventional"[128] or "common"[129]. Invention was defined as the development of a new idea for a product or process and its reduction to practice; innovation was defined as the process of bringing invention into commercial use or an invention brought into

published in 1922, Ogburn developed another classification: invention, accumulation, diffusion, adjustment (p. 377).

124 E. M. Rogers (1962), *Diffusion of Innovations*, New York: Free Press, p. 12-20.

125 E. M. Rogers (1983), *Diffusion of Innovation*, Third Edition, New York: Free Press, p. 136.

126 R. Vernon (1966), International Investment and International Trade in the Product Cycle, *Quarterly Journal of Economics*, 80, p. 190-207; J. M. Utterback and W. J. Abernathy (1975), A Dynamic Model of Process and Product Innovation, *Omega*, 3 (6), p. 639-656.

127 Invention as a short-cut for Basic research → Applied research → Development.

128 A. D. Little (1963), *Patterns and Problems of Technical Innovation in American Industry*, Washington: National Science Foundation, p. 6.

129 US Department of Commerce (1967), *Technological Innovation: Its Environment and Management*, Washington: USGPO, p. 9.

commercial use; and diffusion was defined as the spread of innovation in industry. The sequence became a taken-for-granted "fact" in the OECD literature[130], and a classic proposition or "lesson" for research managers[131].

CONCLUSION

The linear model of innovation as a conceptual framework was not a spontaneous invention arising from the mind of one individual (V. Bush). Rather, it developed over time in three steps. The first linked applied research to basic research, the second added experimental development, and the third added production and diffusion. These three steps correspond in fact to three scientific communities and their successive entries into the field of science studies and/or science policy, each with their own concepts. First were natural scientists (academic as well as industrial), developing a rhetoric on basic research as the source for applied research or technology; second were researchers from business schools, having been interested in science studies long before economists and studying the industrial management of research and the development of technologies; third were economists, bringing forth the concept of innovation into the discipline. All three communities got into the field by adding a term (their stamp) to the most primitive term – pure or basic research –and its sequence. The three steps also correspond to three phases of policy preoccupations or priorities: the public support to university research (basic research), the strategic importance of technology for industry (development), and the impact of research on the economy and society (diffusion).

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130 OECD (1966), *Government and Technical Innovation*, Paris: OECD, p. 9.

131 J. R. Bright (1969), Some Management Lessons from Innovation Research, *Long Range Planning*, 2 (1), p. 36-41. For an example of the use of the model in project evaluation, see: A. Albala (1975), Stage Approach for the Evaluation and Selection of R&D Projects, *IEEE Transactions on Engineering Management*, EM-22 (4), p. 153-164.

Despite its widespread use, the linear model of innovation was not without its opponents. In 1967, the Charpie report, an influential study by the US Department of Commerce on measuring the costs of innovation, estimated that research amounts to only 10% of the costs of innovation[132]. Briefly stated, innovation does not depend on either research or basic research specifically. Other "steps" are more important[133]. The US Department of Defense also challenged the linear sequence. As we have seen with Anthony's study conducted for the Department's Research and Development Board, the Department of Defense was a pioneer in the use of the R&D categories, even developing its own classification of R&D activities and using the linear model to manage its programs[134]. In the mid-1960s, however, the Department began to defect from its previous optimism regarding investments in basic research as a factor in innovation. The Department was, in a sense, beginning to question aspects of the linear model. It therefore conducted an eight-year analysis of twenty major weapons technologies, concluding that only 0.3% of innovation "events" came from "undirected science"[135]. The National Science Foundation replied with its own study, and came to opposite conclusions. The organization found that 70% of the key events in the development of five recent technological innovations stemmed from basic research[136]. These two studies, each carrying the

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132 US Department of Commerce, Technological Innovation: Its Environment and Management, Washington: USGPO.

133 The numbers were based on a "rule of thumb", and were widely criticized. See: E. Mansfield et al. (1971), Research and Innovation in the Modern Corporation, New York: Norton; H. Stead (1976), The Costs of Technological Innovation, Research Policy, 5: 2-9.

134 See: A. C. Lazure (1957), Why Research and Development Contracts are Distinctive, in A. C. Lazure and A. P. Murphy (eds.), Research and Development Procurement Law, Washington: Federal Bar Journal, p. 255-264.

135 US Department of Defense (1969), *Project Hindsight Final Report*, Office of the Director of Defense Research and Engineering, Washington.

136 IIT Research Institute (1968), *Technology in Retrospect and Critical Events in Science (TRACES)*, Washington: NSF; Battelle Columbus Labs.

message of its respective community (industrialists in the case of Defense, scientists for the NSF) were among the first of a long series of debates on aspects of the linear model of innovation.

In the 1960s, academics also leveled criticisms concerning the linearity of the model[137]. However, it was historians and histories of technology that proved the most productive and convincing: the literature documented the complex interrelationships between science and technology[138], and developed the idea of technology-as-knowledge as a "substitute" for basic research in engineering[139]. Despite these efforts, the linear model continued to feed public discourses and academic analyses – despite the widespread mention, in the same documents that used the model, that linearity was a fiction.

In a sense, we owe this persistent image the very simplicity of the model. The model is a rhetorical entity. It is a thought figure that simplifies and affords administrators and agencies a sense of orientation when it comes to thinking about allocation of funding to R&D. However, official statistics are as important in explaining the continued use of the linear model. By collecting numbers on research

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(1973), *Interactions of Science and Technology in the Innovative Process: Some Case Studies*, Washington: NSF

137 J. Schmookler (1966), Invention and Economic Growth, *op. cit*.; W. J. Price and L. W. Bass (1969), Scientific Research and the Innovative Process, *Science*, 164, 16 May, p. 802-806; S. Myers and D. G. Marquis (1969), Successful Industrial Innovation: A Study of Factors Underlying Innovation in Selected Firms, *op. cit*.

138 The journal *Technology and Culture* published several issues and articles on the topic from 1959 on. For early representatives of the discussions on the non-causality between science and technology, see: D. J. D. Price (1965), Is Technology Historically Independent of Science? A Study in Historiography, *Technology and Culture*, 6 (4), p. 553-568; M. Kranzberg (1968), The Disunity of Science-Technology, *American Scientist*, 56 (1), p. 21-34.

139 E. T. Layton (1974), Technology as Knowledge, *Technology and Culture*, 15 (1), p. 31-41. See also the collected papers of Vincenti in W. G. Vincenti (1990), *What Engineers Know and How They Know It*, Baltimore: Johns Hopkins University Press.

as defined by three components, and presenting and discussing these components one after the other within a linear framework, official statistics helped to crystallize the model as early as the 1950s. In fact, statistics on the three components of research were for a long time (and still are for many), the only available statistics allowing one to "understand" the internal organization of research, particularly within firms. Furthermore, as innovation came to define the science-policy agenda, statistics on R&D were seen as a legitimate proxy for measuring technological innovation because they included development (of new products and processes). Having become entrenched in discourses and policies with the help of statistics and methodological rules, the model became a "social fact".

Recent efforts to modify or replace the model have been limited with regard to their impact. First, alternative models, with their multiple feedback loops[140], look more like modern artwork or a "plate of spaghetti and meatballs"[141] than a useful analytical framework. Second, efforts to measure the new interactive models have not yet been fruitful, at least in the official literature: statistics and indicators on flows of knowledge between economic sectors, performers and users of research, and types of activities are still in the making[142]. Equally, very few accurate numbers on the costs of innovation have come from the official innovation surveys, at least not robust enough numbers to supplement R&D figures. All in all, the success of the linear model suggests how statistics are often required to give (long)

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140 S. J. Kline (1985), Innovation is not a Linear Process, *Research Management*, July-August, p. 36-45; R. Rothwell (1992), Successful Industrial Innovation: Critical Factors for the 1990s, *R&D Management*, 22, p. 221-239.

141 This is how Kelly et al. contrasted their "ecological" model to the linear model. See: P. Kelly, M. Kranzberg, F. A. Rossini, N. R. Baker, F. A. Tarpley and M. Mitzner (1975), *Technological Innovation: A Critical Review of Current Knowledge*, Volume 1, Advanced Technology and Science Studies Group, Georgia Tech, Atlanta, Georgia, Report submitted to the National Science Foundation, p. 33.

142 See chapters 8 and 9 below.

life to concepts, but also how their absence can be a limitation in changing analytical models and frameworks.

CHAPTER TWO

THE MAKING OF STATISTICAL STANDARDS: THE OECD FRASCATI MANUAL AND THE ACCOUNTING FRAMEWORK

In the 1950s and 1960s, a new type of analysis appeared in the then-emerging field of science, technology and innovation studies: accounting exercises. The analyses were of two types. A first one was growth accounting. Economists developed different techniques, among them econometric equations, most of them based on the concept of labour productivity, to estimate the contribution of science and technology to economic growth. Among the forerunners were J. Schmookler and M. Abramovitz[1]. In 1957, R. Solow formalized these analyses, using an equation called the production function[2]. This is discussed below (chapters 3 and 4).

A second type of accounting analyses was national accounting. Here, academics measured the "costs" of science and technology and its share in the national income or budget. One influential such study was Machlup's *The Production and Distribution of Knowledge in the United States*, published in 1962[3], and discussed in Chapter 8 below. But there were public organizations involved in such types of analyses as well, among them the US National Science Foundation

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1 J. Schmookler (1952), The Changing Efficiency of the American Economy, 1869-1938, *Review of Economics and Statistics*, 34, p. 214-231; M. Abramovitz (1956), Resource and Output Trends in the United States Since 1870, *American Economic Review*, 46, p. 5-23; J. Kendrick (1956), Productivity Trends, Capital and Labor, *Review of Economics and Statistics*, 38, p. 248-257.

2 R. Solow (1957), Technical Change and the Aggregate Production Function, *Review of Economics and Statistics*, 39, p. 312-320.

3 F. Machlup (1962), *The Production and Distribution of Knowledge in the United States*, Princeton: Princeton University Press.

and the OECD. From then on, accounting became a basic framework for policies for decades to come. It allowed identification of where research is conducted, what amount is invested, and for what purposes.

Accounting, as measurement of science, was quite different from the previous statistics produced from the 1860s onward. Then, what was measured were men of science, or scientists, and their output: knowledge, or scientific publications. J. M Cattell, an American psychologist and editor of *Science* from 1895 to 1944, was the first producer of systematic statistics on men of science, based on data from a directory he started publishing regularly in 1906[4]. The systematic counting of scientific publications we also owe to psychologists. At the same time as Cattell, psychologists started collecting data on the discipline's output, in order to contribute to the advancement of psychology as a science[5].

Then costs, or money devoted to research activities, became the privileged statistics. This chapter looks at national accounting of science, and at the OECD Frascati manual as a major contributor to the field. Adopted by member countries in 1963, the manual is a methodological document for conducting surveys on research and development (R&D)[6]. It suggests definitions, classifications and indicators for national statisticians in order to compile comparable statistics among countries. According to the OECD, the manual "has probably been one of the most influential documents issued by this Directorate (…)"[7]. It allowed the collection of standardized statistics among several countries, and made possible, for the first time in

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4 B. Godin (2007), From Eugenics to Scientometrics: Galton, Cattell and Men of Science, *Social Studies of Science*, forthcoming.

5 B. Godin (2006), On the Origins of Bibliometrics, *Scientometrics*, 68 (1), p. 109-133.

6 OECD (1962), *The Measurement of Scientific and Technical Activities: Proposed Standard Practice for Surveys of Research and Development*, DAS/PD/62.47. Hereafter cited as FM.

7 OECD (1979), *Notes by the Secretariat on the Revision of the Frascati Manual*, DSTI/SPR/79.37, p. iii.

history, international comparisons on science. The manual is now in its sixth edition (2002), and is the standard used in every national statistical office.

This paper shows what accounting for science owes to the manual, by looking at the manual's first forty years of existence (1962-2002). From its very beginning, science policy was defined according to the anticipated economic benefits of science. To contribute to this end, the Frascati manual offered a statistical, or accounting, answer to three policy questions or issues of the time: the allocation of resources (how much should government invest in science), the balance between choices or, priorities (where to invest), and efficiency (what are the results).

The first part of this chapter traces the origins of national accounting for scientific activities. It discusses the main 20th century developments leading up to the Frascati manual. The second part looks at the manual's central statistic for allocating resources to science – Gross Expenditures on R&D (GERD) – and discusses what goes into the measurement. The third part looks at the use of statistics to "balance" the science budget, while the last part looks at efficiency. This last part suggests that, although the Frascati manual was entirely devoted to measuring inputs, this was only the first stage toward input/output analyses, or measuring the efficiency of science, technology and innovation.

NATIONAL ACCOUNTING

National accounting for science is part of a larger movement. National accounting for the economy appeared in England at the end of the 17th century. Using data from various sources, among them population figures and tax records, William Petty and Gregory King produced the first estimates of national "income of the people". The aims were twofold: calculate the taxable capacity of the nation and effect policies, and compare the material strength or wealth of the country to that of rival nations. The two authors would soon be followed by others, first of all in England, but also in other countries like France (P. Boisguilbert, M. Vauban).

Prior to World War II, such exercises were mainly conducted by individual investigators[8]. Then in 1932, with the impetus of the Great Depression and the need to devise macroeconomic policy, the US Congress gave the Department of Commerce a mandate to prepare a comprehensive set of national accounts. Economist Simon Kuznets, who had done considerable work with the National Bureau of Economic Research's early national accounting exercises in the 1920s, set the basic framework for what became the System of National Accounts[9]. Similar works in Great Britain, conducted by Richard Stone[10] led to a standardized system conventionalized by international organizations like the United Nations and the OEEC (Organization for European Economic Co-Operation), the predecessor to the OECD, and used in most countries of the world[11].

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8 See: P. Deane (1955), The Implications of Early National Income Estimates for the Measurement of Long-Term Economic Growth in the United Kingdom, *Economic Development and Cultural Change*, 4 (1), Part I, p. 3-38; P. Studenski (1958), *The Income of Nations: Theory, Measurement, and Analysis, Past and Present*, New York: New York University Press; N. Ruggles and R. Ruggles (1970), *The Design of Economic Accounts*, National Bureau of Economic Research, New York: Columbia University Press; J. W. Kendrick (1970), The Historical Development of National-Income Accounts, *History of Political Economy*, 2 (1), p. 284-315; A. Sauvy (1970), Histoire de la comptabilité nationale, *Économie et Statistique*, 14, p. 19-32; C. S. Carson (1975), The History of the United States National Income and Product Accounts: the Development of an Analytical Tool, *Review of Income and Wealth,* 21 (2), p. 153-181; F. Fourquet (1980), *Les comptes de la puissance*, Paris: Encres; A. Vanoli (2002), *Une histoire de la comptabilité nationale*, Paris: La Découverte.

9 S. S. Kuznets (1941), *National Income and its Composition, 1919-1938*, New York: National Bureau of Economic Research.

10 On the contribution of Stone, see: T. Suzuki (2003), The Epistemology of Macroeconomic Reality: the Keynesian Revolution from an Accounting Point of View, *Accounting, Organizations and Society*, 28, p. 471-517.

11 The system of national accounts, now in its fourth edition, was developed in the early 1950s and conventionalized at the world level by the United

While early national accounting exercises focused on measuring *incomes*, the System of National Accounts also collects information on the *production* (value) of goods and services in a country, and their consumption. As C. S. Carson suggested, the central question for government with regard to the development of the accounts during the 1940s was: "Given government expenditures, how much of the total product will be left for civilian consumption?"[12]. The focus on products had consequences on estimates of the national wealth: production was restricted to material production and to marketed (prices) production. This produced the indicator known as Gross National Product (GNP).

The System of National Accounts is a *representation* of the economic activity as production and circulation. Such a representation was first suggested by the French physiocrat F. Quesnay in 1758, and came to be framed into an accounting model (the exemplar of which is the firm) in the 20th century. The measurement of science, technology and innovation has adopted this framework to a significant degree. Since the 1950s, official statistics on science, technology and innovation have been collected and presented in an accounting framework. The emblematic model for such an understanding is the OECD Frascati manual. The manual offers national statisticians definitions, classifications and methodologies for measuring the expenditures and human resources devoted to R&D.

How did an accounting framework get into science, technology and innovation? Official statistics on R&D started to be collected in the early 1920s in the United States, then in Canada and Great Britain[13]. Before the 1950s, official measurement of R&D was usually

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Nations: United Nations (1953), *A System of National Accounts and Supporting Tables*, Department of Economic Affairs, Statistical Office, New York; OEEC (1958), *Standardized System of National Accounts*, Paris.

[12] C. S. Carson (1975), The History of the United States National Income and Product Accounts, *op. cit.*, p. 169.

[13] B. Godin (2005), *Measurement and Statistics on Science and Technology: 1920 to the Present*, London: Routledge.

conducted piecemeal. Organizations surveyed either industrial or government R&D, for example, but very rarely aggregated the numbers to compute a "national research budget". The first such efforts arose in Great Britain and the United States, and were aimed at assessing the share of expenditures that should be devoted to science (and basic science) compared to other economic activities, and at helping to build a case for increased R&D resources.

The British scientist J. D. Bernal was one of the first academics to perform measurement of science expenditures in a Western country. He was also one of the first to figure out how much was spent nationally on R&D – the **budget of science**, as he called it. In *The Social Function of Science* (1939), Bernal estimated the money devoted to science in the United Kingdom using existing sources of data: government budgets, industrial data (from the Association of Scientific Workers) and University Grants Committee reports[14]. He had a hard time compiling the budget, however, because "the sources of money used for science do not correspond closely to the separate categories of administration of scientific research"[15]. "The difficulties in assessing the precise sum annually expended on scientific research are practically insurmountable. It could only be done by changing the method of accounting of universities, Government Departments, and industrial firms"[16]. The national science budget was nevertheless estimated at about four million pounds for 1934, and Bernal added: "The expenditure on science becomes ludicrous when we consider the enormous return in welfare which such a trifling expenditure can produce"[17].

Bernal also suggested a type of measurement that became the main indicator on science, technology and innovation: the research budget as a percentage of the national income. He compared the UK's

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14 J. D. Bernal (1939) [1973], *The Social Function of Science*, Cambridge (Mass.): MIT Press, p. 57-65.

15 *Ibid*., p. 57.

16 *Ibid*., p. 62.

17 *Ibid*., p. 64.

performance with that of the United States and the USSR, and suggested that Britain should devote between one-half percent and one percent of its national income to research[18]. The number was arrived at by comparing expenditures in other countries, among them the United States, which invested 0.6%, and the Soviet Union, which invested 0.8%, while Great Britain spent only 0.1%. "This certainly seems a very low percentage and at least it could be said that any increase up to tenfold of the expenditure on science would not notably interfere with the immediate consumption of the community; as it is it represents only 3% of what is spent on tobacco, 2% of what is spent on drink, and 1% of what is spent on gambling in the country"[19]. "The scale of expenditure on science is probably less than one-tenth of what would be reasonable and desirable in any civilized country"[20].

The source of Bernal's idea is probably a very early calculation made by British economist L. Levi in 1869[21]. Using data from a circular sent to British scientific societies, Levi computed a ratio of incomes of scientific societies to national income of 0.04%. Another such calculation before Bernal was that of E. B. Rosa, chief scientists at the US Bureau of Standards. In 1920, Rosa compiled, for the first time in American history, a government budget for "research-

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18 *Ibid*., p. 65.

19 *Ibid*., p. 64. Already in 1914, J. M. Cattell, editor of *Science*, offered a similar rationale: "Over a billion dollars a year are spent in the United States on the drinking of alcohol and its consequences, a comparable amount on prostitution and its ensuing diseases. We devote twice as much money to each of these destructive agencies as to our entire educational work. Pleasure automobiles or moving-picture shows cost each year more than the support of the teachers in all our schools. The national wealth is ample to double the salary of every teacher (…)" (p. 161-162). See J. M. Cattell (1914), Science, Education and Democracy, *Science*, 39 (996), January 30, p. 154-164.

20 J. D. Bernal (1939), The Social Function of Science, *op. cit*., p. 65.

21 L. Levi (1869), On the Progress of Learned Societies, Illustrative of the Advancement of Science in the United Kingdom during the Last Thirty Years, in *Report of the 38th Meeting of the British Association for the Advancement of Science* (1868), London: John Murray, p. 169-173.

education-development"[22]. Rosa estimated that government's expenditures on research amounted to 1% of the federal budget. In the following year, J. M. Cattell, editor of *Science,* would use the ratio (1%) in his crusade for the advancement of science[23]. In the next decades, variants of the ratio took on names like research intensity, then technology intensity[24].

The next experiment toward estimating a national budget was conducted in the United States by V. Bush in his well-known report to the President titled *Science: The Endless Frontier*[25]. Primarily using existing data sources, the Bowman committee – one of the four committees involved in the report – estimated the national research budget at $345 million (1940). These were very rough numbers, however: "since statistical information is necessarily fragmentary and dependent upon arbitrary definition, most of the estimates are subject to a very considerable margin of error"[26]. The committee showed that industry contributed by far the largest portion of the national research expenditure, but calculated that the government's expenditure expanded from $69 million in 1940 to $720 million in 1944. It also documented how applied, rather than basic, research benefited most from the investments (by a ratio of 6 to 1), and developed a rhetoric arguing that basic research deserved more resources from government[27].

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[22] E. B. Rosa (1921), Expenditures and Revenues of the Federal Government, *Annals of the American Academy of Political and Social Sciences*, 95, May, p. 26-33. See also: E. B. Rosa (1920), Scientific Research: The Economic Importance of the Scientific Work of the Government, *Journal of the Washington Academy of Science*, 10 (12), p. 341-382.

[23] J. M. Cattell (1922), The Organization of Scientific Men, *The Scientific Monthly*, June, p. 568-578.

[24] See Chapter 5 below.

[25] V. Bush (1945) [1995], *Science: The Endless Frontier*, North Stratford: Ayer Co., p. 85-89.

[26] *Ibid*., p. 85.

[27] B. Godin (2003), Measuring Science: Is There Basic Research Without Statistics?, *Social Science Information*, 42 (1), p. 57-90.

The committee added data on national income in its table on total expenditures, and plotted R&D per capita of national income on a graph. But nowhere did the committee use the data to compute the research budget as a percentage of national income, as Bernal had. It was left to the US President's Scientific Research Board to innovate in this respect. In 1947, at the request of the US President, the Board published its report *Science and Public Policy*, which estimated, for the second time in as many years, a **national R&D budget**[28]**.** With the help of a questionnaire it sent to 70 industrial laboratories and 50 universities and foundations, the Board in fact conducted the first survey of resources devoted to R&D using precise categories, although these did not make it "possible to arrive at precisely accurate research expenditures" because of the different definitions and accounting practices employed by institutions[29]. The Board estimated the US budget at $600 million (annually) on average for the period 1941-45. For 1947, the budget was estimated at $1.16 billion. The federal government was responsible for 54% of total R&D expenditures, followed by industry (39%) and universities (4%).

Based on the numbers obtained in the survey, the Board proposed quantified objectives for science policy. For example, it suggested that resources devoted to R&D be doubled in the next ten years, and that resources devoted to basic research be quadrupled. The Board also introduced into science policy the indicator first suggested by Bernal, and that is still used by governments today: R&D expenditures as a percentage of national income. Unlike Bernal however, the Board did not explain how it arrived at a 1% goal for 1957. Nevertheless, President Truman subsequently incorporated this

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28 US President's Scientific Research Board (1947), *Science and Public Policy*, President's Scientific Research Board, Washington: USGPO, p. 9.

29 *Ibid*., p. 73.

objective into his address to the American Association for the Advancement of Science (AAAS) in 1948[30].

The last exercise in constructing a total R&D figure before the US National Science Foundation, as official producer of statistics on science, technology and innovation, entered the scene, came from the US Department of Defense in 1953[31]. Using many different sources, the Office of the Secretary of Defense for R&D estimated that $3.75 billion, or over 1% of the Gross National Product, was spent on **research funds** in the United States in 1952. The report presented data regarding both sources of expenditures and performers of work: "The purpose of this report is to present an over-all statistical picture of present and past trends in research, and to indicate the relationships between those who spend the money [funders] and those who do the work [performers]". The Office's concepts of sources (of funds) and performers (of research activities) would soon become the main categories of the National Science Foundation's accounting system for R&D. The statistics showed that, as sources of funds, the federal government was responsible for 60% of the total[32], industry 38% and non-profit institutions (including universities) 2%. With regard to the performers, industry conducted the majority of R&D (68%) – and half of this work was done for the federal government – followed by the federal government itself (21%) and non-profit institutions and universities (11%).

Then came the National Science Foundation. According to its mandate, the organization started measuring R&D across all sectors of the economy with specific and separate surveys in 1953: government, industry, university and non-profit[33]. Then, in 1956, it

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30 H. S Truman (1948), *Address to the Centennial Anniversary*, AAAS Annual Meeting, Washington.

31 Department of Defense (1953), *The Growth of Scientific R&D*, Office of the Secretary of Defense (R&D), RDB 114/34, Washington.

32 The Department of Defense and the Atomic Energy Commission were themselves responsible for 90% of the federal share.

33 B. Godin (2002), The Number Makers: Fifty Years of Science and Technology Official Statistics, *Minerva*, 40 (4), p. 375-297; B. Godin

published its "first systematic effort to obtain a systematic across-the-board picture"[34] – one year before Great Britain did[35]. It consisted of the sum of the results of the sectoral surveys for estimating national funds[36]. The National Science Foundation calculated that the national budget amounted to $5.4 billion in 1953[37].

The organization's analyses made extensive use of gross national product (GNP). To the National Science Foundation, this was its way to relate R&D to economic output: "despite the recognition of the influence of R&D on economic growth, it is difficult to measure this effect quantitatively", stated the National Science Foundation[38]. Therefore, this "analysis describes the manner in which R&D expenditures enter the gross national product in order to assist in establishing a basis for valid measures of the relationships of such expenditures to aggregate economic output"[39]. The ratio of research funds to GNP was estimated at 1.5% for 1953, 2.6% for 1959 and 2.8% for 1962. The NSF remained careful, however, with regard to interpretation of the indicator: "Too little is presently known about the complex of events to ascribe a specified increase in gross national product directly to a given R&D expenditure"[40].

(2003), The Emergence of S&T Indicators: Why did Governments Supplement Statistics with Indicators?, *Research Policy*, 32 (4), p. 679-691.

34 National Science Foundation (1956), Expenditures for R&D in the United States: 1953, *Reviews of Data on R&D*, 1, NSF 56-28, Washington.

35 Advisory Council on Scientific Policy (1957), *Annual Report 1956-57*, Cmnd 278, HMSO: London.

36 The term "national" appeared for the first time only in 1963. See: National Science Foundation (1963), National Trends in R&D Funds, 1953-62, *Reviews of Data on R&D*, 41, NSF 63-40.

37 The data were preliminary and were revised in 1959. See: National Science Foundation (1959), Funds for R&D in the United States, 1953-59, *Reviews of Data on R&D*, 16, NSF 59-65.

38 National Science Foundation (1961), R&D and the GNP, *Reviews of Data on R&D*, 26, NSF 61-9, p. 2.

39 *Ibid*., p. 1.

40 *Ibid*., p. 7.

In the same publication, the National Science Foundation innovated in another way over previous attempts to estimate the national budget. Using the Department of Defense categories, the organization constructed a matrix of financial flows between the sectors, as both sources and performers of R&D (Table 1). Of sixteen possible financial relationships (four sectors as original sources, and also as ultimate users), ten emerged as significant (major transactions). The matrix showed that the federal government sector was primarily a source of funds for research performed by all four sectors, while the industry sector combined the two functions, with a larger volume as performer. Such tables were thereafter published regularly in the National Science Foundation bulletin series *Reviews of Data on R&D*[41], until a specific and more extensive publication appeared in 1967[42].

The matrix was the result of deliberations on the US research system conducted in the mid-fifties at the National Science Foundation[43] and of demands to relate science and technology to the economy: "An accounting of R&D flow throughout the economy is of great interest at present (…) because of the increasing degree to which we recognize the relationship between R&D, technological innovation, economic growth and the economic sectors (…)", suggested H. E. Stirner from the Operations Research Office at Johns Hopkins University[44]. But "today, data on R&D funds and personnel are

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41 *Reviews of R&D Data*, Nos. 1 (1956), 16 (1959), 33 (1962), 41 (1963); *Reviews of Data on Science Resources*, no. 4 (1965).

42 National Science Foundation (1967), *National Patterns of R&D Resources*, NSF 67-7, Washington.

43 "Our country's dynamic research effort rests on the interrelationships – financial and non-financial – among organizations" stated K. Arnow. See K. Arnow (1959), National Accounts on R&D: The National Science Foundation Experience, in National Science Foundation, *Methodological Aspects of Statistics on Research and Development: Costs and Manpower*, NSF 59-36, Washington, p. 57.

44 H. E. Stirner (1959), A National Accounting System for Measuring the Intersectoral Flows of R&D Funds in the United States, in National

perhaps at the stage of growth in which national income data could be found in the 1920s"[45]. Links with the System of National Accounts were therefore imagined: "The idea of national as well as business accounts is a fully accepted one. National income and product, money flows, and inter-industry accounts are well-known examples of accounting systems which enable us to perform analysis on many different types of problems. With the development and acceptance of the accounting system, data-gathering has progressed at a rapid pace"[46].

Science Foundation, Methodological Aspects of Statistics on R&D: Costs and Manpower, *op. cit.*, p. 37.

45 K. Arnow (1959), National Accounts on R&D: The National Science Foundation Experience, in National Science Foundation, Methodological Aspects of Statistics on R&D: Costs and Manpower, *op. cit.*, p. 61.

46 H. E. Stirner (1959), A National Accounting System for Measuring the Intersectoral Flows of R&D Funds in the United States, in National Science Foundation, Methodological Aspects of Statistics on R&D: Costs and Manpower, *op. cit.*, p. 32.

Table 5. Transfers of Funds Among the Four Sectors as Sources of R&D Funds and as R&D Performers, 1953 (in millions)

	R&D PERFORMERS				
Sector	Federal Government	Industry	Colleges/ universities	Other institutions	Total
SOURCES of R&D FUNDS					
Federal Government agencies	$970	$1,520	$280	$50	$2,810
Industry		2,350	20		2,370
Colleges/ universities			130		130
Other institutions			30	20	50
Total	$970	$3,870	$460	$70	$5,370

The National Science Foundation methodological guidelines – as well as the matrix – became international standards with the adoption of the OECD methodological manual by member countries in Frascati (Italy) in 1963.

THE FRASCATI MANUAL

The Frascati manual is a methodological document aimed at national statisticians for collecting and framing the data on R&D. It proposes standardized definitions, classifications and a methodology for conducting R&D surveys. The first edition was prepared by British economist C. Freeman from the National Institute of Economic and Social Research (London), who was assigned at the time to improving the survey on industrial R&D conducted by the Federation of British Industries (FBI). Freeman was recommended as expert to the OECD by E. Rudd, from the British Department of Scientific and Industrial Research (DSIR). He visited the main countries where measurements were conducted. The manual owes a great deal to the National Science Foundation and its series of surveys in the early 1950s[47].

The Frascati manual essentially developed three sets of guidelines. Firstly, norms were proposed for defining science as "systematic" research and demarcating research from other activities so these other activities could be excluded: research/related scientific activities, development/production, research/teaching. Secondly, the manual suggested classification of research activities according to 1) the sector that finances or executes the research: government, university, industry or non-profit organizations and, in relation to this latter dimension, 2) the type or character of the research, which is either basic, applied or concerned with the development of products and processes, 3) the activities classified by discipline in the case of universities (and non-profit organizations), by industrial sector or product in the case of firms, and by functions or socioeconomic objectives in the case of governments. Finally, the manual suggested a basic statistic as an indicator for policy targets.

Accounting for Science

The Frascati manual suggests collecting two types of statistics: the financial resources invested in R&D, and the human resources devoted to research activities. The main indicator to come out of the manual is Gross Domestic Expenditures on R&D (GERD) – the sum of R&D expenditures in the four main economic sectors: business, university, government and non-profit[48]. The manual's specifications also allow one to follow the flow of funds between sectors (by way of a matrix), specifically between funders and performers of R&D, as the National Science Foundation had already suggested.

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47 This is admitted in the first edition, FM (1962), p. 7.

48 The measure includes R&D funded from abroad, but excludes payments made abroad.

GERD is the term invented by the OECD for measuring what was, before the 1960s, called national funds or budget[49]. In line with the System of National Accounts, and following the National Science Foundation, the manual recommended summing R&D according to the main economic sectors of the system of national accounts: business, government and private non-profit[50], to which the OECD, following the NSF again, added a fourth one: higher education. The following rationale was offered for the decision[51]:

> The definitions of the first three sectors are basically the same as in national accounts, but higher education is included as a separate main sector here because of the concentration of a large part of fundamental research activity in the universities and the crucial importance of these institutions in the formulation of an adequate national policy for R&D.

Why align R&D statistics with the system of national accounts? The first edition of the OECD Frascati manual stated that the classification of R&D data by economic sector "corresponds in most respects to the definitions and classifications employed in other statistics of national income and expenditure, thus facilitating comparison with existing statistical series, such as gross national product, net output, investment in fixed assets and so forth"[52].

When the system of national accounts, now in its fourth edition, was developed in the early fifties and conventionalized at the world level by the United Nations, R&D was not recognized as a category of expenditures that deserved a specific mention in the national

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49 FM (1962), p. 34-36.

50 Households, that is, the sector of that name in the system of national accounts, was not considered by the manual.

51 FM (1962), p. 22.

52 FM (1962), p. 21.

accounts[53]. In 1993 again, during the last revision of the system of national accounts, the United Nations rejected the idea of recognizing R&D "because it was felt that it opened the door to the whole area of intangible investment"[54]. It decided instead to develop a functional classification of expenditures that would make items such as R&D visible in the system of national accounts by way of what was called "satellite accounts". However, R&D is not part of the accounting system of nations, despite the many efforts of statisticians for whom "being part of the National Accounts [would] raise the importance and visibility of R&D statistics and statisticians"[55]. Despite its alignment with the system of national accounts, the Frascati manual still uses a different system of classification in a number of cases, including, for example, the coverage of each economic sector[56].

The GERD, as statistics on national research, remains fragile. The first edition of the Frascati manual suggested that national "variations [in R&D statistics] may be gradually reduced" with standardization[57]. But the collection of statistics on R&D expenditures still remains a very difficult exercise: not all units surveyed have an accounting system to track the specific expenses defined as composing R&D. The OECD regularly has to adjust or estimate national data to correct discrepancies. It also started a series called *Sources and Methods*, documenting national differences with regard to OECD standards. It finally developed a whole system of

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53 Only institutions primarily engaged in research are singled out as a separate category.

54 J. F. Minder (1991), *R&D in National Accounts*, OECD, DSTI/STII (91) 11, p. 3.

55 OECD (2003), *Summary Record of the Working Party of NESTI*, OECD/EAS/STP/NESTI/M (2003) 2, p. 4. The current revision of the system promises some changes, however.

56 S. Peleg (2000), Better Alignment of R&D Expenditures as in Frascati Manual with Existing Accounting Standards, OECD/EAS/STP/NESTI (2000) 20; OECD (2001), Better Alignment of the Frascati Manual with the System of National Accounts, DSTI/EAS/STP/NESTI (2001)14/PART8.

57 FM (1962), p. 6.

footnotes, allowing for the construction of comparable data among member countries, while black-boxing the data's limitations[58]. Consequently, what one observes is increasing reliance with time on what official statisticians would call "sub-optimal" (or non-survey) techniques of measurement in member countries, to the point that the Frascati manual has started "standardizing" these techniques.

This is the case for R&D in the higher education sector. In the 1970s, the OECD launched a series of studies on its international surveys of R&D[59]. After having analyzed the data, the OECD refused to publish the report devoted to university R&D[60], the data being qualified as "rather unsatisfactory" because of "serious conceptual and practical problems" that prevented reliable international comparisons[61]. How, for example, could a country spend twice as much as another on university research and yet report similar numbers of university personnel involved in R&D? Why did expenditures on basic research differ by a ratio of 1 to 2 between otherwise similar countries? The sources of the discrepancies were[62]: the coverage of the university

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58 B. Godin (2005), Metadata: How Footnotes Make for Doubtful Numbers, op. cit.

59 The OECD does not conduct surveys among performers of R&D, but rather collects the data from national sources. OECD (1971), R&D in OECD Member Countries: Trends and Objectives; OECD (1975), Patterns of Resources Devoted to R&D in the OECD Area, 1963-1971; OECD (1975), Changing Priorities for Government R&D: An Experimental Study of Trends in the Objectives of Government R&D Funding in 12 OECD Member Countries, 1961-1972; OECD (1979), Trends in Industrial R&D in Selected OECD Countries, 1967-1975; OECD (1979), Trends in R&D in the Higher Education Sector in OECD Member Countries Since 1965 and Their Impact on National Basic Research Efforts, SPT (79) 20.

60 OECD (1979), Trends in R&D in the Higher Education Sector in OECD Member Countries Since 1965 and Their Impact on National Basic Research Efforts, *op. cit*.

61 *Ibid.*, p. 1.

62 Some of these were already well identified as early as 1969. See: OECD (1969), *The Financing and Performance of Fundamental Research in the OECD Member Countries*, DAS/SPR/69.19, p. 4. See B. Godin (2005), Is

sector differed according to country (some institutions, like university hospitals and national research councils, were treated differently); estimates were used in place of surveys because they were cheaper, and coefficients derived from the estimates were little more than informed guesswork and were frequently out-of-date; general university funds were attributed either to the funder or to the performer; the level of aggregation (fields of science classification) was generally not detailed enough to warrant analysis; finally, there was a great deal of subjectivity involved in classifying research activities, according to a basic/applied scheme that was "no longer used in certain countries, although policy makers still persist in requesting such data in spite of its many shortcomings"[63].

These difficulties led to a small study of national methods for measuring resources devoted to university research in 1981[64], updated in 1983[65], a workshop on the measurement of R&D in higher education in 1985[66] and, as a follow-up, a supplement to the Frascati manual in 1989[67], which was later incorporated into the manual as Appendix 3. The supplement recommended norms for coverage of the university sector, the activities and types of costs to be included in research, and the measurement of R&D personnel. However, subsequent editions of the Frascati manual "authorized" national estimates of R&D expenditures based on techniques that the

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There Basic Research Without Statistics, in Measurement and Statistics on Science and Technology, *op. cit*.

63 OECD (1986), Summary Record of the OECD Workshop on Science and Technology Indicators in the Higher Education Sector, DSTI/SPR/85.60, p. 24.

64 OECD (1981), Comparison of National Methods of Measuring Resources Devoted to University Research, DSTI/SPR/81.44.

65 OECD (1984), Comparison of National Methods of Measuring Resources Devoted to University Research, DSTI/SPR/83.14.

66 OECD (1985), Summary Record of the OECD Workshop on Science and Technology Indicators in the Higher Education Sector, DSTI/SPR/85.60.

67 OECD (1989), The Measurement of Scientific and Technical Activities: R&D Statistics and Output Measurement in the Higher Education Sector, Paris.

unpublished report had disqualified[68]. Estimates were used in place of surveys because they were cheaper, but coefficients derived from the estimates were little more than informed guesswork and were frequently out-of-date.

This was only the first example of deviating from the norm concerning the survey as the preferred instrument[69]. Government R&D was a second example. The OECD began collecting data on socioeconomic objectives of government funded R&D in the early 1970s, and introduced corresponding standards in the third edition of the Frascati manual (1975)[70]. The method was in fact supplied by the European Commission. A work group of European statisticians was set up as early as 1968 by the Working Group on Scientific and Technical Research Policy in order to study central government funding of R&D. The purpose was to "indicate the main political goals of government when committing funds to R&D"[71]. The implicit goal was to contribute to the "construction" of a European science policy and budget. To this end, in 1969 the Commission adopted the *Nomenclature for the Analysis and Comparison of Science Programmes and Budgets* (NABS)[72] produced by the a

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68 FM (1993), p. 146ss.

69 While a certain amount of R&D data can be derived from published sources, there is no substitute for a special R&D survey", stated the manual. See FM (1981), p. 22.

70 The first two editions of the Frascati manual included preliminary and experimental research classifications.

71 Eurostat (1991), *Background Information on the Revision of the NABS*, Room document to the Expert Conference to Prepare the Revision of the Frascati Manual for R&D Statistics, OECD.

72 The first NABS was issued in 1969 and revised in 1975 (and included in the 1980 edition of the Frascati Manual) and again in 1983 (to include biotechnology and information technology, not as categories, but broken down across the whole range of objectives). In 1993, improvements were made in the Environment, Energy, and Industrial Production categories.

working group, and published a statistical analysis based on the classification[73].

In line with the spirit of the OECD Brooks report, which had argued for changes in the objectives of government-funded R&D[74], the OECD Directorate for Science, Technology and Industry (DSTI) adopted the European Commission's approach to obtaining appropriate statistics[75]. However, few governments actually conducted surveys of government R&D[76]. Most preferred to work with budget documents because, although less detailed and accurate than a survey, the information was easier and cheaper to obtain[77]. Among the methodology's advantages was speed, since the data were extracted directly from budget documents without having to wait for a survey. But it also had several limitations[78], among them the fact that national data relied on different methodologies and concepts, and on different administrative systems. With regard to the classification of expenses, it reflected the intention to spend, and not actual expenditures. Furthermore, data were difficult to extract from budgets because they lacked the required level of detail: "the more detailed

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73 CEC (1970), *Research and Development: Public Financing of R&D in the European Community Countries, 1967-1970*, BUR 4532, Brussels.

74 OECD (1972), *Science, Growth and Society*, Paris.

75 The first OECD (experimental) analysis of data by socioeconomic objective was published in 1975: OECD (1975), Changing Priorities for Government R&D: An Experimental Study of Trends in the Objectives of Government R&D Funding in 12 OECD Member Countries, 1962-1972, *op. cit.*

76 Exceptions were Canada and the United Kingdom. Other countries either produced text analysis of budgets or estimate appropriations from budget documents. For methodologies used in European countries, see: Eurostat (1995), *Government R&D Appropriations: General University Funds*, DSTI/STP/NESTI/SUR (95) 3, p. 2-3.

77 Eurostat (2000), *Recommendations for Concepts and Methods of the Collection of Data on Government R&D Appropriations*, DSTI/EAS/STP/NESTI (97) 10, p. 3.

78 Eurostat (2000), The Frascati Manual and Identification of Some Problems in the Measurement of GBAORD, DSTI/EAS/STP/NESTI (2000) 31.

the questions are, the less accurate the data become" because it was not always possible to define the specific NABS sub-level in the budget since budget items can be quite broad[79]. Finally, OECD statisticians were also confronted with a wide diversity of budgetary and national classification systems in member countries, systems over which they had relatively little control[80]:

> The unit classified varied considerably between countries (…) because national budget classification and procedures differ considerably. In some countries, such as Germany, the budget data are available in fine detail and can be attributed accurately between objectives. In others, such as the United Kingdom and Canada, the budgetary data are obtained from a survey of government funding agencies which is already based on an international classification. However, in others again such as France, the original series are mainly votes by ministry or agency.

To better harmonize national practices, a draft supplement to the Frascati manual specifically devoted to measurement of the socioeconomic objectives of government R&D was completed in 1978[81], but it was never issued as a separate publication. These data "play only a modest role in the general battery of science and technology indicators and do not merit a separate manual" stated the OECD[82]. Instead of being put in a separate manual, the specifications

79 OECD (2000), The Adequacy of GBAORD Data, DSTI/EAS/STP/NESTI (2000) 18, p. 3.

80 OECD (1990), Improving OECD Data on Environment-Related R&D, DSTI/IP (90) 25, p. 9.

81 OECD (1978), Draft Guidelines for Reporting Government R&D Funding by Socio-Economic Objectives: Proposed Supplement to the Frascati Manual, DSTI/SPR/78.40.

82 OECD (1991), Classification by Socio-Economic Objectives, DSTI/STII (91) 19, p. 9.

were abridged and included within a chapter in the fourth edition of the Frascati manual[83].

All in all, the GERD is not really a national budget, but “a total constructed from the results of several surveys each with its own questionnaire and slightly [one could rather say very] different specifications”[84]. Some data come from a survey (industry), others are estimated using different mathematical formulas (university), still others are proxies (government). For this reason, “The GERD, like any other social or economic statistic, can only be approximately true (…). Sector estimates probably vary from 5 to 15% in accuracy. The GERD serves as a general indicator of science and technology and not as a detailed inventory of R&D (…). It is an estimate and as such can show trends”[85].

Nonetheless, according to a recent survey by the OECD Secretariat, GERD is currently the most cherished indicator among OECD member countries[86], despite the age-old suggestion that human resources are a better statistic[87]. Over the last fifty years, the

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83 In 1991, Australia again proposed that there should be a supplement to the manual dealing with detailed classification by socioeconomic objective and by field of science. See: OECD (1992), Summary Record of the Meeting of NESTI, DSTI/STII/STP/NESTI/M (92) 1.

84 D. L. Bosworth, R. A. Wilson and A. Young (1993), Research and Development, Reviews of United Kingdom Statistical Sources Series, vol. XXVI, London: Chapman and Hill, p. 29.

85 Statistics Canada (2002), Estimates of Total Expenditures on R&D in the Health Fields in Canada, 1988 to 2001, 88F0006XIE2002007.

86 OECD (1998), How to Improve the MSTI: First Suggestions From Users, DSTI/EAS/STP/NESTI/RD (98) 9.

87 R. N. Anthony (1951), *Selected Operating Data: Industrial Research Laboratories*, Harvard Business School, Division of Research, Boston, p. 3-4: “In view of these difficulties [accounting methods and definitions], we decided to collect only a few dollar figures (…) and to place most of our emphasis on the number of persons”; W. H. Shapley (1959), Problems of Definition, Concept, and Interpretation of R&D Statistics, in National Science Foundation, Methodological Aspects of Statistics on R&D: Costs and Manpower, *op. cit.* p. 13: “Manpower rather than dollars may be a preferable and more meaningful unit of

indicator has been used for several purposes, from rhetorically displaying national performance to lobbying for more funds for science to setting policy targets. The OECD was responsible for this worldwide popularization of the indicator. The organization was also an ardent promoter of the GERD/GDP ratio as policy target. In fact, the American GERD/GDP ratio of the early 1960s, that is 3%, was mentioned in the first paragraphs of the first edition of the Frascati manual, and became the ideal to which member countries would aspire[88]. In every OECD statistical publication, the indicator was calculated, discussed, and countries ranked according to it, because "it is memorable"[89], and is "the most popular one at the science policy and political levels, where simplification can be a virtue"[90].

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measurement"; C. Freeman (1962), Research and Development: A Comparison Between British and American Industry, *National Institute Economic Review*, 20, May, p. 24: "The figures of scientific manpower are probably more reliable than those of expenditures"; C. Falk, and A. Fechter (1981), *The Importance of Scientific and Technical Personnel Data and Data Collection Methods Used in the United States*, Paper presented for the OECD Workshop on the Measurement of Stocks of Scientific and Technical Personnel, October 12-13, 1981, p. 2: "At the current time scientific and technical personnel data seem to be the only feasible indicator of overall scientific and technical potential and capability and as such represent a most valuable, if not essential, tool for S&T policy formulation and planning".

88 FM (1963), p. 5. In fact, at the time of the first edition of the Frascati manual, the US GERD/GDP was 2.8%. See: National Science Foundation (1962), Trends in Funds and Personnel for R&D, 1953-61, *Reviews of Data on R&D*, 33, NSF 62-9, Washington; National Science Foundation (1963), National Trends in R&D Funds, 1953-62, *Reviews of Data on R&D*, 41, NSF 63-40.

89 OECD (1984), Science and Technology Indicators, Paris, p. 26.

90 OECD (1992), Science and Technology Policy: Review and Outlook 1991, Paris, p. 111. The French translation is interesting, and reads as follows: "le plus prisé parmi les responsables de la politique scientifique et des hommes politiques, pour lesquels la simplification se pare parfois de certaines vertus" (p. 119).

What Accounting Measures?

The accounting framework and its methodology, or rather methodological difficulties, has had enormous impact on what was and could be measured. To properly understand the difficulties, one must turn to history. The Frascati manual was the OECD's response to at least three methodological problems that prevented early statisticians from comparing surveys, drawing historical series or even believing in the numbers generated prior to the 1960s. The first problem concerned definitions of research. Two situations prevailed at the time. Firstly, more often than not, there was no definition of research at all, as was discussed above (Chapter 1). This was the case for the US National Research Council directory of industrial R&D[91], the US National Resources Planning Board[92], and Canada's Dominion Bureau of Statistics[93].

The second situation regarding definitions was the use of categories of research in lieu of a precise definition. Both the V. Bush[94] and US President's Scientific Research Board[95] reports, as well as the first survey from the British Department of Scientific and Industrial Research[96], suggested categories that resembled each other (basic, applied and development) – but that were never in fact the same. As a rule, these categories served to help respondents decide what to include in their responses to the questionnaire, but disaggregated data were not available for calculating statistical breakdowns. Others, such

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91 National Research Council, Research Laboratories in Industrial Establishments of the United States of America, Bulletin of the NRC, vol. 1, part 2, March 1920, p. 45.

92 National Resources Planning Board (1941), Research: A National Resource (II): Industrial Research, Washington: USGPO, p. 173.

93 Dominion Bureau of Statistics (1941), Survey of Scientific and Industrial Laboratories in Canada, Ottawa.

94 V. Bush (1945), Science: The Endless Frontier, *op. cit.*, p. 81-83.

95 President's Scientific Research Board (1947), Science and Public Policy, *op. cit.*, p. 300-301.

96 DSIR (1958), *Estimates of Resources Devoted to Scientific and Engineering R&D in British Manufacturing Industry*, 1955, London, p. 8.

as the US National Resources Committee, simply refused to use such categories because of the intrinsic connections between basic and applied research, which seemed to prevent any clear distinctions from being made[97].

The second problem of pre-1960s R&D surveys, closely related to the problem of definition, concerned the demarcations of research and non-research activities. The main purpose of both the Harvard Business School study[98] and the US Bureau of Labor Statistics[99] survey, two influential studies of the early 1950s, was to propose a definition of R&D and to measure it. Two problems were identified: there were too many variations on what constituted R&D, so they claimed, and too many differences among firms concerning which expenses to include in R&D. Although routine work was almost always excluded, there were wide discrepancies at the frontier between development and production, and between scientific and non-scientific activities: testing, pilot plants, design and market studies were sometimes included in research and at other times not. Indeed, companies had accounting practices that did not allow these activities to be easily separated[100]. K. Arnow, of the US National Science Foundation, summarized the problem as follows:

> Even if all the organizations responding to the NSF's statistical inquiries shared, by some miracle,

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97 National Resources Committee (1938), *Research: A National Resource (I): Relation of the Federal Government to Research*, Washington: USGPO, p. 6.

98 D. C. Dearborn, R. W. Kneznek and R. N. Anthony (1953), *Spending for Industrial Research, 1951-1952*, Division of Research, Graduate School of Business Administration, Harvard University.

99 US Department of Labor, Bureau of Labor Statistics, Department of Defense (1953), *Scientific R&D in American Industry: A Study of Manpower and Costs*, Bulletin no. 1148, Washington.

100 O. S. Gellein and M. S. Newman (1973), *Accounting for R&D Expenditures, American Institute of Certified Accountants*, New York; S. Fabricant, M. Schiff, J. G. San Miguel and S. L. Ansari (1975), *Accounting by Business Firms for Investments in R&D*, Report submitted to the National Science Foundation, New York University.

> a common core of concepts and definitions, they might still not be able to furnish comparable data, since they draw on a diversity of budget documents, project reports, production records, and the like for estimating R&D expenditures[101].

According to R. N. Anthony, author of the Harvard Business School survey, accounting practices could result in variations of up to 20% in numbers on industrial R&D[102]. Both the US Bureau of Census and the National Science Foundation also believed that only better accounting practices could correct such errors[103].

A third and final problem of early R&D surveys concerned the population under study. We have noted how the US National Research Council directory was open to all firms who agreed to complete the questionnaire: "the National Research Council surveys were designed for the purpose of compiling a series of directories of research laboratories in the United States. The schedules were therefore sent out without instructions which would have been necessary had it been intended to use the data for purposes of statistical analysis"[104]. When statisticians finally began addressing the problem, however, their methodologies differed: some limited the

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

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

[103] H. Wood, Some Landmarks in Future Goals of Statistics on R&D, in National Science Foundation (1959), *Methodological Aspects of Statistics on Research and Development: Costs and Manpower*, NSF 59-36, Washington, p. 52; National Science Foundation (1960), *Research and Development in Industry, 1957*, NSF 60-49, Washington, p. 99.

[104] G. Perazich and P. M. Field (1940), Industrial Research and Changing Technology, *op. cit.* p. 52.

survey to distinct laboratories[105], others sent the questionnaire on a consolidated company basis[106], and still others concentrated on big firms to “speed up results”[107]. There were no real standards.

All in all, the absence of norms made survey comparisons impossible before the 1960s, resulting in statistics that were often of limited value. The US President’s Scientific Research Board wrote that it was “not possible to arrive at precisely accurate research expenditures” because of three limitations: 1) variations in definition, 2) variations in accounting practices and 3) the absence of a clear division between science and other research activities[108]. Similarly, the National Science Foundation admitted that the industrial R&D surveys it conducted before 1957 were not comparable to those it conducted after that date[109].

The Frascati manual aimed to improve the situation with precise definitions. Surprisingly, the first edition carried no definition of research at all. Research was rather contrasted to routine work:

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

The manual therefore put emphasis on discussing precisely what routine activities were – not in order to measure them, but to exclude

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105 R. N. Anthony (1951), Selected Operating Data: Industrial Research Laboratories, *op. cit.* p. 42.

106 D. C. Dearborn, R. W. Kneznek and R. N. Anthony (1953), Spending for Industrial Research, 1951-1952, *op. cit.* p. 43.

107 Dominion Bureau of Statistics (1956), *Industrial Research-Development Expenditures in Canada, 1955,* Ottawa, p. 22.

108 President’s Scientific Research Board (1947), Science and Public Policy, *op. cit.* p. 73, 301.

109 National Science Foundation (1960), Funds for R&D: Industry 1957, *op. cit.* p. 97-100

them from measurement[110]. The first edition dealt extensively with boundaries (frontiers) between routine work and R&D. It distinguished R&D from two other types of activities: related scientific activities and non-scientific activities (of which industrial production was perhaps the most important). It is here that the main differences were said to exist between member countries. According to the 1962 edition, related scientific activities fall into four classes: 1) scientific information (including publications), 2) training and education, 3) data collection and 4) testing and standardization. Non-scientific activities are of three kinds: 1) legal and administrative work for patents, 2) testing and analysis and 3) other technical services.

Not measuring related scientific activities was a decision as important as measuring R&D. As UNESCO constantly reminded national statisticians, what was defined as related scientific activities includes many important scientific and technological activities[111]. These activities cover, for example, information, data collection, testing and standardization. Without these activities, many R&D activities would not be possible, or at least not possible in their current form: "the optimal use of scientific and technological information depends on the way it is generated, processed, stored, disseminated, and used". [112] In some countries, related scientific activities amount to over one-third of all scientific and technological activities. The Frascati manual also recognized the centrality of these activities to a country[113]:

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[110] As a UNESCO document once reported, there have never been any positive criteria for defining related scientific activities. See J.-C. Bochet, *The Quantitative Measurement of Scientific and Technological Activities Related to R&D Development*, CSR-S-2, Paris: UNESCO, 1974, p. 2.

[111] K. Messman (1975), *A Study of Key Concepts and Norms for the International Collection and Presentation of Science Statistics*, COM-75/WS/26, UNESCO, p. 33-34.

[112] UNESCO, Guide to Statistics on Scientific and Technological Information and Documentation (STID), ST-84/WS/18, Paris, 1984, p. 5.

[113] FM (1962), p. 13.

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

The first edition of the manual suggested measuring these activities, but separately[114], while the following editions recommended excluding them unless they serve R&D directly[115]. The rationale for the non-treatment of these activities was offered as early as the first edition: "It is not possible here to make a detailed standard recommendation for related scientific activities (…). The objective of this manual is to attain international comparability in the narrower field of R&D (…). Arising from this experience, further international standards can be elaborated by the OECD for related activities"[116]. The recommendation for standards was soon abandoned, however, despite talks about extending the Frascati manual to related scientific activities as early as 1964[117]: "We are not concerned here with the

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[114] The Frascati manual nevertheless recommended that: "All calculation of deductions for non-research activities of research organizations, and of additions for R&D activities of non-research organizations should be made explicit, that is to say, recorded both by individual respondents and by those compiling national totals from the data furnished by individual respondents. Furthermore, whenever possible, related scientific activities such as documentation and routine testing, should be measured simultaneously with R&D and reported separately". FM (1962), p. 14.

[115] Starting with FM (1970), p. 17.

[116] FM (1962), p. 14-15.

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

problem of measuring R&D related activities," stated the manual, "but with the conventions to be used to exclude them when measuring R&D activities"[118].

Such an understanding of what scientific activities are was in line with a "moral" hierarchy in vogue for decades: "The facilities available in the laboratories make it possible for the scientist to devote his time exclusively to *work of a professional caliber* [R&D]. He is not required to perform *routine* tasks of testing and experimentation but is provided with *clerical and laboratory assistants* who carry on this work"[119]. 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[120].

Having delimited what was not considered research in the first edition, the OECD turned to a precise definition of research in the second edition: R&D is "creative work undertaken on a *systematic* basis to increase the stock of scientific and technical knowledge, and the use of this stock of knowledge to devise new applications"[121]. The idea of systematicness comes from the industrial R&D surveys conducted in the United States since the 1940s[122]. It equated research with large organizations that had experimental laboratories, or "organized" research facilities. The US Works Progress Administration report, for example, began with the following fact: "The *systematic* application of scientific knowledge and methods to

118 FM (1962), p. 14.

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

120 For an historical point of view, see: S. Shapin (1989), The Invisible Technician, *American Scientist*, 77, p. 554-563.

121 FM (1970), p. 8.

122 National Research Council (1941), *Research: A National Resource (II): Industrial Research*, National Resource Planning Board, Washington: USGPO; D. C. Dearborn, R. W. Kneznek and R. N. Anthony (1953), Spending for Industrial Research, 1951-1952, *op. cit*.

research in the production problems of industry has in the last two decades assumed major proportions"[123]. The authors contrasted colonial times, when research was random, haphazard and unorganized because it was conducted by independent inventors[124], with modern times when, between 1927 and 1938 for example, "the number of organizations reporting research laboratories has grown from about 900 to more than 1,700 affording employment to nearly 50,000 workers"[125]. And the report continued: "Industry can no longer rely on random discoveries, and it became necessary to organize the *systematic* accumulation and flow of new knowledge. This prerequisite for the rise of industrial research to its present proportions was being met by the formation of large corporations with ample funds available for investment in research"[126].

Similarly, the Harvard Business School study showed that firm size was one of the main variables explaining R&D investment. Consequently, the authors suggested limiting the samples to larger units: [127]

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

[124] *Ibid.*, p. 46-47.

[125] *Ibid.*, p. 40.

[126] *Ibid.*, p. 41. This was, in fact, the common understanding about the emergence of industrial research for at least two decades (1920): "The starting and development of most manufacturing businesses depended upon discoveries and inventions made by some individual or group of individuals who developed their original discoveries into an industrial process". This was more often than not accidental. "With the increasing complexity of industry and the parallel growth in the amount of technical and scientific information necessitating greater specialization, the work of investigation and development formerly performed by an individual, has been delegated to special departments of the organization, one example of which is the modern industrial research laboratory". C. E. K. Mees (1920), *The Organization of Industrial Scientific Research*, New York: McGraw Hill, p. 5-6.

[127] R. N. Anthony and J. S. Day (1952), *Management Controls in Industrial Research Organizations*, Cambridge (Mass.): Harvard University Press, p. 6-7.

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

To the OECD, systematic research meant research conducted on a regular basis. However, it was 1993 before there was an explicit OECD rationale for this definition. In fact, the word "systematic" had never been defined explicitly in any edition of the Frascati manual. During the fourth revision of the manual in 1991, then, the French delegate suggested certain modifications to the definition of research[128]. Two options were discussed. One was the omission of references to "systematic" in the definition of R&D. This was rejected because it was felt that the term was useful in excluding non-R&D activities. The other option was to qualify "systematic" as "permanent and organized" in the definition of R&D. This option was also rejected. However, a precise number was proposed and adopted for defining (core) R&D: a minimum of one full-time equivalent person working on R&D per year[129]. From then on, the manual began distinguishing R&D according to whether it was continuous or *ad hoc*[130]:

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128 OECD (1991), *R&D and Innovation Surveys: Formal and Informal R&D,* DSTI/STII/(91)5 and annex 1.

129 FM (1994), p. 106.

130 *Ibid*., p. 51.

> R&D by business enterprises may be organized in a number of ways. Core R&D may be carried out in units attached to establishments or in central units serving several establishments of an enterprise. In some cases, separate legal entities may be established to provide R&D services for one or more related legal entities. *Ad hoc* R&D, on the other hand, is usually carried out in an operational department of a business such as the design, quality or production department.

In 1993, the manual explicitly recommended concentrating on continuous R&D only[131]:

> R&D has two elements. R&D carried out in formal R&D departments and R&D of an informal nature carried out in units for which it is not the main activity. In theory, surveys should identify and measure all financial and personnel resources devoted to all R&D activities. It is recognised that in practice it may not be possible to survey all R&D activities and that it may be necessary to make a distinction between "significant" R&D activities which are surveyed regularly and "marginal" ones which are too small and/or dispersed to be included in R&D surveys. (…) This is mainly a problem in the business enterprise sector where it may be difficult or costly to break out all the ad hoc R&D of small companies.

This meant that a part of R&D, that part conducted by small and medium-sized enterprises, would continue to be poorly surveyed because R&D was thought to be "a statistically rare event in smaller

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131 *Ibid.,* p. 105-106.

units", i.e.: not systematic[132]. And indeed, surveys conducted by academics have documented how official R&D figures underestimate R&D conducted by undercounting small and medium-sized enterprises by at least 30%[133]. The definition of research as systematic research has also restricted the coverage of the sciences surveyed. The Frascati manual was restricted to the natural and engineering sciences until the third edition. In 1976, the manual included the social and human sciences for the first time[134]. The social sciences and humanities had been excluded from definitions and measurements because they were considered as conducting not organized (systematic) but individual research. Even after being included, "some deviations from the standards may still have to be accepted", stated the OECD Frascati manual[135]. Today, the bias continues in other OECD methodological manuals[136], where a system of "priorities" is established with the natural sciences and engineering situated at its core[137].

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132 FM (1981), p. 72.

133 A. Kleinknecht (1987), Measuring R&D in Small Firms: How Much Are We Missing?, *The Journal of Industrial Economic*, 36 (2): 253-256; A. Kleinknecht and J. O. N. Reijnen (1991), More evidence on the undercounting of Small Firm R&D, *Research Policy*, 20: 579-587. For similar numbers in France, see: S. Lhuillery and P. Templé (1994), L'organisation de la R&D dans les PMI-PME, *Économie et Statistique*, 271-272, p. 77-85. For Italy, see: E. Santarelli and A. Sterlacchini (1990), Innovation, Formal vs Informal R&D and Firm Size, *Small Business Economics*, 2, p. 223-228.

134 The definition of R&D was modified as follows, and an appendix specifically dealing with these sciences was added: "R&D may be defined as creative work undertaken on a *systematic* basis to increase the stock of scientific and technical knowledge, including knowledge of man, culture and society and the use of this stock of knowledge to devise new applications". FM (1976), p. 29.

135 FM (1981), p. 17.

136 OECD (1995), *Manual on the Measurement of Human Resources Devoted to S&T*, OECD/GD (95) 77.

137 "The Nordic group [of countries] had difficulties in accepting the use of the term "low priority" in connection with the humanities (…). It was agreed that the priorities terminology be replaced by coverage": OECD

When official definitions and surveys began to cover the social sciences and humanities[138], the conventions designed for the natural sciences in the previous decade were strictly applied to these new disciplines. Therefore, activities such as data collection and scientific and technical information – among them the production of statistics – which are the raw material of the social sciences and humanities, and which are an integral part of research in these disciplines, were excluded because they were considered as related scientific activities[139]. Similarly, economic studies and market research were never considered as research activities by industry surveys[140].

That research came to be equated with systematized research or large organizations with dedicated laboratories[141] is due partly to methodological difficulties of accounting and the costs of conducting a survey. Because there are tens of thousands of firms in a country, units surveyed have to be limited to manageable proportions. This was done by introducing a bias in industrial surveys: the survey identified all major R&D performers, that is, big firms with laboratories (or "organized" research) and surveyed them all, but selected only a sample of smaller performers, when they selected any. This decision was also supported by the fact that only big firms had

(1994), *NESTI: Summary Record of the Meeting Held on 18-20 April 1994 in Canberra*, Australia, DSTI/EAS/STP/NESTI/M (94) 1, p. 4.

138 Today, nine OECD countries still do not include the social sciences and humanities in their surveys.

139 P. Lefer (1971), *The Measurement of Scientific Activities in the Social Sciences and Humanities*, UNESCO: Paris, CSR-S-1; OECD (1970), *The Measurement of Scientific Activities: Notes on a Proposed Standard Practice for Surveys of Research in the Social Sciences and Humanities*, DAS/SPR/70.40, Paris.

140 In the case of industrial R&D, the exception was: D. C. Dearborn, R. W. Kneznek and R. N. Anthony (1953), Spending for Industrial Research, 1951-1952, *op. cit*.

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

precise book-keeping practices on R&D since the activity could be located in a distinct and formal entity, the laboratory.

All in all, the manual and its statistics brought forth a specific definition of science[142]. According to the Frascati manual science is:

- An activity, rather than knowledge or output;
- Research, rather than research plus its supporting activities;
- Research as R&D, and mainly development of products and processes (accounting for two thirds of R&D);
- Systematic, or organized and institutionalized R&D.

Such a definition is due to many factors, among them the institutionalization of research in organizations and its role in the economy, the importance of firms in the national research budget, and the limitations of statistics and their collection.

ACCOUNTING AND SCIENCE POLICY

That the OECD developed a methodological manual on R&D based on an accounting framework had to do with policy. As the NSF suggested in 1951: "A sound policy must rest on a sound foundation of fact"[143]. And again in 1952: "The necessary first step in policy development is the assembly of an adequate body of fact"[144]. Such a rationale for the collection and analysis of data was also offered at OECD in the early 1960s when discussions on science policy emerged. Science was now becoming recognized as a factor in

142 B. Godin (2007), *What is Science: Defining Science by the Numbers, 1920-2000*, Project on the History and Sociology of STI Statistics, Paper no. 35, Montreal: INRS.

143 National Science Foundation, *First Annual Report, 1950-51*, Washington: USGPO, p. 13.

144 National Science Foundation, *Second Annual Report, Fiscal Year 1952*, Washington: USGPO, p. 5.

economic growth, at least by OECD bureaucrats. In order that science might optimally contribute to progress, however, science policies had to be developed. And to inform the latter, statistics were essential, so thought the organization: "Informed policy decisions (…) must be based on accurate information about the extent and forms of investment in research, technological development, and scientific education", argued the OECD's Piganiol report[145]. "Provision for compilation of data is an indispensable prerequisite to formulating an effective national policy for science"[146]. Freeman would identify similar needs in subsequent years, among others in a 1963 study for the first ministerial conference on science: "most countries have more reliable statistics on their poultry and egg production than on their scientific effort and their output of discoveries and inventions". (…) The statistics available for analysis of technical change may be compared with those for national income before the Keynesian revolution"[147].

What were the policy decisions for which data were so necessary? There were three, and all were framed within the vocabulary of neoclassical economics, even among evolutionary economists' hands[148]. The first was how to allocate resources to R&D, or what economists call the optimum level of resources: "Assessing what is in some sense the "right" or "optimum" level of allocation of

145 OECD (1963), Science and the Policies of Government, *op. cit*. p. 24.

146 OECD (1963), Science and the Policies of Government, *op. cit*. p. 24.

147 OECD (1963), *Science, Economic Growth and Government Policy*, Paris, p. 21-22; the same quotation (more or less) can be found on p. 5 of the first edition of the Frascati manual.

148 For a summary of neoclassical economists' view on science policy, see: S. Metcalfe (1995), The Economic Foundations of Technology Policy: Equilibrium and Evolutionary Perspectives, in P. Stoneman (ed.), Handbook of the Economics of Innovation and Technological Change, Oxford: Blackwell, p. 408-512, especially p. 408-447.

resources"[149]. As discussed above, the GERD was developed to serve this end, and the ratio GERD/GDP became a policy target.

The second policy decision was what should be the balance between choices or priorities, or what economists call equilibrium. To many, decisions about research funding were analyzed in terms of tensions between freedom and control, between big science and little science, between socioeconomic objectives, between scientific fields, and between basic and applied research[150]. To the OECD, statistics was the solution to the issue, and a system of classification for statistical breakdowns was proposed.

The first edition of the Frascati manual suggested classifying R&D by dimension. One of the central dimensions was concerned with economic sectors, as discussed above. Other classifications concerned each of the sectors individually. The Frascati manual's recommended system of classification is peculiar in that each economic sector in the system of national accounts has its own

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149 C. Freeman and A. Young (1965), *The Research and Development Effort in Western Europe, North America and the Soviet Union*, Paris: OECD, p. 15.

150 Bernal, J. D. (1939), *The Social Function of Science*, Cambridge (Mass.): MIT Press, 1973; US President's Scientific Research Board (1947), *Science and Public Policy*, Washington: USGPO; T. Parsons (1948), Social Science: A Basic National Resource, paper submitted to the Social Science Research Council, reprinted in S. Z. Klausner and V. M. Lidz (1986), *The Nationalization of the Social Sciences*, Philadelphia: University of Pennsylvania Press, 41-112, p. 109; A. M. Weinberg (1963/1964), Criteria for Scientific Choice, *Minerva* , 1(2), p. 159-171 and 3 (1), p. 3-14; S. Toulmin (1964), The Complexity of Scientific Choice: A Stocktaking, *Minerva*, 2 (3), p. 343-359; National Research Council (1965), *Basic Research and National Goals,* Washington: National Academy Press; National Research Council (1967), *Applied Science and Technological Progress,* Washington: National Academy Press; B. L. R. Smith (1966), The Concept of Scientific Choice, *American Behavioral Scientist*, 9, p. 27-36; C. Freeman (1969), National Science Policy, *Physics Bulletin*, 20, p. 265-270; H. Krauch (1971/1972), Priorities for Research and Technological Development, *Research Policy*, 1, p. 28-39; H. Brooks (1978), The Problem of Research Priorities, *Daedalus*, 107, p. 171-190.

classification. Whereas in most official surveys the units are analyzed according to a common system of classifications (every individual of a population, for example, is classified according to the same age structure), here the main economic sectors of the system of national accounts were distinguished and classified separately. The business sector was classified (and the statistics broken down) according to industry, the university (and private non-profit) sector according to fields of science or scientific disciplines, and the government sector according to socioeconomic objectives. The principal recommendations regarding these classifications were made in the first edition of the Frascati manual, and have been regularly updated since 1970.

Although each economic sector has its own classification, there is one more classification recommended in the manual, and it applies across all economic sectors. It concerns whether R&D is basic, applied or development, and has been an issue discussed for over forty years at the OECD[151]. Since M.J.A. Condorcet in the eighteenth Century, a magic number of 20 is often suggested as the percentage of R&D funds that should be devoted nationally to basic research, and such a target was proposed to the OECD early on[152]. Such a ratio depends on statistical breakdowns of research funds between basic research, applied research and development, the three categories that appear in the linear model of innovation. Former National Science Foundation director D. N. Langenberg once explained how the National Science Foundation "must retain some ability to characterize, even to quantify, the state of the balance between basic and applied research across the Foundation. It must do so in order to

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151 The first discussions on the balance between basic and applied research are to be found in Bernal (1939), Bush (1945) and the US President Scientific and Research Board (1947). For the OECD, see: B. Godin (2005), Measurement and Statistics on Science and Technology: 1920 to the Present, *op. cit*., p. 298-302.

152 OECD (1966), *Fundamental Research and the Policies of Government*, Paris, p. 32-33.

manage the balance properly and to assure the Congress and the scientific and engineering community that it is doing so"[153].

Of all the concepts defined in the first edition of the Frascati manual, the first dealt with what the manual then called fundamental research. While a definition of research itself did not appear until the second edition, fundamental research was defined explicitly as follows[154]:

> Work undertaken primarily for the advancement of scientific knowledge, without a specific practical application in view.

In the last edition of the manual, the definition is substantially the same as the one in 1962, although the term "basic" is now used instead of fundamental[155]:

> Basic research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view.

Between 1962 and 2002, therefore, all six editions of the manual carried essentially the same definition without any significant changes: basic (or fundamental) research is research concerned with knowledge *per se*, as contrasted with applied research, which is concerned with the application of knowledge. Over the same period, however, the definition has frequently been discussed, criticized and, in some cases, even abandoned.

The concept of basic research and its contrast with applied research has a long history that goes back to the nineteenth century, and the integration of the dichotomy into taxonomies used for statistical

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153 D. N. Langenberg (1980), *Memorandum for Members of the National Science Board*, NSB-80-358, Washington, p. 4.

154 FM (1962), p.12.

155 FM (2002), p. 77.

surveys comes from the British scientists J. S. Huxley and J. D. Bernal[156]. V. Bush appropriated the taxonomy for the statistics of his report *Science: the Endless Frontier,* as did the US President's Scientific Research Board. But it was the National Science Foundation that gave the concept of basic research its influential definition with its very first R&D surveys[157].

The first OECD meeting of national experts on the Frascati manual, held in 1963, brought together people and groups from several countries, chief among which was the National Science Foundation. K. S. Arnow[158] and K. Sanow[159] discussed at length the difficulties of defining appropriate concepts for surveys. Indeed, for some time the National Science Foundation devoted a full-time person specifically to this task (K. S. Arnow). At the meeting, C. Oger from France (*Direction générale de la recherche, de la science et de la technologie*) discussed the limitations of a definition of fundamental research based exclusively on researchers' motives, and suggested alternatives[160]. In fact, the main criticism of the concept concerned – and still concerns – its subjectivity: whether a project is classified as basic or applied is still up to the survey respondent[161]. Oger's suggestion (crossing categories of research according to three criteria: aims, results and types of work) appeared without discussion in an appendix to the first edition of the Frascati manual.

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[156] Huxley, J. S. (1934), *Scientific Research* and *Social Needs*, London: Watts and Co.; Bernal, J. D. (1939), The Social Function of Science, *op. cit*.

[157] B. Godin (2003), Measuring Science: Is There Basic Research Without Statistics?, *op. cit*.

[158] K. S. Arnow (1963), Some Conceptual Problems Arising in Surveys of Scientific Activities, OECD, DAS/PD/63.37.

[159] K. Sanow (1963), Survey of Industrial Research and Development in the United States: Its History, Character, Problems, and Analytical Uses of Data, OECD, DAS/PD/63.38.

[160] C. Oger (1963), *Critères et Catégories de recherche*, OECD, DAS/PD/63.30.

[161] Researchers tend to qualify their research as basic, while providers of funds prefer to call it applied or oriented.

Discussions continued over the following few years, resulting in the addition of a brief text to the second edition of the manual. In 1970, the manual discussed a sub-classification of basic research according to whether it was pure or oriented[162]. Pure basic research was defined as research in which "it is generally the scientific interest of the investigator which determines the subject studied". "In oriented basic research the organization employing the investigator will normally direct his work toward a field of present or potential scientific, economic or social interest"[163].

Discussions resumed in 1973. C. Falk, of the National Science Foundation, proposed to the OECD a definition of research with a new dichotomy based on the presence or absence of constraints. He suggested "autonomous" when the researcher was virtually unconstrained and "exogenous" when external constraints were

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162 To the best of my knowledge, the term "oriented research" came from P. Auger (1961), *Tendances actuelles de la recherche scientifique*, Paris: UNESCO, p. 262. The OECD rapidly appropriated the concept in two publications. First, in a document produced for the first ministerial conference on science in 1963, C. Freeman et al. suggested that fundamental research fell into two categories – free research that is driven by curiosity alone, and oriented research (OECD (1963), Science, Economic Growth and Policy, *op. cit.* p. 64). Second, in the second edition of the Frascati manual, the OECD defined oriented research as follows: "In oriented basic research the organization employing the investigator will normally direct his work toward a field of present or potential scientific, economic or social interest": FM (1970), p. 10. A precursor to the concept is Huxley's definition of basic research (J. S. Huxley (1934), *Scientific Research and Social Needs*, London: Watts and Co.) and the definition of basic research offered to firms in the National Science Foundation surveys of industrial research: "Research projects which represent original investigation for the advancement of scientific knowledge and which do not have specific commercial objectives, *although they may be in the fields of present or potential interest* to the reporting company": National Science Foundation (1959), *Science and Engineering in American Industry: Report on a 1956 Survey*, Washington, NSF 59-50, p. 14.

163 FM(1970), p. 10.

applied to the research program[164]. He recommended that some form of survey be undertaken by the OECD to test the desirability and practicality of the definitions. He had no success: “the experts (…) did not feel that the time was ripe for a wholesale revision of this section of the manual. It was suggested that as an interim measure the present division between basic and applied research might be suppressed”[165]. However, the only modifications that member countries accepted – to appear in the 1981 edition of the Frascati manual – were that the discussion of the difference between pure and basic research was transferred to another chapter, separated from the conventional definitions.

Then, in 1992, the delegates from the United Kingdom and Australia tried to introduce the term “strategic research” into the Frascati manual – the Australian going so far as to delay publication of the Frascati manual[166]: strategic research was “original investigation undertaken to acquire new knowledge which has not yet advanced to the stage when eventual applications to its specific practical aim or objective can be clearly specified”[167]. After “lively discussions”, as the Portuguese delegate described the meeting[168], they failed to win consensus. We read in the 1993 edition of the Frascati manual that: “while it is recognized that an element of applied research can be described as strategic research, the lack of an agreed approach to its

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[164] C. Falk (1973), The Sub-Division of the Research Classification: A Proposal and Future Options for OECD, OECD, DAS/SPR/73.95/07.

[165] OECD (1973), Results of the Meeting of the Ad Hoc Group of Experts on R&D Statistics, DAS/SPR/73.61, p. 8.

[166] This is only one of two discussions concerning the taxonomy of research at the time. A new appendix was also suggested but rejected. It concerned distinguishing between pure and “transfer” sciences. See OECD (1991), Distinction Between Pure and Transfer Sciences, DST/STII(91)12; OECD (1991), The Pure and Transfer Sciences, DSTI/STII(91)27.

[167] OECD (1992), Frascati Manual – 1992, DSTI/STP(92)16; OECD (1993), The Importance of Strategic Research Revisited, DSTI/EAS/STP/NESTI(93)10.

[168] OECD (1993), Treatment of Strategic Research in the Final Version of Frascati Manual - 1992, DSTI/EAS/STP/NESTI/RD(93)5.

separate identification in member countries prevents a recommendation at this stage"[169].

The 1992 debate at the OECD centered on, among other things, where to locate strategic research. There were three options. First, subdivide the basic research category into pure and strategic, as the OECD had suggested. Second, subdivide the applied research category into strategic and specific, as the British government did. Third, create an entirely new category (strategic research) as recommended by the Australian delegate[170]. In the end, "delegates generally agreed that strategic research was an interesting category for the purposes of science and technology policy but most felt that it was very difficult to apply in statistical surveys"[171].

In 2000, the question was on the agenda again during the fifth revision of the Frascati manual[172]. This time, countries indicated a "strong interest in a better definition of basic research and a breakdown into pure and oriented basic research" but agreed that discussions be postponed and addressed in a new framework after they had advanced on policy and analytical ground[173]. To this end, a workshop was held in Oslo (Norway) in 2001 as part of a project related to the financing of basic research, entitled *Steering and Funding Research Institutions*[174]. The final report of the project, however, completely evaded the question and did not discuss

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169 FM (1994), p. 69.

170 See OECD (1991), Ventilation fonctionnelle de la R-D par type d'activité, DSTI/STII(91)7.

171 OECD (1993), *Summary Record of the NESTI Meeting*, DSTI/EAS/STP/NESTI/M(93) 1, p. 5.

172 OECD (2000a), Review of the Frascati Manual: Classification by Type of Activity, DSTI/EAS/STP/NESTI/RD(2000)4; OECD (2000b), Ad Hoc Meeting on the Revision of the Frascati Manual R&D Classifications: Basic Research, DSTI/EAS/STP/NESTI/RD(2000)24.

173 OECD (2000), *Summary Record*, DSTI/EAS/STP/NESTI/M (2000) 1, p. 5.

174 OECD (2002), *Workshop on Basic Research: Policy Relevant Definitions and Measurement: Summary Report*, http://www.oecd.org/dataoecd/61/8/2676067.pdf.

definitions. The rationale given by the OECD was the following: "the key question is not to find a new conceptual definition for basic research, but to define its scope sufficiently broadly to cover the whole range of research types needed to establish a sound body of knowledge to achieve socio-economic advances"[175].

The result of all this was that, beginning in the mid-1970s, governments started to delete the question on basic research from their surveys. Today, only half of OECD member countries collect data on basic research. The OECD itself deleted the question on basic research from the list of mandatory questions on the R&D questionnaire, and rarely published numbers on basic research except for sector totals because of the low quality of the data, and because too many national governments failed to collect the necessary information[176]. Beginning with the 1981 edition, the manual also added reservations on the classification because it was qualified as subjective[177]. All in all, it seems that the current statistical breakdown of research, and the numbers generated, are not judged by several people to be useful for balancing the budget[178]. As W. H. Shapley, from the US Bureau of Budget, once suggested: "breakdowns do not

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175 OECD (2003), Governance of Public Research: Toward Better Practices, Paris, p. 101.

176 The only numbers appear in the *Basic Science and Technology Statistics* series, but missing data abound.

177 FM (1981), p. 21.

178 Neither are they by industrialists (see: H. K. Nason (1981), Distinctions Between Basic and Applied in Industrial Research, *Research Management*, May, p. 23-28). According to the NSF itself, industrial representatives "prefer that the National Science Foundation not request two separate figures" (basic and applied), but "the Foundation considers it to be extremely important" to distinguish both (K. Sanow (1963), Survey of Industrial Research and Development in the United States: Its History, Character, Problems, and Analytical Uses of Data, *op. cit*. p. 13). With regard to government representatives, the second OECD users group reported that the least-popular of all the standard indicators were those concerning basic research, applied research and experimental development: OECD (1978), *Report of the Second Ad Hoc Review Group on R&D Statistics*, STP (78) 6.

tell anything about balance (…). Two programs are not in "balance" in any meaningful sense just because the same number of dollars happens to be applied to them in some particular year"[179]. Equally, as the Frascati manual itself admits, classifications are "not detailed enough to be of use to one significant class of potential users of R&D data (…) [because] this manual is essentially designed to measure national R&D efforts (…)"[180].

THE EFFICIENCY OF RESEARCH

We suggested that there were three policy decisions that required data, according to the OECD. The first was how to allocate resources to R&D. The second was how to balance the budget. The third decision, defined again according to neoclassical economics, was how to determine the **efficiency**, or effectiveness of research. The first edition of the Frascati manual set the stage for measuring efficiency by using an input-output approach as a framework for science statistics, linking what comes out of science, technology, and innovation (output) to investments (input). Certainly the manual was primarily concerned with proposing standards for the measurement of inputs. But this was only a first stage[181]. Despite this focus, the manual did discuss output, and inserted a chapter (section) specifically dedicated to its measurement because "in order really to assess R&D efficiency, some measures of output should be found"[182]. However, stated the manual, "measures of output have not yet reached the stage of development at which it is possible to

179 W. H. Shapley (1959), Problems of Definition, Concept, and Interpretation of R&D Statistics, in National Science Foundation, Methodological Aspects of Statistics on R&D: Costs and Manpower, *op. cit*. p. 14.

180 FM (1981), p. 21.

181 FM (1962), p. 11.

182 *Ibid*.

advance any proposals for standardization"[183]. "It seems inevitable that for some time to come it will not be possible to undertake macro-economic analysis and to make international comparisons on the basis of the measurement of output (…). This is an important limitation"[184].

Nevertheless, from its very first edition, the Frascati manual suggested that a complete set of statistics and indicators, covering both input and output, was necessary in order to properly measure science. The output indicators suggested were patents and payments for patents, licensing and technical know-how[185]. Things began to really change in 1976. According to the OECD, the manual had "reached maturity"[186] and the Secretariat began looking at other indicators than R&D expenditures. In December, the OECD Committee for Scientific and Technological Policy organized a meeting of national experts on R&D statistics in order to prepare the work of the second *ad hoc* review group on statistics. The OECD Secretariat submitted the question of indicators to the group: "Science indicators are a relatively new concept following in the wake of the long-established economic indicators and the more recent social indicators. So far, the main work on this topic has been done in the United States where the National Science Board of the National Science Foundation has published two reports: *Science Indicators 1972* (issued 1973) and *Science Indicators 1974* (issued 1975)"[187]. The background document for the meeting analyzed the indicators that appeared in *Science Indicators* in depth, and compared them to the statistics available and to those that could be collected, and at

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183 FM (1962), p. 37.

184 FM (1962), p. 37-38.

185 An early statistical analysis of two indicators was conducted by the director of the OCED statistical unit and presented at the Frascati manual meeting in 1963. See: Y. Fabian (1963), *Note on the Measurement of the Output of R&D Activities*, DAS/PD/63.48.

186 *Ibid*., p. 3.

187 OECD (1976), *Science and Technology Indicators*, DSTI/SPR/76.43, p. 3.

what cost[188]. The group was asked "to draw some lessons for future work in member countries and possibly at OECD".

The final report of the review group suggested a three-stage program for the development of new indicators[189]:

- Short-term: input indicators (like industrial R&D by product group).
- Medium-term: manpower indicators (like occupations of scientists and engineers).
- Long-term: output (productivity, technological balance of payments, patents) and innovation indicators, as well as indicators on government support to industrial R&D.

A few months later, in November 1978, the OECD Directorate for Science, Technology and Industry responded to the *ad hoc* review group report and made proposals to member countries[190]. It suggested limiting indicators to those most frequently requested by users of statistics, i.e.: input indicators. The decision was dictated by the need to accelerate the dissemination of data – a limitation already identified by the first *ad hoc* review group on statistics. It was nevertheless suggested that a database be created, from which a report based on indicators would be published every two years. The report would "be modeled to some extent on the National Science Foundation *Science Indicators* reports"[191].

The Canadian delegate, H. Stead, judged these proposals too timid. He suggested that the Frascati manual be revised in order to turn it

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188 See particularly the annex of OECD (1976), Science and Technology Indicators, *op. cit*.

189 OECD (1978), Report of the Second Ad Hoc Review Group on R&D Statistics, STP (78) 6, p. 17-21.

190 OECD (1978), General Background Document for the 1978 Meeting of the Group of National Experts on R&D Statistics, DSTI/SPR/78.39 and annex.

191 *Ibid*., p. 8.

into an indicator manual that would cover more aspects or dimensions of science than just R&D[192]. The first part would match more or less the current content of the manual, while the second part would deal with other indicators, namely scientific and technical personnel, related scientific activities, outputs and high-technology trade. His suggestions were rejected as premature[193], but the Introduction to the manual was rewritten for the 1981 edition in order to place R&D statistics in the larger context of indicators, including output. By 1981, the manual included an appendix specifically devoted to output, and discussed a larger number of indicators, namely innovations, patents, technological payments, high-technology trade and productivity. The tone of the manual had also changed. While recognizing that there still remained problems of measurement, it stated that: "Problems posed by the use of such data should not lead to their rejection as they are, for the moment, the only data which are available to measure output"[194]. As the next two chapters document, an input-output approach to science, technology, and innovation finally developed in the following years.

CONCLUSION

Accounting and the Frascati manual were the statistical answer or policy tool to contribute to the anticipated economic benefits of science. At the OECD, these benefits had to do with economic growth. In 1961, the organization and member countries adopted a

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192 *Ibid*., p. 16-17.

193 OECD (1979), *Summary of the Meeting of NESTI*, STP (79) 2, p. 4. YThey concluded that the revised Frascati manual should continue to deal essentially with R&D activities and that separate manuals in the *Measurement of Scientific and Technical Activities* series should be developed for S&T output and impact indicators which are derived from entirely different sources from R&D statistics": OECD (1988), *Summary of the Meeting of NESTI*, STP (88) 2.

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

50% economic growth target. All divisions of the organization aligned themselves with the objective, first among them the Directorate for Scientific Affairs[195]. With regard to R&D, a whole program of work on the economics of science was developed. The Committee for Scientific Research (CSR) of the Directorate for Scientific Affairs recommended that the OECD Secretariat "give considerable emphasis in its future program to the economic aspects of scientific research and technology"[196].

The Committee for Scientific Research proposal was based on the fact that there is "an increasing recognition of the role played by the so-called third factor [technical progress] in explaining increases in GNP"[197]. But, the committee continued, "the economist is unable to integrate scientific considerations into his concepts and policies because science is based largely on a culture which is anti-economic"[198]. Thus, the OECD gave itself the task of filling the gap. To this end, the organization developed a research program on the economy of science that led to a statement on science in relation to economic growth as a background document for the first ministerial conference held in 1963[199]. The document contained one of the first international comparisons of R&D efforts in several countries based on existing statistics, conducted by Freeman *et al.*[200].

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195 OECD (1962), *The 50 Per Cent Growth Target*, CES/62.08, Paris.

196 OECD (1962), *Economics of Research and Technology*, SR (62) 15, p. 1.

197 *Ibid*., p. 2.

198 *Ibid*., p. 5.

199 OECD (1963), Science, Economic Growth and Government Policy, *op. cit.*

200 The year before, S. Dedijer (Sweden) had published the first such comparison: S. Dedijer (1962), Measuring the Growth of Science, *Science*, 138, 16 November, p. 781-788. Two other international statistical comparisons, again based on existing statistics, would soon follow: A. Kramish (1963), *Research and Development in the Common Market vis-à-vis the UK, US and USSR*, report prepared by the RAND Corporation for the Action Committee for a United Europe (under the chairmanship of J. Monnet); C. Freeman and A. Young (1965), The

The committee went further than simply recommending the collection of statistics. It also suggested that the OECD conduct studies on the relationships between investment in R&D and economic growth. Indeed, "comprehensive and comparable information on R&D activity is the key to [1] a clearer understanding of the links between science, technology and economic growth, [2] a more rational formulation of policy in government, industry and the universities, [3] useful comparisons, exchange of experience, and policy formation internationally"[201]. The main obstacle to this suggestion was identified as being the inadequacy of available data[202]. To enlighten policy, the committee thus supported the development of a methodological manual[203].

The OECD had been responsible for a major achievement in the field of science measurement, that of conventionalizing a specific and particular vision of science as research accounting. Today, every country uses the framework and its statistics to analyze science, technology and issues. The importance of the OECD contribution is considered so great, by the OECD itself, that: "if the OECD were to close its doors tomorrow, the drying up of its statistics would probably make a quicker and bigger impact on the outside world than would the abandonment of any of its other activities"[204].

An important aspect of the OECD's accounting framework was that it occurred without any opposition from member countries. This is quite different from the history of other standards and statistics. Dissemination of the French meter outside France, for example, has not been an easy task, and the meter is still not universally used

Research and Development Effort in Western Europe, North America and the Soviet Union, *op. cit.*

201 OECD (1963), *A Progress and Policy Report*, SR (63) 33, p. 4-5.

202 OECD (1962), Economics of Research and Technology, *op. cit.*, p. 10.

203 OECD (1962), *Draft 1963 Programme and Budget*, SR (62) 26, p. 19.

204 OECD (1994), Statistics and Indicators for Innovation and Technology, DSTI/STP/TIP (94) 2, p. 3.

today[205]. Similarly, the standardization of time units for a while saw its English proponents opposed to the French[206].

At least three factors contributed to the easy acceptance of the Frascati manual and its accounting framework among OECD countries. Firstly, few countries collected data on science in the early 1960s. The OECD offered a ready-made model for those who had not yet developed the necessary instruments. For the few countries that already collected data, mainly the United States, Canada and Great-Britain, the manual reflected their own practices fairly well: it carried a community of views that they already shared. Secondly, the accounting was proposed by an international organization and not by a specific country, as in the case of the meter or the time unit, for example. This was perceived as evidence of neutrality, although the United States exercised overwhelming influence. Thirdly, the OECD introduced the manual with a step-by-step strategy. First step: as with the first edition, the document began as an internal document only (1962). It would not be published officially before the third edition (1976). Second step: the manual was tested (1963-64) in a large number of countries. Third step: it was revised in light of the experience gained from the surveys. Regular revisions followed, the manual being in its sixth edition now. The philosophy of the OECD was explicitly stated in 1962 in the following terms[207]:

> It would be unrealistic and unwise to expect certain Member governments to adapt completely and immediately their present system of definition and classification of research and development activity to a proposed standard system of the OECD. However, it should perhaps be possible for governments to present the results of their surveys following a proposed OECD system, in addition to

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205 D. Guedj (2000), Le mètre du monde, Paris: Seuil.

206 E. Zerubavel (1982), The Standardization of Time: A Socio-Historical Perspective, American Journal of Sociology, 88 (1), p. 1-23.

207 FM (1962), p. 2.

> following their own national systems. Furthermore, governments could take account of a proposed OECD system when they are considering changes in their own system. Finally, those government who have yet to undertake statistical surveys of R&D activity could take account of, and even adopt, a proposed OECD system.

An additional factor explaining the relative consensus of OECD member countries with regard to accounting was the involvement of national statisticians in the construction of OECD statistics and methodological manuals. This took three forms. Firstly, the creation of a group of National Experts on Science and Technology Indicators (NESTI) to guide OECD activities. Secondly, the setting up of regular *ad hoc* review groups on science statistics to align OECD statistical work to users' needs. Thirdly, the active collaboration of member countries in developing specific indicators.

In the end, the Frascati manual was the product of a large number of influences: ideological, political, administrative, historical and individual. First, the manual owes its existence to the early policy demand for statistics. It was the OECD Directorate for Scientific Affairs that pushed and piloted the whole operation. It did this, secondly, with a view to orienting policies, and therefore the statistics, toward accounting. Third, the manual is the product of official statisticians who hold a specific view of the field and who "control" its measurement (via the national survey). Fourth, it owes most of its concepts to previous experiments in measurement, chief among them that of the US National Science Foundation. The Foundation was an influential source of ideas for several concepts like systematic research, basic research and the GERD matrix, but UNESCO, the United Nations, and the European Commission also played an important role, in classifications for example. Finally, one individual was behind several of these early developments – the manual but also the (economic) analyses of the time – the economist Freeman. Besides writing the first edition of the Frascati manual

(1962), Freeman would produce one of the first international statistical comparisons of R&D for the first OECD ministerial conference on science (1963). This analysis would be very influential on subsequent OECD studies of technological gaps. Freeman would also produce the first comparison of methodologies used in different countries to measure science (1965). In this study, he inaugurated the use of multiple indicators to measure science and technology. Finally, Freeman would contribute to the diffusion of OECD norms and methods on accounting to developing countries: he wrote the UNESCO manual for the measurement of scientific and technical activities (1969)[208].

[208] UNESCO (1969), The Measurement of Scientific and Technological Activities: Proposals for the Collection of Statistics on Science and Technology on an Internationally Uniform Basis, COM.69/XVI-15 A, Paris.

CHAPTER THREE

SCIENCE AND EFFICIENCY:
THE INPUT-OUTPUT FRAMEWORK

With its periodic publication, titled *Report of the World Social Situation*, first published in 1952, UNESCO launched a series of measurements of society based on an accounting framework. The exercise would soon be imitated worldwide, first of all in the United States[1]. According to Mancur Olson, contributor to the first such exercise in the United States, while the national income measures the growth or decline in the economy, a social report should measure "social gains and losses"[2]. The aim of social accounting is to go further than measurements of an economic type: "for all its virtues, the national income statistics don't tell us what we need to know about the condition of American society. They leave out most of the things that make life worth living (…). The most notable limitation of the national income statistics is that they do not properly measure those external costs and benefits that are not fully reflected in market prices"[3]. For Olson, the national welfare is also concerned, among other things, with learning, culture… and science.

Despite these suggestions, the example or model behind a social accounting is that of economic accounting. In fact, "the figures on the national income are probably the most impressive and elaborate type

1 US Department of Health, Education, and Welfare (1970), *Towards a Social Report*, Ann Arbor: University of Michigan Press.

2 M. Olson (1969), The Plan and Purpose of a Social Report, *The Public Interest*, 15, p. 86.

3 *Ibid*.

of socioeconomic measure that we have", admitted Olson[4]. Therefore, "the structure and parallelism of the chapters of *Towards a Social Report* derives in part from the paradigm of the national income and product accounts"[5].

Olson's proposal for including science in social reports had no impact. Rather, one must turn to specific publications dedicated to this end. The first such exercise appeared in 1973, and was prepared by the National Science Foundation (NSF) in the United States[6]. Inspired by the work of the OECD in the late 1960s when it collected multiple indicators to document technological gaps between the United States and Europe, the report collected several statistics that measured science according to several dimensions[7]. The model used to collect and analyze the newly imagined data on science was framed in terms of input and output. Inputs are investments in the resources necessary to conduct scientific activities, like money and scientific and technical personnel. Outputs are what come out of these activities: knowledge and inventions. A very simple framework defined the relationship between input and output as follows:

$$\text{Input} \rightarrow \text{Research activities} \rightarrow \text{Output}$$

Since the early 1960s, this framework has guided analysts in framing statistics into "meaningful" categories, within the academic literature (science and technology studies) as well as official circles like OECD and its member countries. As the OECD stated: "The term R&D [research and development] statistics covers a wide range of possible

4 *Ibid*.

5 *Ibid.*, p. 87.

6 National Science Board (1973), *Science Indicators 1972*, Washington: National Science Foundation.

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

statistical series measuring the *resources* devoted to R&D stages in the activity of R&D [input] and the *results* of the activity [output]"[8]. An international community of official statisticians has, over time, developed standards for measuring inputs devoted to R&D activities – known as the OECD Frascati manual – and produced a whole "family" of methodological manuals specifically dedicated to measuring output. Today, both series of statistics are collected and published in documents called compendiums or scoreboards of science and technology statistics.

Where does the input-output framework come from? Certainly, the framework is not alien to a long tradition of cost-benefit analyses in engineering and their use in policy decisions[9]. The framework is also not alien to input-output tables, as originally developed by W. Leontief[10], and used in the System of National Accounts. In this chapter, however, the origin of the framework is traced back to the economic literature and an econometric equation called the production function. At exactly the same time governments were getting interested in measuring science systematically, such analyses were very popular (and still are today). Several of these works were published under the auspices of the US National Bureau of Economic Research. This was the first real "concerted" attempt to integrate

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8 OECD (1981), *The Measurement of Scientific and Technical Activities: Proposed Standard Practice for Surveys of Research and Experimental Development*, Paris: OECD, p. 17.

9 For the introduction of accounting in "science policy" (or public decisions and programs involving scientific and technological activities), see T. M. Porter's discussion of the role of engineers in cost-benefit analyses: T. M. Porter (1995), *Trust in Numbers: The Pursuit of Objectivity in Science and Public Life,* Princeton: Princeton University Press. On accounting and science generally, see M. Power (ed.) (1994), *Accounting and Science: Natural Inquiry and Commercial Reason*, Cambridge: Cambridge University Press.

10 Leontief founded input/output accounts, and developed his first I-O tables in the 1930s to study the effects of technological change on the American economy. See: W. Leontief (1936), Quantitative Input-Output Relations in the Economic System of the United States, *Review of Economics and Statistics*, 18 (3), p. 105-125.

science into the economic equation. The analyses immediately offered a framework and a semantic to official statisticians for organizing statistics on science, technology and innovation.

Some authors have argued that economics has been framed into an accounting "metaphor" for a very long time[11]. A metaphor is a figure of speech used to understand one thing in terms of another. This chapter is concerned with how the input-output framework, as accounting metaphor, got into a specific kind of activity – science, technology and innovation, and its measurement. The chapter is divided into three parts. The first reviews the economists' model for studying science and its impact on the economy: the production function. Framed within an input-output vocabulary, the semantic was perfectly adapted to the official collection and interpretation of statistics for measuring the efficiency of science, technology and innovation investments. A large part of this section is devoted to the US National Bureau of Economic Research conference organized in 1960, which examined for the first time in history various aspects of the input-output framework. The second part looks at how the semantics of input and output entered into official statistics on science, technology and innovation. The work of the OECD and an influential consultant, Chris Freeman, serves here as the vehicle for examining the impact of the input-output framework on official science and technology statistics. The third part looks at what remains of the framework in current official statistics. It argues that the input-output framework is a symbolic representation or metaphor and has little to do with accounting as such.

From the start, a distinction and a clarification must be made. The input-output framework should not be confused with another framework, called the linear model of innovation[12]. The former is an accounting framework for science activities, and is concerned with measuring upstream and downstream quantities and establishing

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11 A. Klamer and D. McCloskey (1992), Accounting as a Master Metaphor of Economics, *European Accounting Review*, 1, p. 145-160.

12 See Chapter 1 above.

empirical relationships between the two. The linear model of innovation is devoted rather to explaining research activities themselves. Certainly, the activities or steps identified by the linear model are usually measured using input and output indicators. But the linear model is an analytical one – that owes a large debt to statistics, certainly – while the input-output framework is a framework that leaves research activities themselves as a "black box".

THE PRODUCTION FUNCTION

Science, technology and innovation came to be studied in quantitative terms by economists in the 1930s, namely in the context of increased mechanization of industries and the role of machines in the Great Depression. In order to measure technology as a cause of unemployment (technological unemployment as it was called), economists developed statistics linking technology to labor productivity (that is, equating the two), defined as "quantity output per employee man-year". Most economists then "showed" that technology increases the productivity of labor[13].

The US Work Projects Administration has been quite influential. With over sixty projects conducted between 1938 and 1940, among them one on the impact of the depression on industrial laboratories[14], D. Weintraub, as director of the project on Reemployment Opportunities and Recent Change in Industrial Techniques, thought, in line with a study he conducted for the National Bureau of

13 D. Weintraub (1937), Unemployment and Increasing Productivity, in National Research Council, *Technological Trends and National Policy*, Washington.

14 G. Perazich and P. M. Field (1940), *Industrial Research and Changing Technology*, Work Projects Administration, National Research Project, report no. M-4, Pennsylvania: Philadelphia.

Economic Research in 1932[15], that measuring labor productivity as a ratio of "quantity output per employee man-year" would answer the question on technology and unemployment, "since the net effects of the underlying economic factors find their quantitative expression in the net changes of the volume of production and employment, a statistical analysis of the relationship between the total volume of goods and services produced in the country and the number of hired workers engaged in the production offers an approach toward a better understanding of the nature of a problem which has come to be referred popularly as that of technological unemployment"[16]. To Weintraub, "the unit-labor-requirement ratio indicates changes in man-years employed per unit of total output"[17]. If the same number of workers or less is required to produce the same level of output or more, it means that technology causes increased productivity, and therefore unemployment. Indeed, Weintraub found a disparity between production and employment: "while production in 1935 was 14 percent above 1920, the productivity of hired workers was 39 percent higher or the unit labor requirement was 28 percent lower (…). While 146 units of the nation's output were being produced in 1929 for every 100 in 1920, only 16 percent more man-years were employed in 1929"[18].

Weintraub admitted, however, that his ratio of labor productivity "cannot be interpreted as measures of the extent of technological

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15 For an early economic writer on framing the problem of technological unemployment in terms of productivity, or input/output ratio, see: P. H. Douglas (1930), Technological Unemployment, *American Federationist*, 37 (8), p. 923-950; P. H. Douglas (1930), Technological Unemployment: Measurement of Elasticity of Demand as a Basis for Prediction of Labor Displacement, *Bulletin of the Taylor Society*, 15 (6), p. 254-270; P. H. Douglas and A. Director (1931), *The Problem of Unemployment*, New York: Macmillan, p. 119-164.

16 D. Weintraub (1937), Unemployment and Increasing Productivity, *op. cit.*, p. 67.

17 *Ibid.*, p. 72.

18 *Ibid.*, p. 71-72.

advance"[19]. "To measure the full effect of even a single technological change on displacement or absorption would necessitate the virtually impossible task of tracing it through the innumerable factors which bear on the total volume of production and employment"[20]. "The effect of strictly technological change on employment in a single industry or even a single plant cannot be isolated (…). Over-all productivity ratios (…) reflect a variety of factors in addition to the mechanical improvements"[21]. In the end, Weintraub concluded that the productivity ratios "can be regarded as indicative of the effects of technological changes only in the broadest sense"[22].

Despite these caveats, measuring labor productivity became the main statistics on the outcomes of science and technology. Using the production function, economists began interpreting movements in the curve as technological change (the substitution of capital for labor), while others equated labor productivity with science (technological change is likely to result, all other things being equal, in labor productivity), and still others correlated R&D with productivity measures.

We often read in the literature that R. Solow was the first author to quantify, although imperfectly, the impact of science, technology and innovation on the economy. This is probably because his article is part of the very formalized tradition of econometrics[23]. Yet other authors preceded him by several years, as M. Abramovitz recalled[24], and used the same kind of model: the production function.

The production function is an equation, or econometric "model" that links the quantity produced of a good (output) to quantities of input.

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19 *Ibid.*, p. 78.

20 *Ibid.*, p. 80.

21 *Ibid.*, p. 79.

22 *Ibid*.

23 R. M. Solow (1957), Technical Change and the Aggregate Production Function, Review of Economics and Statistics, 39, August, p. 312-320.

24 M. Abramovitz (1989), Thinking About Growth, New York: Cambridge University Press, p. 71.

There are, at any given time, or so argue economists, inputs (labour, capital, technology) available to the firm, and a large variety of techniques by which these inputs can be combined to yield the desired (maximum) output. As E. Mansfield explained: "The production function shows, for a given level of technology, the maximum output rate which can be obtained from a given amount of inputs"[25]. Other economists shared his description: "Basically, technological progress consists of any change (…) of the production function that either permits the same level of output to be produced with less inputs or enables the former levels of input to produce a greater output"[26].

The production function was the first framework used to integrate science, technology and innovation into economic analyses. It had several variants: some simply interpreted movements in the production function, or curve, as technological change (the substitution of capital for labour), while others equated labour productivity with science (technological change is likely to result, all other things being equal, in labour productivity), and still others correlated R&D with multifactor productivity.

The production function is directly inspired by classical economics and the maximization axiom, or rationality as efficiency (means-ends): maximizing output for a given input, or minimizing input for a given output. C. W. Cobb and P. H. Douglas were the first to formalize the idea of the production function in the late 1920s[27]. With

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[25] E. Mansfield (1968), The Economics of Technological Change, New York: Norton, p. 13.

[26] C. Ferguson (1969), *Microeconomic Theory*, Homewood: Richard D. Irwin Inc, p. 386.

[27] C. W. Cobb and P. H. Douglas (1928), A Theory of Production, *American Economic Review*, 18, March, p. 139-165; P. H. Douglas (1948), Are There Laws of Production?, *American Economic Review*, 38, March, p. 1-41. Douglas also contributed to the debate on technological unemployment in the 1930s, using the concept of productivity. See: P. H. Douglas (1930), Technological Unemployment, *American Federationist*, 37 (8), p. 923-950; P. H. Douglas (1930), Technological Unemployment: Measurement of Elasticity of Demand as a Basis for Prediction of Labor

regard to science, we find an early use in J. Schumpeter's works – a fact often forgotten today. In *Business Cycles*, Schumpeter defined innovation by means of the production function[28]: "This function describes the way in which quantity of product varies if quantities of factors vary. If, instead of quantities of factors, we vary the form of the function, we have an innovation"[29]. "Whenever at any time a given quantity of output costs less to produce than the same or a smaller quantity did cost or would have cost before, we may be sure, if prices of factors have not fallen, that there has been innovation somewhere"[30]. Innovation, then, is "the combination of factors in a new way", "the setting up of a new production function": a new commodity, a new form of organization, or opening up of new markets.

We had to wait for the patronage of the US National Bureau of Economic Research to see the development of a systematic and continued interest in science, technology and innovation and the production function, a development of which Solow was part (see Table 1). The 1930s, and the following decades, can in fact be described as the beginning of a long series of studies on productivity and the role of science in explaining growth rates.

In 1960, in collaboration with the US Social Science Research Council, the National Bureau of Economic Research organized an important conference on the economics of science. The conference was probably the first time the production function was extensively discussed for studying science. In fact, most of the papers were concerned with an input-output framework. As Z. Griliches reported, the conference's focus was "on the knowledge producing industry, its output, the resources available to it, and the efficiency with which

Displacement, *Bulletin of the Taylor Society*, 15 (6), p. 254-270; P. H. Douglas and A. Director (1931), *The Problem of Unemployment*, New York: Macmillan, p. 119-164.

28 J. Schumpeter (1939), Business Cycles, *op. cit*.

29 *Ibid.*, p. 87.

30 *Ibid.*, p. 89.

they are being used"[31]. Equally, to F. Machlup, "the analysis of the supply of inventions divides itself logically into three sections": input, input-output relationship (the transformation of inventive labour into useful inventions), output[32].

The framework was not without its detractors. Perhaps the most critical was W. Leontief who, in the late 1960s, would argue that "elaborate aggregative growth models can contribute very little to the understanding of processes of economic growth, and they cannot provide a useful theoretical basis for systematic empirical analysis"[33]. Regular users like Griliches were also critical: "the concept of a production function, frontier, or possibilities curve [is] a very unsatisfactory tool of analysis"[34]. The criticisms generally centered around two lines of argument. First, how do we measure input and output with regard to science and technology? Second, what is the relationship between input and output?

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31 Z. Griliches (1962), Comment on W. R. Mueller's paper, in National Bureau of Economic Research, *The Rate and Direction of Inventive Activity*, Princeton: Princeton University Press, p. 347.

32 F. Machlup (1962), The Supply of Inventors and Inventions, in National Bureau of Economic Research, The Rate and Direction of Inventive Activity, *op. cit*. p. 143.

33 W. Leontief (1970), Comment on J. S. Chipman's paper, in R. Vernon (ed.), *The Technology Factor in International Trade*, National Bureau of Economic Research, New York: Columbia University Press, p. 132.

34 Z. Griliches (1962), Comment on W. R. Mueller's paper, *op. cit*. p. 348.

Table 6. US National Bureau of Economic Research's Early Studies on Productivity, Science, Technology and Innovation

D. Weintraub (1932), The Displacement of Workers Through Increases in Efficiency and their Absorption by Industry.

F. C. Mills (1932), Economic Tendencies in the United States.

H. Jerome (1934), Mechanization in Industry.

F. C. Mills (1936), Prices in Recession and Recovery.

F. C. Mills (1938), Employment Opportunities in Manufacturing Industries of the United States.

G. S. Stigler (1947), Trends in Output and Employment.

S. Fabricant (1954), Economic Progress and Economic Change.

J. W. Kendrick (1961), Productivity Trends in the United States.

National Bureau of Economic Research (1962), The Rate and Direction of Inventive Activity.

These questions were discussed at length by Z. Griliches, S. Kutznets, F. Machlup, J. Schmookler and researchers from RAND[35], among others, at the National Bureau of Economic Research conference. Defining invention and understanding the process of invention was an issue addressed by almost every speaker. To a certain extent, the issue relied on appropriate statistics for measuring input and output. Almost all available statistics were criticized. In one of two introductory papers to the conference, B. S. Sanders, from the Patent, Trademark, and Copyright Foundation of George Washington University, declared: "none of the measures used to date is satisfactory even as a crude measure of inventiveness as such or

35 K. J. Arrow, C. J. Hitch, B. H. Klein, A. W. Marchall, W. H. Meckling, J. R. Minasian and R. R. Nelson.

inventive activity"[36]. With regard to input measures, Sanders argued that labour devoted to inventive activity was badly measured, as were expenditures on R&D, because they were limited to institutions and subject to judgment. All in all, "neither the quality nor the completeness of the information which we now have, nor our conceptual understanding of the functional relationship between input and inventions, are such as to enable us to determine from apparent trends in input the trends in inventions"[37]. With regard to output, Sanders was equally critical: "We have devised no objective yardstick for the measurement of this quantity and may never be able to devise one (…). Substituting in its place some measurable end product far removed from the initial act of inventing (…) may be the nearest we shall ever be able to come to measuring invention"[38]. J. Schmookler did not entirely agree, particularly on patent statistics: "No one will dispute that accurate measures of a thing are always better than an uncertain index of it (…). In the meantime, much as we might prefer caviar, we had better settle for plain bread when that is all we can get. The question, therefore, is not whether to use statistics of aggregate patents granted or applied, but how"[39].

S. Kuznets was as pessimistic as Sanders, particularly with regard to the new data series on R&D coming out of the National Science Foundation's recently-launched series of surveys, because it included development – an activity Kuznets qualified as adjustment, not original invention – and excluded the efforts of individuals and independent inventors[40]. The National Science Foundation

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[36] B. S. Sanders (1962), Some Difficulties in Measuring Inventive Activity, in National Bureau of Economic Research, The Rate and Direction of Inventive Activity, *op. cit*. p. 53.

[37] *Ibid.*, p. 63.

[38] *Ibid.*, p. 65.

[39] J. Schmookler (1962), Comment on B. S. Sanders's paper, in National Bureau of Economic Research, The Rate and Direction of Inventive Activity, *op. cit*. p. 78.

[40] S. Kuznets (1962), Inventive Activity: Problems of Definition and Measurement, in National Bureau of Economic Research, The Rate and Direction of Inventive Activity, *op. cit*. p. 19-51.

representative, H. I. Liebling, accused Kuznets of applying "somewhat more rigorous standards to the R&D series than he does to the national income category we have learned from him"[41]. To Liebling, "in the construction of any complex set of statistics, attention must be given to its operational requirements in obtaining a successful measure, often requiring the adoption of certain conventions"[42]. To the National Science Foundation, he added, the "series on R&D expenditures is designed [mainly] to measure the scope of the scientific effort for government policy purposes"[43].

Defining input and output was only one of the two issues addressed during the conference. The other was the relationship between input and output. "Our economy operates on the belief that there is a direct causal relationship between input and the frequency and extent of inventions", recalled Sanders[44]. "No doubt there is a direct relationship of some kind, but we have no evidence that this relationship does not change". Griliches asked the participants "whether an increase in inputs in the knowledge producing industry would lead to more output"[45]. Machlup's answer was: "a most extravagant increase in input might yield no invention whatsoever, and a reduction in inventive effort might be a fluke result in the output that had in vain been sought with great expense"[46]. To Griliches, "none of [the] studies [from the conference: J. R. Minasian,

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41 H. I. Liebling (1962), Comment on S. Kuznets' paper, in National Bureau of Economic Research, The Rate and Direction of Inventive Activity, *op. cit*. p. 89.

42 *Ibid.*, p. 88.

43 *Ibid.*, p. 90.

44 B. S. Sanders (1962), Some Difficulties in Measuring Inventive Activity, *op. cit*., p. 55. For a highly lucid analysis on the same topic at about the same time, see: W. H. Shapley (1959), Problems of Definition, Concept, and Interpretation of Research and Development Statistics, in National Science Foundation, *Methodological Aspects of Statistics on Research and Development: Costs and Manpower*, NSF 59-36, Washington

45 Z. Griliches (1962), Comment on W. R. Mueller's paper, *op. cit.*, p. 349.

46 F. Machlup (1962), The Supply of Inventors and Inventions, *op. cit*., p. 153.

R. R. Nelson, J. L. Enos, A. W. Marshall and W. H. Meckling] comes anywhere near supplying us with a production function for inventions", and when they establish a relationship between input and output, these relationships "are not very strong or clear"[47].

The problem with regard to the relationship between input and output was threefold, the last part of which several participants discussed at the conference. First, there was the well-known problem of causality. Although J. R. Minasian, from RAND Corporation, concluded his study by affirming that "beyond a reasonable doubt, causality runs from research and development to productivity, and finally to profitability"[48], what the production function demonstrated was a correlation between input and output, rather than any causality. The production function is "only an abstract construction designed to characterize some quantitative relationships which are regarded as empirically relevant", stated Machlup[49]. Second, there was the problem of lags between invention and its diffusion, which complicates measurements and was rarely addressed by econometricians. Related to this problem, and finally, there were difficulties in accounting correctly for returns on R&D. To Machlup, there were two schools of thought here: "According to the acceleration school, the more that is invented the easier it becomes to invent still more – every new invention furnishes a new idea for potential combination (…). According to the retardation school, the more that is invented, the harder it becomes to invent still more – there are limits to the improvement of technology"[50]. To Machlup, the first hypothesis was "probably more plausible", but "an increase in opportunities to invent need not mean that inventions become easier to make; on the contrary, they become harder. In this case there

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47 Z. Griliches (1962), Comment on W. R. Mueller's paper, *op. cit.*, p. 350.

48 J. R. Minasian (1962), The Economics of Research and Development, in National Bureau of Economic Research, The Rate and Direction of Inventive Activity, *op. cit*. p. 95.

49 F. Machlup (1962), The Supply of Inventors and Inventions, *op. cit*., p. 155.

50 *Ibid*., p. 156.

would be a retardation of invention (…)"[51], because "it is possible for society to devote such large amounts of productive resources to the production of inventions that additional inputs will lead to less than proportional increases in output"[52].

From the conference and its participants, we can conclude that the semantics of input and output, and a model linking the two, were definitely in place by the early 1960s, at least in economists' prose. The model was far from perfect, but economists would make extensive use of it in the following decades, calculating social and private rates of return on R&D[53], estimating multifactor productivity and economic growth[54], and measuring sectoral flows of technology[55], as an extension to input-output tables[56].

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51 *Ibid*., p. 162.

52 *Ibid*., p. 163.

53 Z. Griliches (1958), Research Costs and Social Return: Hybrid Corn and Related Innovations, *Journal of Political Economy*, 66 (5), p. 419-431; E. Mansfield (1965), Rates of Return from Industrial R&D, *American Economic Review*, 55 (2), p. 310-32; J. R. Minasian (1969), R&D, Production Functions, and Rates of Return, *American Economic Review*, 59 (2), p. 80-85; E. Mansfield et al. (1977), Social and Private Rates of Return From Industrial Innovations, *Quarterly Journal of Economics*, May, p. 221-240.

54 E. F. Denison (1962), *The Sources of Economic Growth in the United States and the Alternatives Before Us*, Committee for Economic Development, New York; E. F. Denison (1967), *Why Growth Rates Differ*, Washington: Brookings Institution; D. W. Jorgensen and Z. Griliches (1967), The Explanation of Productivity Change, *Review of Economic Studies*, 34 (3), p. 249-283.

55 C. Maestre (1966), Vers une mesure des échanges intersectoriels entre la recherche et l'industrie, *Progrès scientifique*, 102, November, p. 2-45; F. M. Scherer (1982), Inter-Industry Technology Flows in the United States, *Research Policy*, 11, p. 227-245; K. Pavitt (1984), Sectoral Patterns of Technical Change: Towards a Taxonomy and a Theory, *Research Policy*, 13, p. 343-373; M. Robson, J. Townsend and K. Pavitt (1988), Sectoral Patterns of Production and Use of Innovations in the UK, 1945-1983, *Research Policy*, 17, p. 1-14.

56 W. Leontief (1936), Quantitative Input-Output Relations in the Economic System of the United States, *op. cit*.; W. Leontief (1953), Domestic Production and Foreign Trade: the American Capital Position Re-

Two years after the National Bureau of Economic Research conference, Machlup published his work on the knowledge economy, defined and measured as education, R&D, communication, information[57]. The whole work was based on an accounting framework. In his chapter on R&D, Machlup constructed a much-quoted table where a list of indicators on input and output were organized according to stages of research (basic research, applied research, development, innovation) and according to whether they were tangible or intangible, and whether they were measurable (see Appendix 3)[58]. Machlup's table marked a transition here. From a theoretical and "abstract construct", the production function became a "practical" tool as well. Official statisticians would follow Machlup and adapt the input-output semantic to their efforts at measuring science. To understand how the input-output framework got into official statistics and indicators on science, technology and innovation, one has to turn to the OECD and UNESCO, and the work of an economist as consultant, Chris Freeman.

THE ECONOMICS OF SCIENCE

As documented in the previous chapter, the first edition of the OECD Frascati manual, written by C. Freeman, set the stage for an input-

Examined, *Proceedings of the American Philosophical Society*, 97 (4); W. Leontief (ed.) (1953), Studies in the Structure of the American Economy, *op. cit.*; W. Leontief (1966), *Input-Output Economics*, Oxford: Oxford University Press, 1986.

57 For a very early collection of several statistics on science (patents, inventions, discoveries) used for measuring knowledge and its growth, see W. F. Ogburn and S. C. Gilfillan (1933), The Influence of Invention and Discovery, in *Recent Social Trends in the United States*, Report of the President's Research Committee on Social Trends, New York: McGraw Hill, p. 126.

58 F. Machlup (1962), *The Production and Distribution of Knowledge in the United States*, Princeton: Princeton University Press, p. 178-179. The table, with an acknowledgement to Machlup, first appeared in E. Ames (1961), Research, Invention, Development and Innovation, *American Economic Review*, 51 (3), p. 370-381.

output approach as a framework for science statistics. Freeman continued to advocate an input-output framework in the following years, to UNESCO officials among others. “There is no nationally agreed system of output measurement, still less any international system”, repeated C. Freeman in 1969 in a study on output conducted for UNESCO. “Nor does it seem likely that there will be any such system for some time to come. At the most, it may be hoped that more systematic statistics might become possible in a decade or two”[59]. The dream persisted, however, because “it is only by measuring innovations (…) that the efficiency of the [science] system (…) can be assessed”, continued Freeman[60]. “The output of all stages of R&D activity is a flow of information and the final output of the whole system is innovations – new products, processes and systems”[61].

To Freeman, “the argument that the whole output of R&D is in principle not definable is unacceptable (…). If we cannot measure all of it because of a variety of practical difficulties, this does not mean that it may not be useful to measure part of it. The GNP does not measure the whole of the production activity of any country, largely because of the practical difficulties of measuring certain types of work. The measurement of R&D inputs omits important areas of research and inventive activity. But this does not mean than GNP or R&D input measures are useless”[62]. And what about the relationship between input and output? “The argument that the input/output relationship is too arbitrary and uncertain in R&D activity to justify any attempts to improve efficiency or effectiveness (…) rests largely on the view that unpredictable accidents are so characteristic of the process that rationality in management is impossible to attain (…). The logical fallacy lies in assuming that, because accidental features

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59 C. Freeman (1969), *Measurement of Output of Research and Experimental Development*, UNESCO, ST/S/16, p. 8.

60 *Ibid.*, p. 25.

61 *Ibid.*, p. 27.

62 *Ibid.*, p. 10-11.

are present in individual cases, it is therefore impossible to make useful statistical generalizations about a class of phenomena"[63].

Armed with such a "convincing" rationale, the Frascati manual continued, edition after edition, to suggest an input-output framework for science (under paragraph 1.4), as well as offering its readers an appendix discussing output indicators. It also continued to argue for the development of output indicators as follows: "Problems posed by the use of such data should not lead to their rejection as they are, for the moment, the only data which are available to measure output"[64]. "At present, only R&D inputs are included in official R&D statistics and, thus, in the body of this manual. This is regrettable since we are more interested in R&D because of the new knowledge and inventions which result from it than in the activity itself"[65].

The 1993 edition of the manual innovated, however, by adding a table presenting the OECD "family" of methodological manuals on measuring science, among them three manuals on output indicators[66]. What happened that could explain such a sudden development on output indicators (Table 7)?[67]

In 1973, the National Science Foundation published the first edition of *Science Indicators*, a compendium of statistics on science covering

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63 *Ibid.*, p. 11.

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

65 *Ibid.*, p. 17.

66 This was a small innovation, however, compared to the proposal, made fifteen years before, about transforming the Frascati manual into a manual on indicators. See: OECD (1978), *General Background Document for the 1978 Meeting of the Group of National Experts on R&D Statistics*, DSTI/SPR/78.39 and annex.

67 To this table, we could add a working paper on bibliometrics: Y. Okubo (1997), *Bibliometric Indicators and Analysis of Research Systems: Methods and Examples*, OECD/GD (97) 41. This document, however, was not really a methodological manual.

both input and output[68]. What characterized the NSF publication, besides the fact that it was the first of a regular series that systematically collected a large number of statistics on science, was that it carried an input-output framework. Despite the quality of the publication, this framework was rapidly criticized by academics at conferences held in 1974 and 1976[69] and by other public organizations: *Science Indicators* is "too constricted by an input-output framework. In this approach, science and technology are seen as resources which go into, and tangible results which come out of, a black box", complained the US General Accounting Office (GAO)[70].

Table 7. The OECD Family of R&D Manuals

1962	The Measurement of Scientific and Technical Activities: Proposed Standard Practice for Surveys of Research and Development (Frascati manual).
1990	Proposed Standard Practice for the Collection and Interpretation of Data on the Technological Balance of Payments.
1992	Proposed Guidelines for Collecting and Interpreting Technological Innovation Data (Oslo manual).
1994	Data on Patents and Their Utilization as Science and Technology Indicators.
1995	Manual on the Measurement of Human Resources in Science and Technology (Canberra manual).

68 B. Godin (2003), The Emergence of Science and Technology Indicators: Why Did Governments Supplement Statistics with Indicators?, *Research Policy*, 32 (4), p. 670-690.

69 Papers from the conferences can be found in: Y. Elkana et al. (1978), *Towards a Metric of Science: The Advent of Science Indicators*, New York: John Wiley; H. Zuckerman and R. Balstad-Miller (eds.) (1980), Science Indicators 1976, *Scientometrics*, 2 (5-6), Special Issue.

70 GAO (1979), *Science Indicators: Improvements Needed in Design, Construction, and Interpretation*, Washington, p. 19.

Be that as it may, the publication caught the attention of the OECD and its second *ad hoc* review group on science statistics: output could be measured. The publication served as a catalyst to OECD efforts on measuring output. After more than twenty years devoted almost exclusively to collecting and analyzing data on inputs[71], the OECD organized a large conference on output indicators in 1980, launched experimental studies and convened workshops concerned with specific output indicators: patents, technological receipts and payments, high-technology and innovation[72]. These activities produced two results.

First, an analytical series entitled *Science and Technology Indicators* was started in 1984. Three editions were published, then replaced in 1988 by *Main Science and Technology Indicators*, a collection of statistics on science for each member country, covering both input and output series: GERD, R&D personnel, patents, technological balance of payments and high-technology trade. *Main Science and Technology Indicators* was complemented, in the mid 1990s, by a series titled *Science, Technology and Industry Scoreboard*, containing a larger set of statistics, and ranking countries accordingly. The second result from the OECD work was a series of methodological manuals on measuring output, and intended for official statisticians.

From the start, national statisticians vehemently criticized the indicators on output. The main point of controversy related to

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71 OECD (1967), *A Study of Resources Devoted to R&D in OECD Member Countries in 1963/64: The Overall Level and Structure of R&D Efforts in OECD Member Countries*, Paris; OECD (1971), *R&D in OECD Member Countries: Trends and Objectives*, Paris; OECD (1975), *Patterns of Resources Devoted to R&D in the OECD Area, 1963-1971*, Paris; OECD (1975), *Changing Priorities for Government R&D: An Experimental Study of Trends in the Objectives of Government R&D Funding in 12 OECD Member Countries, 1961-1971*, Paris; OECD (1979), *Trends in Industrial R&D in Selected OECD Countries, 1967-1975*, Paris.

72 B. Godin (2005), Measuring Output: When Economics Drives Science and Technology Measurement, in B. Godin, Measurement and Statistics on Science and Technology, *op. cit.*

methodology[73]. Every indicator was said to measure the phenomenon improperly, a point already made by Sanders and Kuznets, because of the limitation of the concepts underlying the indicators: patents measured only part of innovations; technological receipts and payments did not consider non-market exchanges of technology; and high-technology indicators minimized embodied technology and diffusion. To the OECD, however, these limitations were manageable. On patents, for example, the OECD argued: "There has been continuing controversy over the use of patent statistics. (…). But, as J. Schmookler wrote, we have a choice of using patent statistics continuously and learning what we can from them, and not using them and learning nothing. (…). All progress in this field will come ultimately from the reasoned use of this indicator which, while always taking into account the difficulties it presents, works to reduce them[74]. Similarly, for the indicator on high-technology: "Obviously, one has to be very careful in making policy conclusions on the basis of statistically observed relationships between technology-intensity measures and international competitiveness. Yet, as emphasized by one participant, to deny that policy conclusions can be made is to ignore some of the most challenging phenomena of the last decade"[75].

The main reason for criticizing output indicators, however, and one rarely avowed, had to do with the fact that the data came from other sources than the official survey, sources over which the official statisticians had no control[76]. Nevertheless, one output indicator gained rapid and widespread consensus among national statisticians: the measurement of technological innovation. From the beginning, science policy was definitively oriented toward economic goals and

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73 *Ibid*.

74 OECD (1983), State of Work on R&D Output Indicators, SPT (83) 12, p. 11.

75 OECD (1980), Preliminary Report of the Results of the Conference on Science and Technology Indicators, SPT (80) 24, p. 18.

76 B. Godin (2005), Measuring Output: When Economics Drives Science and Technology Measurement, op. cit.

technological innovation. In fact, to policy-makers, innovation was always considered to be the final output of the science system, as suggested by Freeman. What helped achieve the consensus view on innovation indicators was the fact that official statisticians could develop a tool that they controlled: the survey of innovation activities[77].

Having measured input and output, the OECD could then turn to the task of relating them to one another. It did so precisely on the same topic as that studied by economists in the 1950s – growth and productivity – and with the same methodology: the production function and multifactor productivity. In the 1990s, as discussed below (Chapter 4), as part of the OECD Growth Project, the Directorate for Science, Technology and Industry analyzed economic growth and productivity trends and the role that information and communication technologies play in it.

AN ACCOUNTING FRAMEWORK

Linking input to output came quite late in official statistical work on science. As a matter of fact, no input-output ratio has even been constructed by national bureaus of statistics to measure the efficiency of science. The one and only ratio in the official literature is GERD/GDP[78]. Certainly, one could argue that GDP accounts for (economic) output. But the ratio GERD/GDP measures intensity or efforts (that part of economic activities devoted to R&D), not efficiency.

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77 B. Godin (2005), The Rise of Innovation Surveys: Measuring a Fuzzy Concept, in B. Godin, Measurement and Statistics on Science and Technology, op. cit.

78 And variants on this measure. See: B. Godin (2004), The Obsession for Competitiveness and its Impact on Statistics: The Construction of High-Technology Indicators, *Research Policy*, 33 (8), p. 1217-1229.

Nor can one find any trace of input-output framework in recent scoreboards of statistics. Certainly, the very first editions of the scoreboards included some elements, in the sense that indicators were grouped into categories corresponding, among others, either to inputs or outputs, the latter with this precise label. The following editions, however, reorganized the groupings and re-labeled the categories without any trace of the input-output semantics. Scoreboards are actually simple collections of statistics, where ranking of countries is the (very indirect and only) measure of efficiency.

We have, then, to look elsewhere for traces of accounting and efficiency in official statistics on science. The very first edition of the Frascati manual suggested classifying R&D by dimension. One of the central dimensions was concerned with economic sectors. In line with the system of national accounts, and following the practice of the National Science Foundation[79], the manual recommended collecting and classifying R&D according to the following four main economic sectors: business, government, university and private non-profit[80]. This alignment to the system of national accounts gave us Gross Expenditures on R&D (GERD), which is the sum of R&D expenditures in the four economic sectors, and gave us the matrix of R&D flows between economic sectors of the System of National Accounts.

Yet this "accounting" is not real accounting. First, with regard to inputs: despite its alignment with the system of national accounts, GERD is not really a national budget, as we have documented in the previous chapter. Second, outputs are measured via proxies rather than as actual outputs, and are constructed from different sources that

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79 K. Arnow (1959), National Accounts on R&D: The National Science Foundation Experience, in NSF, Methodological Aspects of Statistics on R&D, *op. cit*. p. 57-61; H. E. Stirner (1959), A National Accounting System for Measuring the Intersectoral Flows of R&D Funds in the United States, in NSF, Methodological Aspects of Statistics on R&D, *op. cit*. p. 31-38.

80 Households, as a sector in the SNA, was not considered separately by the manual, but was included in the non-profit sector.

do not share any common framework. Third, very few, if any, official statistics exists that link input to output as measures of efficiency. In retrospect, the efficiency in official statistics on science is rather symbolic, or a semantics based on an accounting metaphor within which numbers are discussed and presented.

What then are the virtues of this framework? A framework is a representation. It provides meaning and organization. The input-output framework was part of the understanding of science policy that developed after World War II. The measurement of science emerged within a background and an intellectual context composed of ideas and models all concerned with accounting and efficiency[81]. The production function was one such, as was the System of National Accounts[82] and the input-output tables[83]. But there were also operations research, cybernetics, system analysis, and the emerging positive political science, all concerned with rational choice and costs-benefit analyses[84]. This whole "philosophy" of accounting

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81 On this context, see: P. Miller and T. O'Leary (1987), Accounting and the Construction of the Governable Person, *Accounting, Organizations and Society*, 12 (3), p. 235-265.

82 P. Studenski (1958), The Income of Nations: Theory, Measurement, and Analysis: Past and Present, New York: New York University Press; N. Ruggles and R. Ruggles (1970), The Design of Economic Accounts, NBER, New York: Columbia University Press; F. Fourquet (1980), Les comptes de la puissance: histoire de la comptabilité nationale et du plan, Paris: Encres; A. Vanoli (2002), Une histoire de la comptabilité nationale, Paris: La Découverte. A. Maddison (2003), The World Economy: Historical Statistics, Paris: OECD.

83 W. Leontief (1966), Input-Output Economics, op. cit.

84 A. Wildavsky (1966), The Political Economy of Efficiency: Cost-Benefit Analysis, Systems Analysis, and Program Budgeting, Public Administration Review, 26 (4), p. 292-310; I. R. Hoos (1972), Systems Analysis in Public Policy: A Critique, Berkeley: University of California Press. RAND, one of the pioneers on the economics of technical change, was part of this movement (see the paper from RAND researchers for the NBER conference). However, the focus at RAND was generally on allocating resources to science and technology rather than with an input-output framework per se. See: D. A. Hounshell, The Medium is the Message, or How Context Matters: the RAND Corporation Builds an Economics of Innovation, 1946-1962, in A. C. Hughes and T. P. Hughes

spread rapidly to official statistics: social indicators[85], education[86], environment[87], health[88], human capital[89] and … science.

In this context, the input-output framework as metaphor served discourses on science policy in the sense that it contributed to making sense of (already made) decisions. C. Freeman's is a good example of such argumentation: "As long as governments or enterprises were spending only very small sums on scientific research, they could afford to regard this outlay in a very similar way to patronage of the arts, using prestige criteria rather than attempting to assess efficiency. But it is one thing to endow an occasional eminent scientist; it is quite another to maintain laboratories regularly employing thousands of scientists and technicians on a continuous basis. The increased scale of scientific activities led inexorably to an increased concern with their effectiveness"[90].

If there was any real accounting in science policy, it did not owe anything to official statistics and its input-output framework. It was conducted elsewhere than in statistical offices – in government departments – and with other kinds of statistics: administrative data.

(eds.) (2000), Systems, Experts, and Computers: The Systems Approach in Management and Engineering, World War II and After, Cambridge (Mass.): MIT Press, p. 255-310.

85 UNESCO (1952), *Report of the World Social Situation*, Paris; US Department of Health, Education, and Welfare (1970), Towards a Social Report, *op. cit*.; United Nations (1975), Towards a System of Social and Demographic Statistics, *Studies in Methods*, Series F, 18, New York, United Nations; United Nations (1989), *UN Handbook on Social Indicators*, New York: United Nations.

86 OECD (1992), *Education at a Glance: OECD Indicators*, Paris.

87 P. Bartelmus et al. (1991), Integrated Environmental and Economic Accounting Framework for a SNA Satellite System, *Review of Income and Wealth*, 2, p. 111-148.

88 OECD (2000), *A System of Health Accounts*, Paris.

89 OECD (1996), *Measuring What People Know: Human Capital Accounting for the Knowledge Economy*, Paris; OECD (1998), *Human Capital Investment: An International Comparison*, Paris.

90 C. Freeman (1969), Measurement of Output of Research and Experimental Development, *op. cit*. p. 7.

Official statistics, because they were "too macro", were usually not appropriate to such tasks. They were what I have elsewhere called "contextual" data[91]. As the OECD admitted recently: "Monitoring and benchmarking are not coupled with policy evaluation (…). They are seldom used for evaluation purposes (…) but to analyze [countries'] position vis-à-vis competing countries and to motivate adaptation or more intense policy efforts (…)"[92].

Official statistics mainly served discourse purposes, and in this sense the input-output framework and the statistics presented within it were influential because they fit perfectly well with the policy discourse on rationality, efficiency and accountability: it aligns and frames the science system, by way of statistics, as goal-oriented and accountable. As it actually exists, accounting and efficiency in official statistics on science is a metaphor[93].

CONCLUSION

Accounting of a certain type exists in science. For decades, firms have constructed input-output ratios to assess rates of return on their

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91 B. Godin (2005), Are Statistics Really Useful? Myths and Politics of Science and Technology Measurement, in B. Godin, Measurement and Statistics on Science and Technology, *op. cit*.

92 OECD (2005), *Governance of Innovation Systems*, vol. 1, Paris: OECD, p. 64.

93 For a reading of accounting as symbolic and metaphoric, see: B. G. Carruthers and W. N. Espeland (1991), Accounting for Rationality: Double-Entry Bookkeeping and the Rhetoric of Economic Rationality, American Journal of Sociology, 97 (1), p. 31-69. Some authors prefer talking of accounting as a "social and organizational" practice for naming the ideology of efficiency by numbers. This includes all types of accounting that are implicated in economic activities such as costing, budgeting, cost-benefit analysis, risk assessment, censuses, samples, etc. See: A. G. Hopwood and P. Miller (eds.) (1994), *Accounting as Social and Institutional Practice*, Cambridge: Cambridge University Press; M. Power (ed.) (1994), Accounting and Science: Natural Inquiry and Commercial Reason, *op. cit.*

investments[94], including investments in R&D[95]. Governments have conducted their evaluation exercises using data that deal with both investments and results[96]. The input-output framework used to frame official statistics on science is part of this movement, as were other official "accounting" exercises such as the measurements of the technological balance of payments, the balance between types of research (fundamental and applied), and human capital.

Academics were very influential in these accounting developments. The first were economists, above all C. Freeman, author of the first edition of the OECD Frascati manual. Very early on, Freeman conducted statistical studies linking input to output[97], and remained a fervent advocate of the input-output framework for decades[98]. This framework came directly from mainstream economics, and F. Machlup has been very influential here. By the end of the 1960s, however, few traces of the production function remained in statistics on science, technology and innovation except in econometric studies on productivity. The input-output framework now had a life of its own. D. J. D. Price, an historian of science and one of the founders of

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94 H. T. Johnson and R. S. Kaplan (1987), *Relevance Lost: The Rise and Fall of Management Accounting*, Boston: Harvard Business School Press.

95 F. Olsen (1948), Evaluating the Results of Research, in C. C. Furnas (ed.), *Research in Industry: Its Organization and Management*, Princeton: D. Van Nostrand, p. 402-415.

96 Office of Technology Assessment (1978), *Research Funding as an Investment: Can We Measure the Returns?*, USGPO: Washington.

97 C. Freeman (1962), Research and Development: A Comparison Between British and American Industry, *National Institute Economics Review*, 20, May, p. 21-39; C. Freeman, R. Poignant and I. Svennilson (1963), Science, Economic Growth and Government Policy, *op. cit*.

98 C. Freeman and A. Young (1965), The Research and Development Effort in Western Europe, North America and the Soviet Union, *op. cit;* C. Freeman (1967), Research Comparisons, *Science*, 158 (3800), October 27, p. 463-468; C. Freeman (1969), Measurement of Output of Research and Experimental Development, *op. cit.*; C. Freeman (1974), *The Economics of Industrial Innovation*, London: Penguin Books; C. Freeman (1982), *Recent Developments in Science and Technology Indicators: A Review*, mimeo, Brighton: SPRU.

scientometrics and bibliometrics[99], was an influential person in this respect. He collected several indicators to measure science as a system, presented them in an input-output framework, and suggested all sort of input-output ratios[100]. The National Science Foundation, with its series of indicators published every two years from 1973 onward, was equally influential. In the following decades, most researchers would use an input-output framework to conduct "accounting" or evaluation exercises of investments in science.

A second historical source for the input-output framework has to be mentioned, namely the management of industrial research and cost control. Establishing a relationship between input and output at the national level, that is, the level that interests governments most, is in fact the analogue of the firms' "return on investment" (ROI) ratio. For decades, managers have constructed such ratios in order to evaluate their investments[101]. Very early on, these ratios came to be

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99 D. J. D. Price (1963), *Little Science, Big Science*, New York: Columbia University Press.

100 See, for example: D. J. D. Price (1967), Nations can Publish or Perish, *Science and Technology*, October, p. 84-90; D. J. D. Price (1967), Research on Research, in D. L. Arm (ed.), *Journeys in Science*, University of New Mexico Press, p. 1-21; D. J. D. Price (1978), Toward a Model for Science Indicators, in Y. Elkana et al. (eds.), *Towards a Metric of Science: The Advent of Science Indicators*, New York: Wiley & Sons, p. 69-95; D. J. D. Price (1980), *Towards a Comprehensive System of Science Indicators*, Paper presented to the Conference on "Evaluation in Science and Technology: Theory and Practice", Dubrovnik, July; and to the "Quality Indicators Seminar", MIT, October; D. J. D. Price (1980), A Theoretical Basis for Input-Output Analysis of National R&D Policies, in D. Sahal (ed.), *Research Development and Technological Innovation*, D. C. Heath and Co., p. 251-260.

101 A. D. Chandler (1977), *The Visible Hand: The Managerial Revolution in American Business*, Cambridge: Belknap Press; H. T. Johnson (1978), Management Accounting in an Early Multidivisional Organization: General Motors in the 1920s, *Business History Review*, 52 (4), p. 490-517; H. T. Johnson and R. S. Kaplan (1987), *Relevance Lost: The Rise and Fall of Management Accounting*, Boston: Harvard Business School Press; D. A. Hounshell and J. K. Smith (1988), *Science and Corporate Strategy: Du Pont R&D*, 1902-1980, Cambridge: Cambridge University Press.

applied to R&D activities. By the 1950s, most companies calculated ratios like R&D as a percentage of earnings, as a percentage of sales, or as a percentage of value-added[102], and a whole "industry" developed around studying the "effectiveness" of research[103]. Very few administrative decisions really relied consistently on metrics[104], but it was not long before performance ratios came to be applied to

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[102] F. Olsen (1948), Evaluating the Results of Research, in C. C. Furnas (ed.) (1948), *Research in Industry: Its Organization and Management*, Princeton: D. Van Nostrand, p. 402-415; A. Abrams (1951), Contribution to the Session on Measuring the Returns from Research, in Engineering Research Institute, *Proceedings of the Fourth Annual Conference on the Administration of Research*, University of Michigan, September 11-13, 1950, University of Michigan, p. 22-24; R. N. Anthony and J. S. Day (1952), *Management Controls in Industrial Research Organizations*, Boston: Harvard University, p. 286-300; J. B. Quinn (1960), How to Evaluate Research Output, *Harvard Business Review*, March-April, p. 69-80.

[103] R. M. Hogan (1950), Productivity in Research and Development, *Science*, 112 (2917), November 24, p. 613-616; D. C. Pelz (1956), Some Social Factors Related to Performance in a Research Organization, *Administrative Science Quarterly*, 1, p. 310-325; J. B. Quinn (1959), *Yardsticks for Industrial Research: The Evaluation of Research and Development Output*, New York: Ronald Press; N. Kaplan (1960), Some Organizational Factors Affecting Creativity, *IEEE Transactions of Engineering Management*, 30, p. 24-30; The Institution of Chemical Engineers (1963), *Productivity in Research*, Proceedings of a Symposium held in London on 11-12 December 1963, London; B.-A. Lipetz (1965), *The Measurement of Efficiency of Scientific Research*, Carlisle: Intermedia; R. E. Seiler (1965), *Improving the Effectiveness of Research* and Development, New York: McGraw Hill; M. C. Yovits et al. (eds.) (1966), *Research Program Effectiveness*, New York: Gordon and Breach; D. C. Pelz and F. M. Andrews (1966), *Scientists in Organizations: Productive Climate for Research and Development*, New York: John Wiley; B. V. Dean (1968), *Evaluating, Selecting, and Controlling R&D Projects*, American Management Association.

[104] For evidence, see: National Science Foundation (1956), Science and Engineering in American Industry, *op. cit*, Washington; A. H. Rubenstein (1957), Setting Criteria for R&D, *Harvard Business Review*, January-February, p. 95-104; N. C. Seeber (1964), Decision-Making on R&D in the Business Firm, *Reviews of Data on R&D*, 44, February, NSF 64-6, Washington: National Science Foundation.

aggregated statistics on industrial R&D[105] and national R&D expenditures[106]. In the latter case, GDP served as denominator, producing the famous GERD/GDP ratio as the objective of science policies.

There are currently two explanations or rationales offered for statistics and accounting on science. The most common rationale is "controlling" science, in the sense of limiting expenses, for example. The very first edition of the Frascati manual assigned two main goals to this practical side of statistics: managing research and assessing returns on R&D[107]. Management of research (or management control) consists of "the optimum use of resources" and involves concepts like the productivity of research and the balance between types of research. Assessment of returns deals with the effectiveness of research. Yet science policy is full of statistics used not to control

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105 J. V. Sherman (1941), Research as a Growth Factor in Industry, *op. cit*.; K. T. Compton (1941), Industrial Research Expenditures, in *Ibid.*, p. 124-125; US National Association of Manufacturers (1949), Trends in Industrial Research and Patent Practices, *op. cit*.; US Bureau of Labor Statistics (1953), *Industrial R&D: A Preliminary Report*, Department of Labor and Department of Defense; Bureau of Labor Statistics (1953), *Scientific R&D in American Industry: A Study of Manpower and Costs*, Bulletin no. 1148, Washington; D. C. Dearborn, R. W. Kneznek and R. N. Anthony (1953), Spending for Industrial Research, 1951-1952, *op. cit*.; National Science Foundation (1956), Science and Engineering in American Industry, *op. cit.*; National Science Foundation (1960), *Funds for R&D in Industry: 1957*, NSF 60-49, Washington. For Great Britain, see: Federation of British Industries (1952), *R&D in British Industry*, London: FBI; DSIR (1958), Estimates of Resources Devoted to Scientific and Engineering R&D in British Manufacturing, *op. cit*. For Canada, see: Dominion Bureau of Statistics (1956), *Industrial R&D Expenditures in Canada, 1955*, Reference paper no. 75, Ottawa.

106 J. D. Bernal (1939), *The Social Function of Science*, Cambridge (Mass.): MIT Press, 1973; R. H. Ewell (1955), Role of Research in Economic Growth, *Chemical and Engineering News*, 18 July, p. 2980-2985; NSF (1956), Expenditures for R&D in the United States: 1953, *Reviews of Data on R&D*, 1, NSF 56-28, Washington.

107 OECD (1962), The Measurement of Scientific and Technical Activities: Proposed Standard Practice for Surveys of Research and Development, *op. cit*. p. 9-11.

science, but to make a case for providing increasing resources to science, such as in the current official literature on the knowledge-based economy.

A second rationale relates to the theoretical use of statistics and the input-output framework – and this was mentioned in the first edition of the Frascati manual[108]. The framework is a kind of "model" that explains science activities. It is centered on a specific kind of "mechanisms" and has a certain truth: inputs come first, and without money and personnel there would be no output. It is an administrative or accounting view, and is concerned exclusively with accounting of an economic type. Another understanding, developed by academics with the same semantics, started with suggesting that science is a complex phenomenon, or system as Price suggested. To measure science properly, one therefore needs to take account of several dimensions: inputs, but also outputs and outcomes[109]. This "philosophy" is known as multiple converging indicators.

A third rationale, or use, is for efficiency in science to act as "rhetoric". We have seen how accounting in official statistics on science is a representation. By representation, we do not mean just an idea. A representation, like an imaginary or ideology, is an ideal. It is a "common understanding that makes possible common practices and a widely shared sense of legitimacy"[110]. A representation incorporates expectations and norms about how people or things behave and fit together, and suggests courses of action. By definition, the representation carried by official statistics is (usually) that of its patron, the State. Whether or not the representation really serves accounting as such does not matter. It suffices that the rhetoric (of

108 Information and description, evolution, comparison.

109 K. Pavitt (1982), R&D, Patents and Innovative Activities, *Research Policy*, 11, p. 33-51; B. R. Martin and J. Irvine (1983), Assessing Basic Research: Some Partial Indicators of Scientific Progress in Radio Astronomy, *Research Policy*, 12, p. 61-90.

110 C. Taylor (2004), *Modern Social Imaginaries*, Durham: Duke University Press, p. 23.

efficiency) appear to be real, since rationalizing and justifying decisions to the nation rest in large part on a web of discourses that look coherent and seem to make sense with decisions taken at the organizational level where accounting is real.

CHAPTER FOUR

ECONOMIC GROWTH, PRODUCTIVITY AND THE NEW ECONOMY

Spending money on research in order that society and the economy benefit has always been the driving force behind public investment in science and technology. Even during the so-called "policy for science" period (1950s-1960s), governments never funded research for its own sake. The goals were varied and many, and ultimately utilitarian – political, economic and social.

In the literature, most if not all measured impacts of science and technology concentrate on the economic dimension. In the 1950s, economists began integrating science and technology into their models, and focused on the impact of R&D on economic growth and productivity. Cost/benefit analyses were conducted and econometric models developed that tried to measure what the economy owed to science and technology. The limitations of the studies were many, as this chapter documents, but never so large, from the economist's point of view, as to question the validity of the results.

In the 1990s, these studies coalesced into new growth theories and the concept of the New Economy. The new economy referred to data that indicated the appearance of new economies in the United States and in a number of smaller OECD countries not very "vibrant" in terms of entrepreneurship. What characterized new economies was the acceleration of trend growth and productivity. Technologies, particularly information and communication technologies, were believed to be at the heart of the phenomenon, and several researchers, both from universities and governments, developed programs of work to study the phenomenon.

Why and how did governments and statistical offices develop an interest in measuring growth and productivity and the role of science, technology and innovation? I suggest looking to the OECD to answer this question because, as a think tank, the organization has over time developed an influential framework used in its member countries.

This chapter is divided into three parts. The first is a brief presentation of early academic methodologies for measuring the economic impact of R&D. The second part traces the main events and decisions that led to the OECD's Directorate for Science, Technology and Industry measuring the contribution of science, technology and innovation to economic growth and productivity. The third and final part examines the rhetorical construction recently developed at the OECD to convince people that there was something new happening in the economy (the New Economy), and shows that the main factor responsible for this situation was technology.

INTEGRATING SCIENCE AND TECHNOLOGY INTO THE ECONOMETRIC EQUATION

In 1955, R. H. Ewell from the National Science Foundation conducted one of the first quantitative analyses of R&D showing (*sic* from the editor of the magazine) a definite correlation between research, economic growth and productivity[1]. According to Ewell, "R&D conducted during the preceding 25-year period contributed to $40 to $80 billion of the GNP in 1953" by way of new products and by lowering the cost of production for old ones[2]. These gains implied that "the GNP would have been only $285 to $325 billion in 1953 if no research had been conducted since 1928 (…), or looked at cumulatively, there would have been a cumulative loss of national

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1 R. H. Ewell (1955), Role of Research in Economic Growth, *Chemical and Engineering News*, 18 July, p. 2980-2985.

2 *Ibid.*, p. 2984.

product of $400 to $800 billion during the period 1928-53 in the absence of research"[3].

Ewell also calculated the return on research investment: R&D expenditures of $1.5 billion produced $40-$80 billion in benefits, that is, a 2,000% to 5,400% overall return, or 100% to 200% annually over a 25 year period, a relatively high rate of return compared to other areas of investment[4]. "In fact, it indicates that from an investment standpoint we probably should be putting more of the national income, or of the national effort, into research than we are now doing"[5]. "This would mean that the $4 billion spent on research in 1955 should result in a cumulative increment to the national product of $100 to $200 billion in 25 years"[6]. All in all, concluded Ewell, "research may be the most important single factor in economic growth in the United States"[7].

The methodology of the study was very sketchy. Ewell used fragmentary data dating back to 1920 (and before, even going back to 1776) to project R&D expenditures of $6.9 billion in 1965 based on past trends, and to project a requirement of 75,000 research scientists and engineers[8]. His estimates of the impact of research on productivity were highly speculative, based on rough over-all estimates and a margin of error by a factor of two[9]. But the limitations, according to the author, did "not really affect the conclusions"[10].

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3 *Ibid*.

4 *Ibid.*, p. 2985.

5 *Ibid*.

6 *Ibid*.

7 *Ibid*., p. 2980.

8 *Ibid*., p. 2982.

9 *Ibid*., p. 2983. Based on cursory analyses of the new products and technological changes in 40 industries since 1928 and on discussions with a number of industrial research leaders.

10 *Ibid*., p. 2980.

Ewell's early efforts at linking science and economic growth would soon be followed by others. The task has occupied economists since the mid-1950s, when they began integrating science, technology and innovation into their theoretical models. These efforts began at the US Department of Agriculture[11] – one of the first departments to set up a Bureau of Economic Research[12] – and the US National Bureau of Economic Research[13].

Until the 1950s, economic growth was explained as a function of capital and labour – the Cobb-Douglas function[14]. Science and technology came to be added in the following two ways. Firstly, R. M. Solow formalized early works on growth accounting (decomposing GDP into capital and labor and equated the residua in his equation with technical change – although it included everything that was neither capital nor labor – as "a shorthand expression for any kind of shift in the production function"[15]. Integrating science and technology into the equation was thus not a deliberate initiative, but it soon became a fruitful one. Solow estimated that nearly 90% of growth was due to the residual. In the following years, researchers began adding variables to the equation in order to better isolate science and technology[16], or adjusting the labour and capital factors

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11 For a brief summary of the studies coming out of the Department, see Z. Griliches (1998), R&D and Productivity: The Econometric Evidence, Chicago: University of Chicago Press, p. 1-3.

12 G. M. Lyons (1969), The Uneasy Partnership: Social Sciences and the Federal Government in the 20th Century, New York: Sage.

13 J. Kendrick (1961), Productivity Trends in the United States, NBER, Princeton: Princeton University Press.

14 R. R. Solow (1956), A Contribution to the Economic Theory of Economic Growth, Quarterly Journal of Economics, 70 (1), p. 65-94.

15 R. M. Solow (1957), Technical Change and the Aggregate Production Function, Review of Economics and Statistics, 39, August, p. 312-320.

16 E. F. Denison (1962), The Sources of Economic Growth in the United States and the Alternatives Before Us, Committee for Economic Development, New York; E. F. Denison (1967), Why Growth Rates Differ, Washington: Brookings Institution.

to capture quality changes in output[17]. Since these first calculations, the literature on the topic has grown considerably[18]. Typically, a 1% increase in the R&D investment is found to lead to a rise in output of between 1% and 5%.

Solow's approach has been the dominant methodology for studies on science, economic growth and productivity, and more recent studies still suggest a large growth residual, generally accounting for one-third of productivity. There was, however, another approach for integrating science and technology into studies of economic growth: calculating rates of return on R&D by way of cost/benefit analyses and econometrics[19]. These studies concluded that the large majority of R&D projects produces social returns that exceeded the private financial returns, generally by a factor of two (between 20% and 50% on average).

The second type of economic model into which science and technology began to be integrated was that dealing with international trade[20]. Until the 1960s, the current model of international trade, known as Heckscher-Ohlin-Samuelson, centered on resource endowments as the main factor explaining international trade patterns. However, in the 1960s, following Wassily Leontief's

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17 D. W. Jorgenson and Z. Griliches (1967), The Explanation of Productivity Change, Review of Economic Studies, 34 (3), p. 249-283.

18 For an overview, see: G. Cameron (1998), Innovation and Growth: A Survey of the Empirical Evidence, Nuffield College, Oxford.

19 Z. Griliches (1958), Research Costs and Social Return: Hybrid Corn and Related Innovations, *Journal of Political Economy*, 66 (5), p. 419-431; E. Mansfield (1965), Rates of Return from Industrial R&D, *American Economic Review*, 55 (2), p. 310-32; J. R. Minasian (1969), R&D, Production Functions, and Rates of Return, *American Economic Review*, 59 (2), p. 80-85; E. Mansfield et al. (1977), Social and Private Rates of Return From Industrial Innovations, *Quarterly Journal of Economics*, May, p. 221-240.

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

work[21], authors began introducing additional factors, among them technology (generally measured by R&D), to explain why some countries led in terms of trade and others lagged[22]. This interest in using technology to explain international trade patterns appeared in response to the persistent and structural shortage of dollars in the world, and the ensuing foreign-trade patterns. The new studies suggested that countries were not equal in terms of publicly available science and technology. Some became leaders because they innovated and disseminated technologies before others[23].

The two models – of economic growth and international trade – are often intimately related today. Studies on convergence of countries or

[21] W. Leontief (1953), Domestic Production and Foreign Trade: the American Capital Position Re-Examined, *Proceedings of the American Philosophical Society*, 97 (4); W. Leontief (ed.) (1953), *Studies in the Structure of the American Economy*, New York: Oxford University Press.

[22] M. V. Posner (1961), International Trade and Technical Change, *Oxford Economic Papers*, 13, p. 323-341; R. Vernon (1966), International Investment and International Trade in the Product Cycle, *Quarterly Journal of Economics*, 80, p. 190-207; R. Vernon (ed.) (1970), *The Technology Factor in International Trade*, NBER, New York: Columbia University Press; S. Hirsch (1965), The United States Electronics Industry in International Trade, *National Institute Economic Review*, 34, p. 92-97; G. C. Hufbauer (1965), The Impact of National Characteristics and Technology on the Commodity of Trade in Manufacturing Goods, in R. Vernon (ed.), The Technology Factor in International Trade, *op. cit*. p. 145-231; D. B. Keesing (1967), The Impact of R&D on United States Trade, *Journal of Political Economy*, 25 (1), p. 38-48; W. Gruber, D. Mehta and R. Vernon (1967), The R&D Factor in International Trade and International Investment of United States Industries, *Journal of Political Economy*, 25 (1), p. 20-37.

[23] M. Abramovitz (1986), Catching Up, Forging Ahead, and Falling Behind, *Journal of Economic History*, XLVI (2), p. 385-406; J. Fagerberg (1994), Technology, and International Differences in Growth Rates, *Journal of Economic Literature*, 32, p. 1147-1175; J. Fagerberg, B. Varspagen and N. von Tunzelmann (1994), *The Dynamics of Technology, Trade and Growth*, Aldershot (Hants): Edward Elgar.

technological gaps (catch-up) are an illustration of such links[24]. In the rest of this chapter, however, I will concentrate on economic growth.

STUDYING GROWTH AND PRODUCTIVITY AT THE OECD

Very early on, the mathematics behind economists' models was qualified as "not strong enough to permit very accurate estimates (…). At best, the available estimates are rough guidelines" wrote E. Mansfield in a review article published in 1972[25]. Twenty-five years later, Z. Griliches concluded that "the quantitative basis for these convictions [links between investments in science, technology and innovation to economic growth] is rather thin", and pleaded for realism[26]. Despite forty years of development, the field is still plagued by important methodological limitations that prevent anyone "proving without doubt" the impact of science and technology and innovation on growth and productivity. As the OECD constantly reminded its readers, everyone is convinced of the contribution of science and technology to the economy (imagine a world without technologies), but statistically, the demonstration remains limited.

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24 M. Abramovitz (1986), Catching Up, Forging Ahead, and Falling Behind, *Journal of Economic History*, XLVI (2), p. 385-406; W. J. Baumol (1986), Productivity Growth, Convergence, and Welfare: What the Long-Run Data Show, *American Economic Review*, 76 (5), p. 1072-1085; J. Fagerberg, B. Varspagen and N. von Tunzelmann (1994), *The Dynamics of Technology, Trade and Growth*, Aldershot (Hants): Edward Elgar; W. J. Beaumol, R. R. Nelson and E. N. Wolff (eds.) (1994), *Convergence of Productivity: Cross-National Studies and Historical Evidence*, Oxford: Oxford University Press; M. Abramovitz and P. A. David (1996), Convergence and Deferred Catch-Up: Productivity Leadership and the Waning of American Exceptionalism, in R. Laudan, T. Taylor and G. Wright (eds.), *The Mosaic of Economic Growth*, Stanford: Stanford University Press: 21-62.

25 E. Mansfield (1972), Contribution of R&D to Economic Growth in the United States, *Science*, 175 (4021), p. 478.

26 Z. Griliches (1998), R&D and Productivity: Econometric Results and Measurement Issues, in R&D and Productivity: The Econometric Evidence, *op. cit*. p. 52-89.

Why, then, had the OECD and its member countries entered the field?

In 1962, the OECD Committee on Scientific Research of the Directorate for Scientific Affairs decided "to give more emphasis in the future to the economic aspects of scientific research and technology"[27]. The committee suggested that governments link science, technology and innovation to economic growth and productivity, and assess the contribution of the former to the latter. Again, in 1976, the second *ad hoc* review group on science and technology statistics suggested that studies on the links between R&D and productivity be established at the Directorate for Science, Technology and Industry[28].

People had to wait until the 1990s, however, to see work on science, technology and innovation and on productivity at the Directorate for Science, Technology and Industry. The lag between the demands of the 1960s and the work of the 1990s can be explained by at least two factors. First was the reluctance of mainstream (classical) economists to bring technology and innovation into theories and econometric models. Second was the difficulties that lie behind linking science, technology and innovation directly to growth and productivity.

Nevertheless, very early on, the OECD responded indirectly to the challenges posed by the new economic theories and models of the 1950s-1960s. With regard to economic growth, in 1963 the OECD conventionalized an indicator combining science/technology and economic output – GERD/GDP – and harmonized its concepts with the System of National Accounts. All OECD studies conducted on R&D in the 1970s and 1980s analyzed the indicator and compared member countries according to it[29]. Concerning theories of

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27 OECD (1962), *Minutes of the 4th Session*, Committee for Scientific Research, SR/M (62) 2, p. 17.

28 OECD (1978), *Report of the Second Ad Hoc Review Group on R&D Statistics*, SPT (78) 6 p. 25-27.

29 Besides this innovation, the OECD produced its first, and very brief, analysis comparing industrial R&D with economic variables in the mid

international trade, the OECD conducted several studies on competitiveness in the 1980s, and developed indicators on the technological balance of payments and trade in high technology.

The real work began, however, in the 1990s. The fact that the OECD and its member countries entered the field of science, technology and innovation, and economic growth, followed the reorientation of its program on science and technology statistics towards more economic issues. Certainly, the economic impact of science and technology has always been a priority for the Directorate for Scientific Affairs and for the Directorate for Science, Technology and Industry's statistical unit, and evolutionary economists as consultants, among them R. Nelson and C. Freeman, pushed for integrating science and technology into economic policy for several years[30]. Beginning in the 1990s, however, OECD classical economists finally began developing an interest in science and technology. Policy had shifted from a focus on macro-economic policies to a focus on micro-economic, such as firm-level innovation. New growth theories were then in vogue, and succeeded in focusing OECD mainstream economists on science and technology as a source of economic growth[31]. According to many, however, there is nothing new under the sun here. New growth theories are only a mathematical – or stylized – formalization of what we have known for decades, and their practitioners have "limited acquaintance (…) with the previous

1970s. See: OECD (1976), *Comparing R&D Data with Economic and Manpower Series*, DSTI/SPR/76.45.

30 See, for example, OECD (1980), *Technical Change and Economic Policy*, Paris; OECD (1991), *Technology and Productivity: the Challenges for Economic Policy*, Paris.

31 G. M. Grossman and E. Helpman (1991), *Innovation and Growth in the Global Economy*, Harvard: MIT Press; P. Aghion and P. Howitt (1992), A Model of Growth through Creative Destruction, *Econometrica*, 60 (2), p. 323-351; P. M. Romer (1990), Endogenous Technological Change, *Journal of Political Economy*, October (98), p. 71-102.

empirical literature"[32]. Be that as it may, the OECD mainstream economists followed the new academic fashion.

With the diverging rates of economic growth across countries in the 1970s and 1980s, the impact of technology on economic growth and productivity became a cause for concern. The Directorate for Science, Technology and Industry developed projects on structural adjustment and technology[33], science and technology in the new economic context[34], and science, technology and competitiveness[35]. But it was during the Technology and Economy Program in the late 1980s-early 1990s and later that work on productivity expanded[36]. The Economic and Statistical Analysis Division of the DSTI came to be associated with several horizontal OECD projects devoted specifically to productivity: analyses were conducted on productivity and job creation for the OECD Job Study project[37], and on the contribution of R&D, innovation and technologies to economic growth for the OECD Growth Project[38] (Table 8).

This followed the transformation of the Directorate for Science, Technology and Industry's statistical unit into a division in 1986. A coordinated project was launched in 1988 (the Structural Analysis

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32 Z. Griliches (1998), Introduction, in R&D and Productivity: The Econometric Evidence, *op. cit*. p. 7. R. R. Nelson (1994), What Has Been the Matter with Neoclassical Growth Theory, in G. Silverberg and L. Soete (eds.), *The Economics of Growth and Technical Change*, Aldershot: Edward Elgar; R. Nelson (1997), *How New is New Growth Theory*, Challenge, September/October, p. 29-58.

33 OECD (1978), *Technology and the Structural Adaptation of Industry*, DSTI/SPR/78.25 and 78.26.

34 OECD (1980), Technical Change and Economic Policy, *op. cit*.

35 OECD (1984), *Technology and International Competitiveness*, DSTI/SPR/84.46.

36 OECD (1992), *Technology and the Economy: the Key Relationships*, Paris.

37 OECD (1996), Technology, Productivity and Job Creation, Paris; OECD (1996), Technology and Industrial Performance, Paris.

38 OECD (2001), The New Economy: Beyond the Hype, Paris.

Program) on indicators of scientific, technological and industrial competitiveness and performance, with three broad goals[39]:

- To establish comprehensive, disaggregated, internationally-comparable databases linking R&D, input-output, industrial and import/export data at the individual industry level.
- To construct a wide range of industry and aggregate-level indicators of the evolution of technological and economic performance.
- To undertake empirical studies of the role of technology in globalization, international competitiveness, productivity growth and structural change.

Table 8. OECD Projects on Science, Technology and Innovation, and the Economy

1. New Economic Context (1976-80)
2. Technology and Structural Change (1975-79)
3. Science, Technology and Competitiveness (1980-84)
4. Innovation and Economic Climate (1981-85)
5. Trade in High-Technology (1984-85)
6. Contribution of Science and Technology to Economic Growth (1987-88)
7. Technology/Economy Programme (TEP) (1988-91)
8. Technology, Productivity and Jobs (1994-99)
9. Growth Project (1999-2001)

The main output of the project was a new database, STAN (Structural Analysis), implemented in 1992[40]. STAN was intended to cover the

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[39] OECD (1994), Statistics and Indicators for Innovation and Technology, DSTI/STP/TIP (94) 2, p. 8.

full data spectrum from basic research to trade indicators. It was designed specifically to underpin analyses of the connection between technology, structural adjustment and economic performance. STAN was "intended to be an analytical tool on which much of the quantitative analysis and modeling carried out in the Directorate for Science, Technology and Industry will be founded (…) and provide a scoreboard of indicators in order to monitor and evaluate the evolution of industrial structures and economic competitiveness and performance in the light of scientific and technological developments"[41]. As a consequence, *Science, Technology and Industry Outlook*, a biennial review combining elements from the *Industrial Review*, the *S&T Policy Outlook* and the earlier *S&T Indicators* reports, was started in 1996[42]. Also, a scoreboard of indicators became regularly available from 1995 onward as *Industry and Technology: Scoreboard of Indicators*.

The work on technology and the economy really started with the Technology and Economy Program, at least at the Directorate for Science, Technology and Industry. Among the eight issues identified during the Technology and Economy Program exercise was "technology and economic growth". To study the issue, the Directorate for Science, Technology and Industry organized an important international conference on technology and productivity in 1989, where M. Abramovitz, Z. Griliches, J. W. Kendrick and R. R. Nelson, among others, participated[43]. The purpose of the conference was to "identify various factors that influence the development, adoption and diffusion of technology and, ultimately, the rate of

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40 OECD (1988), Progress Report on STAN, DSTI/IP/88.19; OECD (1994), STAN Databases and Associated Analytical Work, DSTI/EAS/STP/NESTI (94) 7.

41 OECD (1987), Review of the Committee's Work Since 1980, DSTI/SPR/87.42, p. 18; OECD (1988), Summary of the Meeting of NESTI, SPT (88) 2, p. 10.

42 OECD (1994), Developing STI Reviews/Outlooks: A Proposal, DSTI/IND/STP/ICCP (94) 4.

43 OECD (1991), Technology and Productivity: The Challenge for Economic Policy, *op. cit*.

productivity growth"[44], and particularly to shed light on the productivity (or Solow) paradox: although there was evidence of acceleration of industry's technological efforts in most member countries, this had not yet been reflected in an upturn in productivity.

The conference discussed growth trends since World War II (and the convergence of OECD economies than ensued), the causes of the slowdown that followed in the seventies and after, and the difficulty of measuring the contribution of science, technology and innovation to productivity and economic growth. The output of the conference, at least with regard to the prospects for studies on science, technology and innovation, and on productivity, was not very optimistic. The chairman of the conference concluded[45]:

> A deepening of the research on these complex issues probably requires some redirection of the analysis of productivity growth (…). It is clear that it is important to improve the methods of making *direct* measurements of technological change, rather than trying to interpret residuals (…). We are far away from a situation when policy implications can be derived in a satisfactory way from research in this area.

In a similar tone, R. R. Nelson concluded his communication as follows: "Attempts by governments to influence growth rates are likely to be shallow until the connections among the variables are better understood. And, indeed, I am impressed by the shallowness of most of the prescriptions for faster growth. It is easy enough to recommend that rates of physical investment be increased, or that industrial R&D be expanded, or that time horizons of executives be extended, or that labor and management be more cooperative and less

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44 A. Lindbeck (1991), Lessons From the Conference, in OECD, Technology and Productivity: The Challenge for Economic Policy, *op. cit.* p. 13.

45 *Ibid*., p. 15.

adversarial. But if the prescription stops here, it is hard to see what one actually is to do"[46].

Despite (or because of) these warnings, the Directorate for Science, Technology and Industry entered the field of studies on productivity with the same methodology then in vogue in academic circles. Its first contribution appeared in 1992, in a chapter of the Technology and Economy Program final report that concluded on very low correlations between (embodied as well disembodied) R&D and productivity[47]. "The proposition that investment in R&D and technological progress are essential for future growth has not yet been conclusively empirically demonstrated. Nevertheless, economists generally agree that R&D and technical progress do indeed play a crucial role in economic growth"[48].

The Technology and Economy Program was only a prelude to the Directorate for Science, Technology and Industry efforts on science, technology and productivity. The G7 ministerial conference held in 1994 in Detroit, based on the results of studies conducted at the request of the previous ministerial meeting (1992) on the causes of unemployment (known as the Jobs study project)[49], arrived at the consensus that technological change is *perhaps* the leading force for job creation and economic growth. But everyone agreed that there was a lack of internationally-comparable information to properly document the case. The head of the Private Office of the Secretary-

46 R. R. Nelson (1991), A Conference Overview: Retrospect and Prospect, in OECD, Technology and Productivity: The Challenge for Economic Policy, *op. cit*. p. 584.

47 OECD (1992), Technology and Economic Growth, in OECD, Technology and the Economy: the Key Relationships, *op. cit*. chapter 8.

48 OECD (1992), Technology and Economic Growth, in OECD, Technology and the Economy: the Key Relationships, *op. cit*. p. 184.

49 OECD (1994), The OECD Jobs Study: Facts, Analysis, Strategies, Paris; OECD (1994), The OECD Jobs Study: Evidence and Explanations, Paris; OECD (1995), The OECD Jobs Study: Implementing the Strategy, Paris.

General summarized the issue as follows[50]: "Further work on the relationship between technology, productivity and employment [is] needed for the following reasons: at the beginning of the [Jobs] study, there existed less relevant work in Directorate for Science, Technology and Industry than in [other] directorates (…); studying the link between technology and employment was conceptually more difficult, given its indirect nature and the corresponding lack of statistics; this link could thus be argued rather than proved". The G7 conference therefore asked the OECD Secretariat to examine the relationship between productivity, job creation and technology, especially information and communication technologies. In a letter to the Secretary-General, the US Secretary of the Treasury suggested five topics that became the five focuses of the OECD Secretariat on the horizontal project *Technology, Productivity and Job Creation*[51]:

- relationship between technological change, productivity, job creation and job loss,
- best practice in technology policy,
- demand for highly-skilled labor,
- information technology and changes in industries,
- development of information infrastructure.

This was the background in which the Directorate for Science, Technology and Industry participated in Phase II of the Jobs study: the *Technology, Productivity and Job Creation* project. According to OECD member countries, *Technology, Productivity and Job Creation* was the "most important work undertaken on this difficult

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50 OECD (1994), Summary Record of the Joint Ad Hoc Expert Meeting on Technology, Productivity and Job Creation, DSTI/IND/STP/ICCP/M (94) 1, p. 8.

51 OECD (1994), Future Work on Technology, Productivity and Job Creation: Addendum, DSTI/IND/STP/ICCP (94) 3/ADD1.

subject of technology and jobs to date”[52]. With regard to the relationships between technology and productivity, the Directorate for Science, Technology and Industry conducted two kinds of analyses[53]: 1) at the industry level: looking at the impact of R&D and, above all, (embodied) technology diffusion and acquisition on productivity[54]; 2) at the firm level: analyzing the heterogeneity of firms’ experiences and characteristics within industries and its capacity to explain productivity[55]. The results were published respectively in 1996[56] and 1998[57]. The main message was that both R&D and embodied technology had an impact on productivity, but that the latter was far more important, particularly with regard to information and communication technologies in services. However, “it is very difficult to prove beyond doubt that technology has been a

52 OECD (1996), *Summary* Record *of the 6th Meeting*, DSTI/IND/STP/ICCP/M (96) 2, p. 7.

53 OECD (1994), Future Work on Technology, Productivity and Job Creation: Road Map, DSTI/IND/STP/ICCP (94) 3, p. 6-7.

54 OECD (1994), Technology Diffusion Flows in 10 OECD Countries: Interim Report, DSTI/IND/STP/ICCP (94) 8.

55 OECD (1997), *Technology and Productivity: A Three-Country Study Using Micro-Level Databases*, DSTI/EAS/IND/SWP (97) 7. This very preliminary work was pursued as a follow-up to the Growth project discussed below. See: OECD (2002), *Proposed Work on ICT and Business Performance*, DSTI/ICCP (2002) 2; OECD (2003), *ICT and Economic Growth: Evidence from OECD Countries, Industries, and Firms*, Paris.

56 N. Sakurai, E. Ioannidis and G. Papaconstantinou (1996), *The Impact of R&D and Technology Diffusion on Productivity Growth: Evidence for 10 OECD Countries in the 1970s and 1980s*, OECD/GD (96) 27; OECD (1996), Technology, Productivity and Growth, in OECD, *Technology, Productivity and Job Creation*, Paris, chapter 2; OECD (1996), Technology and Productivity, in OECD, *Technology and Industrial Performanc*e, Paris, chapter 3.

57 OECD (1998), The Dynamics of Industrial Performance: What Drives Productivity Growth? in OECD, *Science, Technology and Industry Outlook*, Paris, chapter 4.

major factor in productivity gains (…). [But] the slowdown would have been worse without new technology“[58].

THE NEW ECONOMY

The ministerial demand for more data and analyses continued. As a follow-up to the *Technology, Productivity and Jobs Creation* project, the OECD Council of Ministers asked the Secretariat in May 1999 to study the causes of growth disparities across and within OECD countries. In the 1950s and 1960s, most OECD countries grew rapidly as they recovered from the war and applied American technology and know-how. This catch-up period came to a halt in the 1970s[59]. In the United States, however, the last decade has seen an acceleration of growth in GDP per capita, but some of the other major economies have lagged. This divergence between countries has caused renewed interest in the main factors driving economic growth and the policies than might influence it. It also gave rise to claims about the emergence of a New Economy[60].

The fundamental question asked by the OECD Council was whether in recent years growth trends have changed in various OECD

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[58] OECD (1996), Technology, Productivity and Growth, in OECD, Technology, Productivity and Job Creation, *op. cit*. p. 48-49.

[59] R. R. Nelson and G. Wright (1992), The Rise and Fall of American Technological Leadership: The Postwar Era in Historical Perspective, *Journal of Economic Literature*, 30, p. 1931-1964; M. Abramovitz (1994), The Origins of the Postwar Catch-Up and Convergence Boom, in J. Fagerberg, B. Varspagen and N. von Tunzelmann (eds.) (1994), The Dynamics of Technology, Trade and Growth, *op. cit*. A. Maddison (1987), Growth and Slowdown in Advanced Capitalist Economies: Techniques of Quantitative Assessment, *Journal of Economic Literature*, 25 (2), June, p. 649-698. A. Maddison (1991), *Dynamic Forces in Economic Development: A Long Run Comparative View*, Oxford: Oxford University Press.

[60] *The Economist* (2000), A Survey of the New Economy, September 23rd; *Business Week* (1997), The New Economy: What It Really Means, November 17-23, p. 38-40.

countries and, if so, what factors can explain this[61]. In response, the OECD launched a two-year multidisciplinary study involving three Directorates[62] and several committees. The first phase was dedicated to fact-finding, and the second to analyzing policies that support grow[63] The results were presented in two steps to the Council of Ministers: June 2000[64] and May 2001[65]. A special edition of the *Science, Technology and Industry Outlook* series followed[66], as well as a background study[67].

The *Growth Project*, as it was called, was inspired by the strong economic performance of the United States. The OECD "confirmed" that there was a New Economy, although uneven across countries. Cross-country disparities (or gaps) in economic growth have increased in the OECD in the 1990s: only about one-fifth of OECD countries experienced a rise in trend growth, among them the United States[68]. The causes behind growth performances were multiple and difficult to single out, according to the OECD, but innovation and technological change, particularly information and communication technologies, were "shown" to be the main drivers of economic

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61 OECD (1999), *Growth Project*, DSTI/IND/STP/ICCP (99) 1.

62 Directorate for Science, Technology and Industry (DSTI), Directorate for Education, Employment, Labour and Social Affairs (DEELSA), Economics Department (ECO).

63 OECD (2000), *The OECD Growth Project: Proposed Work for the Second Year in the DSTI*, DSTI/IND/STP/ICCP (2000) 4.

64 OECD(2000), *Is There a New Economy? First Report on the OECD Growth Project*, Paris; OECD (2000), *A New Economy? The Changing Role of Innovation and Information Technology in Growth*, Paris.

65 OECD (2001), The New Economy: Beyond the Hype, *op. cit*.

66 OECD (2001), *Drivers of Growth: Information Technology, Innovation and Entrepreneurship*, Paris.

67 OECD (2003), *The Sources of Economic Growth in OECD Countries*, Paris.

68 OECD (1999), Economic Growth in the OECD Area: Are the Disparities Growing?, DSTI/EAS/IND/SWP (99) 3; OECD (2000), Economic Growth in the OECD Area: Recent Trends at the Aggregate and Sectoral Level, DSTI/IND/STP/ICCP (2000) 2; OECD (2000), Innovation and Economic Performance, DSTI/STP (2000) 2.

growth: "something new is happening in the structure of OECD economies (…). It is this transformation that *might* account for the high growth recorded in several countries. Crucially, ICT *seems* to have facilitated productivity enhancing changes in the firm, in both new and traditional industries (…)"[69].

How was the discourse constructed and the demonstration arrived at? In a sense, the US issue submitted to the OECD Secretariat, an issue pushed and pulled by central banks[70], was not a new one. As we mentioned above, it has been over 40 years since academics studied the issue. The model used to this end was growth accounting. The economy was represented by a production function linking output (production) to inputs (labor, capital), plus a residual – called multifactor productivity (MFP) today.

In the econometric literature, the contribution of technology to productivity is measured by correlating the residual to indicators of science and technology (R&D, patents): "*All* productivity growth is related to *all* expenditures on R&D and an attempt is made to estimate statistically the part of productivity growth that can be attributed to R&D"[71]. This procedure is considered to be very limited by the experts themselves:

> The theoretical model underlying most research by economists on productivity growth over time, and across countries, is superficial and to some degree

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69 OECD (2001), The New Economy: Beyond the Hype, op. cit. p. 4.

70 For example, see the contributions of the US Federal Reserve economists (S. D. Oliner and K. J. Stiroh): S. D. Oliner and D. E. Sichel (1994), Computers and Output Growth Revisited: How Big is the Puzzle?, Brookings Papers on Economic Activity, 2, p. 273-334; S. D. Oliner and D. E. Sichel, The Resurgence of Growth in the Late 1990s: Is Information Technology the Story?, Journal of Economic Perspectives, 14 (4), p. 3-22; D. W. Jorgenson and K. J. Stiroh (2000), US Economic Growth in the New Millennium, Brookings Papers on Economic Activity,1, p. 125-211.

71 Z. Griliches (1998), Issues in Assessing the Contribution of R&D to Productivity Growth, in R&D and Productivity: The Econometric Evidence, *op. cit*. p. 17.

> even misleading[72]. Despite all the efforts to make the residual go away it still is very much with us. And despite all the efforts to give substance to its interpretation as technological advance, or advance of knowledge, that interpretation is far from persuasive (…). The residual accounts for a hodge-podge of factors (…) difficult to sort out[73].

Indeed, the limitations of studies on technology and productivity are numerous, among them: the factors in the growth equation are not independent of each other and cannot be simply added up; the residual covers many sources of growth besides technological advance; R&D takes time and may not affect productivity until several years have elapsed; only economic impacts are measured, and only those that are measurable with the System of National Accounts. Finally, correlation is not causality, an old lesson frequently overlooked.

The OECD knew these limitations very well: "Innovation and technological change are commonly considered as being the most important drivers of economic growth. However, it is difficult to capture their contribution in empirical analysis"[74]. In 2001, in collaboration with the OECD Statistics Directorate, the Directorate for Science, Technology and Industry therefore published "the first comprehensive" productivity manual aimed at "statisticians, researchers and analysts involved in constructing industry-level productivity indicators". Written by P. Schreyer, from the Statistics Directorate, the manual stated[75]:

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[72] R. R. Nelson (1981), Research on Productivity Growth and Productivity Differences: Dead Ends and New Departures, *op. cit*. p. 1029.

[73] *Ibid*., p. 1035.

[74] OECD (2000), A New Economy? The Changing Role of Innovation and Information Technology in Growth, *op. cit*. p. 27.

[75] OECD (2001), *Measuring Productivity: Measurement of Aggregate and Industry-Level Productivity Growth* (Productivity Manual), Paris, p. 115-117.

> When labour and capital are carefully measured, taking into account their heterogeneity and quality change, the effects of embodied technical change and of improved human capital should be fully reflected in the measured contribution of each factor of production (…). More often than not [however], data and resource constraints do not permit a careful differentiation and full coverage of all labour and capital inputs. As a consequence, some of the embodiment effects of technological change and some or all of the changes in skill composition of labour input are picked up by the MFP [multifactor productivity] residual (…). [But] MFP is not necessarily technology [it also includes the impact of other factors], nor does technological change exclusively translate into changes in MFP.

These limitations did not prevent the Directorate for Science, Technology and Industry from getting involved in productivity studies. Three elements characterized the way the Directorate "demonstrated" the link between science, technology and innovation, and productivity: 1) synthesizing academic works; 2) internationalizing the statistics; 3) developing a visual rhetoric. These are discussed below.

Synthesizing Academic Works

Academics usually convince others that they have done a good job by citing previous work to support their arguments[76]. The OECD reports were no exception. The main argument of the reports on the New Economy was usually reviewing and citing the academic work on the issue. This step was central, since the OECD always conducted a

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[76] B. Latour (1987), *Science in Action*, Cambridge (Mass), Harvard University Press, Chapter 1.

limited number of studies itself. Academic studies have always been the main source of OECD ideas.

The 2000 report on the *Growth Project* reviewed two kinds of work. First was the studies conducted on economic aspects of science and technology[77]. Trends in business R&D over the 1990s were discussed, as well as patents, high-tech trade, changes in research activities like new forms of financing (venture capital) and increased collaboration. Although interesting in themselves, these indicators had nothing to do with growth and productivity measurement *per se*. They have been used for a long time in other contexts, and are now widely grouped under the "knowledge-based economy" concept. In fact, these indicators were eliminated from the final OECD Growth Report (2001) – only to be reinserted later into a Directorate for Science, Technology and Industry specific publication on the subject.

The second kind of work reviewed specifically concerned the contribution of information and communication technologies to productivity[78]. Studies conducted at the aggregate, industry and firm level were discussed. Most if not all of the data were of American origin and, for this reason, were a major limitation in documenting the phenomenon for other countries. Nevertheless, the US growth pattern was sufficient to convince the OECD that something important was happening and waited only to be measured in other countries.

Internationalizing the Statistics

Besides using academic work to support its case, the OECD conducted its own studies. The added value of OECD works on statistics has always been its comparative and international basis. Nowhere else but in the *Growth Project* was this expertise present.

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77 OECD (2000), A New Economy? The Changing Role of Innovation and Information Technology in Growth, *op. cit*, p. 27-47.

78 *Ibid*., p. 50-71; OECD (2001), The New Economy: Beyond the Hype, *op. cit*. p. 16-26.

The OECD extended the American preoccupation on the New Economy and information and communication technologies to other countries.

Notwithstanding the limitations of academic studies, the Directorate for Science, Technology and Industry conducted the same kind of work with the same concepts and methodology, that is, calculating the contribution of R&D and information and communication technologies to multifactor productivity. This was the methodology that had already inspired the Directorate's contribution to the *Technology, Productivity and Job Creation* project. Equally, during the *Growth Project*, two kinds of such work were conducted. The first concentrated on the impact of R&D on productivity in 16 OECD countries[79]. An econometric model was developed that measured the impact of business R&D, public R&D and foreign R&D on productivity. With a few caveats, the author concluded: "Overall, the study points to the importance of technology for economic growth". Despite the positive correlations, however, the group of National Experts on Science and Technology Indicators (NESTI) qualified the study as "having numerous shortcomings and being rather mechanical"[80].

The second kind of study conducted with the multifactor productivity methodology dealt with the impact of information and communication technologies on several OECD countries[81]. At the

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79 D. Guellec (2000), *R&D and Productivity Growth: A Panel Data Analysis of 16 OECD Countries*, DSTI/EAS/STP/NESTI (2000) 40.

80 OECD (2001), *Summary Record of the NESTI Meeting, 14-15 May 2001*, DSTI/EAS/STP/NESTI/M (2001) 1, p. 7.

81 P. Schreyer (2000), The Contribution of ICT to Output Growth: A Study of the G7 Countries, DSTI/DOC (2000) 2; D. Pilat and F. C. Lee (2001), Productivity Growth in ICT-Producing and ICT-Using Industries: A Source of Growth Differentials in the OECD?, DSTI/DOC (2001) 4; A. Colecchia (2001), The Impact of ICT on Output Growth: Issues and Preliminary Findings, DSTI/EAS/IND/SWP (2001) 11; A. Colecchia and P. Schreyer (2001), ICT Investment and Economic Growth in the 1990s: Is the United States a Unique Case? - A Comparative Study of 9 OECD Countries, DSTI/DOC (2001) 7.

aggregate (country) level – where the OECD could innovate – measurements showed only a weak correlation between the importance of the information and communication sector and multifactor productivity: having an information and communication technology *producing* sector is not a prerequisite for growth, the studies concluded. The diffusion of information and communication technologies to *other industries* was therefore looked at, as it was hypothesized that it was this that played a leading role. However, there was insufficient evidence, again, to attribute productivity improvements in these industries directly to their use of information and communication technologies. "Ten years or so from now, it should be easier to assess, for instance, the impacts on growth deriving from information and communication technologies, other new technologies and changes in firm organization"[82]. But at the time, it was impossible.

Developing a Visual Rhetoric

The meagre empirical results did not prevent the OECD from publishing its report on the New Economy, adding a very long section on policies that should be promoted by governments in order to participate in the New Economy[83]. Multifactor productivity was only weakly correlated with growth, yet the report ignored much of its own data and proceeded to trot out the same old policy prescriptions that are open to some of the same criticisms that Nelson made (see p. 133 above).

One should add, however, that the reports were very cautious with regard to the data. They constantly reminded the reader of the limitations of current studies. This was really different from what the Directorate for Science, Technology and Industry has generally done with its own data: policy papers are usually short on caveats

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82 OECD (2001), Drivers of Growth: Information Technology, Innovation and Entrepreneurship, op. cit. p. 119.

83 OECD (2001), The New Economy: Beyond the Hype, *op. cit*. p. 27-68.

concerning data and sources. Here, however, the problems of measurement were amply discussed: the difficulty of measuring productivity correctly (output, services, quality changes); the limitations of using R&D as an indicator of science, technology, and innovation; and the lag before (information and communication) technologies become really productive and have an impact on the statistics. The OECD message was also cautious in another sense. The OECD constantly reminded the reader that the links between science, technology and innovation, and productivity have not been demonstrated. Equally, its own conclusions on these links were very timid, using words like "might" or "seem" (see p. 137 above) or concluding counterfactually (see p. 134 above).

In light of the limitations of the data and methodology, then, how could one make a convincing case for the New Economy? By balancing the limitations with a specific rhetorical device: a plethora of figures and graphs. The final *Growth Report* (2001) contains a total of 74 pages, on which one can find 35 graphs and figures, that is: a graph or figure for every two pages. The purpose here was twofold. First, graphs and figures were used in lieu of tables – only two statistical tables appeared in the report – because it made the document more attractive. Such a rhetorical strategy is important considering the readership of the OECD: ministers, policy-makers, journalists. Second, a large series of graphs and figures could persuade the reader of the seriousness of the study. Although no statistics could be used to prove without doubt the emergence of the New Economy, graphs and figures nevertheless served the purpose (save the image!) of empiricism.

CONCLUSION

In the end, one is thus left with a very modest role for economic statistics in narratives on science, technology and innovation, a role with diminishing returns. After nearly fifty years of studies, one still looks in vain for hard data on the links between science, technology and innovation, and productivity. The parameters for measurement "appear to be chosen not for their relevance but, either because data are already available or, because they are in line with dominant theoretical concepts"[84]. While it finally became possible to get mainstream economists engaged in analyzing technology and innovation, they came to be engaged in a dubious hypothesis, and the methods they used did not help the understanding of the complex phenomenon involved. In fact, the virtue of the framework on the new economy at the OECD has been that of a political device: finding a common ground between the Schumpeterian economists composing the Directorate for Science, Technology and Industry, and active for many years, even decades, on analyzing science, technology and innovation, and those neo-classical economists composing the Economic Directorate, new to the field, and beginning to arrive at far-reaching policy conclusions derived from simple correlations between composite variables, which they could not explain.

Economic growth and productivity issues have had a long history at the OECD. The mystique of growth started after World War II, and owed its existence in Europe mainly to American aid (the Marshall Plan). The OEEC – the predecessor of the OECD – and the European Productivity Agency devoted considerable efforts to convincing member countries to improve their productivity in the 1950s[85]. Today, alongside the OECD, it is the European Commission that most faithfully pursues work on productivity gaps between Europe and the United States in its annual reports on competitiveness. The failure to close the gap appears to be, according to the Commission, what characterizes the New Economy in the United States: higher employment rates, and higher labor productivity as a consequence of investments in information and communication technologies.

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84 G. Bell, F. Chesnais and H. Wienert (1991), Highlights of the Proceedings, in OECD, Technology and Productivity: The Challenge for Economic Policy, *op. cit*. p. 7.

85 B. Godin (2002), Technological Gaps: an Important Episode in the Construction of S&T Statistics, *Technology in Society*, 24 (4), p. 387-413.

At the OECD, measurement of science, technology and productivity waited until the 1990s to appear. Methodological difficulties, but also skepticism, limited the efforts for some time. In 1980, for example, the Directorate for Science, Technology and Industry policy division published a document titled *Technical Change and Economic Policy* (1980) which explicitly rejected the classical economists' work on measuring the contribution of science and technology to productivity[86]:

> To attempt to attribute so much experienced economic growth to technical advance, so much to capital formation, and so much to increased educational attainments of the work force, is like trying to distribute the credit for the flavour of a cake between the butter, the eggs and the sugar. All are essential and complementary ingredients.

Over time, the economists won. The strategy developed at the OECD to integrate productivity into its statistics and reports was threefold. First, digest all available academic work in order to imitate its methodology. Second, internationalize the (academic and national) statistics to make a convincing case for its member countries. Third, organize the narrative into a policy-oriented framework, using buzzwords. In the present case, it was new growth theories and the New Economy that were the buzzwords. But over the OECD history, the buzzwords also shared their popularity with others to which we now turn: competitiveness, globalization, national system of innovation, knowledge-based economy, and information economy.

86 OECD (1980), Technical Change and Economic Policy, *op. cit*. p. 65. The same example appeared in R. R. Nelson (1981), Research on Productivity Growth and Productivity Differences: Dead Ends and New Departures, *op. cit*. p. 1054.

CHAPTER FIVE

COMPETITIVENESS AND TRADE IN HIGH-TECHNOLOGY

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

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

The indicator remains a controversial one for conceptual and methodological reasons. Nevertheless, governments use it continually as part of their economic and innovation policy. As the US National

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[1] J. Tomlinson (1996), Inventing Decline: the Falling Behind of the British Economy in the Postwar Years, *Economic History Review*, 69 (4), p. 731-757.

Science Foundation has put the story, high-technology industries are important to nations for several reasons[2]:

1. High-technology firms innovate, and firms that innovate tend to gain market share, create new products/markets, and/or use resources more productively;
2. Industrial R&D performed by high-technology industries benefits other commercial sectors by generating new products and processes that increase productivity, expand business and create high-wage jobs;
3. High-technology firms develop high-valued-added products and are successful in foreign markets, which results in increased competition.

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

Some authors have qualified the debates on competitiveness as obsessive. To P. Krugman, for example, countries do not compete economically with each other as corporations do[3]. But the metaphor "derives much of its attractiveness from its seeming comprehensibility"[4]. First, the competitive image is exciting, and thrills sell tickets. Second, the metaphor makes difficulties easier to solve (subsidize high technology and be tough on competitor). Third, it is a political device that assists in justifying choices. This chapter shows how statistics contributed to the framework on

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2 National Science Foundation (2002), *Science and Engineering Indicators*, Washington, p. 6-5.

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

4 *Ibid.*, p. 39.

competitiveness, looking at the efforts of official statisticians to rhetorically transform early statistics on R&D into indicators on high technology.

Where does the high-technology indicator come from? Who was behind its construction? What narratives did governments construct using the indicator? This chapter attempts to answer these questions. It is divided into three parts. The first looks at the basic statistics behind the indicator, statistics developed in early analyses of industrial R&D surveys. The second part traces the evolution of the statistic through its use as an indicator of research or technological intensity. The third part discusses the internationalization of the indicator via the OECD.

A VERY BASIC RATIO

The simplest indicator on high technology is constructed by dividing R&D expenditures by production (i.e.: value-added, turn-over or sales) and then classifying industries according to this ratio. As R. N. Anthony, author of an influential survey on industrial R&D, once wrote: “Use of this ratio implies that there is some relationship between research spending and sales; to the extent that sales is a measure of the size of the company, this implication is in general warranted”[5].

The indicator has precursors that go back to the 1930s: following industrial managers’ practices, analyses of industrial R&D have always calculated ratios of R&D to sales. The US National Research Council conducted the first such analysis among the industrialized countries. In 1933, its Division of Engineering and Industrial Research tried to assess the effect of the Great Depression on

[5] R. N. Anthony and J. S. Day (1952), *Management Controls in Industrial Research Organizations*, Boston: Harvard University Press, p. 295.

industrial laboratories[6]. The report classified companies according to whether they spent over 10% of sales revenue on R&D, 5-10%, 1-5% or under 1%. With the data in hand, the authors concluded: "it appears that those companies the products of which more nearly approach the classification of raw materials spent a smaller percentage of their sales income for research than the companies in which products are of a **highly** manufactured character"[7].

The following two industrial surveys in the United States were conducted by or with the National Association of Manufacturers (NAM). In 1941, the organization participated in an industrial survey conducted by the National Research Council. The report measured that: "the median expenditure of the companies for industrial research was (…) 2 percent of gross sales income". This was the only number on R&D expenditures in the report, because the questionnaire had concentrated on personnel data (man-years), which were easier to obtain from companies. Eight years later, the National Association of Manufacturers published the results of a survey of industrial R&D in which these statistics appeared again[8]. The organization reported that in 1947, companies displayed an average ratio of research expenditures to estimated sales of 1.6%[9]. A larger proportion of the sales dollar was being spent by companies making professional, scientific and control instruments and photographic supplies, and electrical goods, the ratios being respectively 3.34% and 2.80%.

In the early 1950s, the US Bureau of Labor Statistics continued with similar statistics, locating some industries above the average (2.0%) – aircraft, electrical machinery, professional and scientific instruments,

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6 M. Holland and W. Spraragen (1933), *Research in Hard Times*, Division of Engineering and Industrial Research, National Research Council, Washington.

7 *Ibid*., p. 3.

8 National Research Council(1941), *Research: A National Resource (II): Industrial Research*, National Resources Planning Board, Washington: USGPO, p. 124.

9 National Association of Manufacturers (1949), *Trends in Industrial Research and Patent Practices*, p. 3, 77-79.

chemicals – and others below it[10]. The practice was thereafter carried over into publications of the National Science Foundation – the official producers of R&D statistics in the United States. The first National Science Foundation survey of industrial R&D, conducted by the Bureau of Labor Statistics (BLS), related R&D expenditures to sales – and tentatively to assets[11]. Then, in its third industrial survey, the Foundation calculated a second kind of ratio: R&D expenditures to value-added. R&D to capital was also calculated, a statistic that was said to "reflect more completely the magnitude of the manufacturing activities of a company or group of companies than do net sales"[12]. The National Science Foundation calculated that the value-added ratio was 4.8%, versus 2.0% for net sales. The statistic was short lived, however, with the Foundation abandoning the ratio in the following editions of the series.

Ratios of R&D expenditures to sales were not confined to the United States. Similar statistics appeared in an early industrial R&D survey conducted in the United Kingdom (R&D to turn-over[13]; R&D to net output[14]) and Canada (R&D as a percentage of sales)[15].

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10 Bureau of Labor Statistics (1953), *Industrial R&D: A Preliminary Report*, Department of Labor and Department of Defense, p. 12-13; Bureau of Labor Statistics (1953), *Scientific R&D in American Industry: A Study of Manpower and Costs*, Bulletin no. 1148, Washington, p. 26-29; D. C. Dearborn, R. W. Kneznek and R. N. Anthony (1953), *Spending for Industrial Research, 1951-1952*, Division of Research, Graduate School of Business Administration, Harvard University, p. 29ss.

11 National Science Foundation (1956), *Science and Engineering in American Industry: Final Report on a 1953-1954 Survey*, Bureau of Labor Statistics, NSF 56-16, Washington, p. 33ss.

12 National Science Foundation (1960), *Funds for R&D in Industry: 1957*, NSF 60-49, Washington, p. 28.

13 Federation of British Industries (1952), *R&D in British Industry,* London: FBI, p. 7.

14 Department of Scientific and Industrial Research (1958), *Estimates of Resources Devoted to Scientific and Engineering R&D in British Manufacturing, 1955*, London: HMSO, p. 17.

15 Dominion Bureau of Statistics (1956), *Industrial R&D Expenditures in Canada, 1955,* Reference paper no. 75, Ottawa, p. 15.

In general, the ratio was presented as a useful guide for managers interested in comparing their performance to other companies. For example, the National Science Foundation suggested: "In deciding upon their research budget, company officials frequently give consideration to certain objective financial standards, such as the ratio of R&D expenditures to sales. Such standards are seldom used in a rigid way but, rather, serve as a guide to management in determining the size of a research budget"[16]. From an analytical point of view, the statistic served to assess and compare the relative efforts of industries in terms of R&D, and to look at the impact of R&D on industries' economic performances. The message was to influence policies supporting R&D, particularly in big firms that invest more than others. A totally different rhetoric accompanies the indicator on high technology.

VARIATIONS ON A THEME

What characterized the construction of the high technology indicator was that a specific rhetoric and narrative came to be associated with the statistic. Firstly, labels were now associated with the ratio of R&D expenditures to sales: research intensity, technology intensity, high technology. Secondly, the indicator was developed and increasingly used in the context of debates on the competitiveness of countries. The United States was at the origins of the rhetoric, and the OECD was at the heart of the indicator's worldwide dissemination[17].

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[16] NSF (1956), Science and Engineering in American Industry, *op. cit*. p. 33.

[17] On the contribution of France to the issue of competitiveness and the technological balance of payments, see B. Godin (2002), Technological Gaps: An Important Episode in the Construction of Science and Technology Statistics, *op. cit*.

Research Intensity

In 1958, E. Hoffmeyer coined the term **research-intensity** to talk about the performances of industries in terms of R&D effort[18]. The balance of payments deficit in the United States was the context in which Hoffmeyer published his analysis of US foreign trade over the 20th Century. In fact, in the late 1950s, the balance of payments came to be an important economic issue (for the second time in a decade), and the competitiveness of countries was measured according to the statistics. A country was considered to be competitive if its exports exceeded its imports. Many countries began expressing concerns about their competitiveness as understood in this sense. Britain, for example, seconded by the OEEC's numbers, increased its laments on "economic decline"[19], particularly in light of its balance-of-payments deficit[20]. France launched a campaign against foreign investment[21] that led to the well-known debate on technological gaps[22]. The United States was no exception. Concerns over the US balance of payments occurred in the late 1950s and early 1960s[23]. Science and technology would soon come to be regarded as a source of strength in economic growth and foreign trade.

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

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

20 J. M. McGeehan (1968), Competitiveness: A Survey of Recent Literature, The Economic Journal, 78 (3), p. 243-262.

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

22 B. Godin (2002), Technological Gaps: An Important Episode in the Construction of Science and Technology Statistics, Technology in Society, 24, p. 387-413.

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

Using the National Science Foundation ratios of R&D expenditures to sales, Hoffmeyer looked at the structure of US foreign trade: eleven industries were classified into four groups according to their research effort or intensity. With the data, Hoffmeyer showed that the United States had a competitive advantage in the research-intensive industries. To the best of my knowledge, Hoffmeyer was the first to use this term, as well as the first to use it in the context of an analysis of international trade[24]. He would soon be imitated worldwide, first of all at the OECD.

In 1963, the OECD published a study it presented to the first ministerial meeting on science. The study, written by C. Freeman, R. Poignant and I. Svennilson, was the result of the OECD's early research program on the economics of science. Using available statistics, the authors looked at industrial R&D and constructed three industry groups, classified according to the ratio of R&D expenditures to sales[25]. The first group (Group A) was called **research-intensive industries** and was composed of aircraft, vehicles, electronics, other electrical, machinery, instruments, and chemicals. The study measured that "all the industrial countries considered show over two-thirds (the United States and the United Kingdom over nine-tenths) of their industrial R&D expenditure in Group A which comprises the research-intensive industries (…)"[26].

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24 In his early studies on the structural (technological) basis of the American economy, W. Leontief had coined the term "capital intensive goods" for those commodities that require for their manufacture large quantities of capital. See W. Leontief (1953), Domestic Production and Foreign Trade: The American Capital Position Reexamined, *Proceedings of the American Philosophical Society*, 97 (4), reprinted in *Input-Output Economics*, Oxford: Oxford University Press, 1986, p. 65-93.

25 OECD (1963), *Science, Economic Growth and Government Policy*, Paris, p. 81. Such a grouping comes from a study published by C. Freeman in 1962, except that no label was used with regard to research intensity: C. Freeman (1962), Research and Development: A Comparison Between British and American Industry, *National Institute Economic Review*, 20, May, p. 21-39.

26 OECD (1963), Science, Economic Growth and Government Policy, *op. cit.*, p. 30.

To the authors, research-intensive industries had several characteristics that made them valuable from the point of view of policies: 1) they were generally the fastest-growing industries[27], 2) their share of world trade was growing[28], and 3) they had the highest technological balance of payments[29].

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

A few years after the 1963 report, the OECD took part in a second campaign, this one calling for the closing of the technological gaps between European countries and the United States. In its main report, the OECD introduced a new term: **science-based industries**[30]**.** Using the same criteria as in 1963 (R&D as a percentage of sales), industries were classified into four groups: science-based, mixed, average, and non-science based (Table 9). The report calculated that the United States had the highest proportion of R&D activity in the science-based industries, and found the largest difference between the United States and other countries in this group.

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27 *Ibid*., p. 29.

28 *Ibid*., p. 32.

29 *Ibid*., p. 33.

30 OECD (1970), *Gaps in Technology: Comparisons Between Member Countries in Education, R&D, Technological Innovation, and International Economic Exchanges*, Paris, p. 135ss. I found only one occurrence of the term before the OECD: C. F. Carter and B. R. Williams (1958), *Investment in Innovation*, London: Oxford University Press, p. 68.

The OECD study took things one step further than the previous study, looking at product groups instead of industries: "a distinction must be made between the industry group and the product field", stated the OECD. While firms are usually classified in an industry group according to their main activity, an industry "may be relevant to several products". The OECD thus classified industrial R&D according to fifty products. It then used the data to study the role of science and technology, particularly science-based industries, in the international competitive position of countries as measured by export performance[31].

Table 9. OECD Research-Intensity Levels (1970)

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

The OECD study – the empirical material for which came from Science Policy Research Unit (SPRU) researchers – was one of the first conducted worldwide linking science and trade[32]. It confirmed earlier findings of the organization. Research-intensive groups accounted for a large share of manufacturing exports, and the Americans had the lead over Europe, followed by the medium-sized countries, then the smaller industrialized OECD member countries: "there is a high concentration of United States exports in those

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31 OECD (1970), Gaps in Technology, *op. cit.* p. 206ss and 253ss.

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

product groups where there is a high concentration of R&D effort"[33]. However, the OECD calculated that the share of the United States in OECD exports had declined from 23.7% in 1962 to 21.3% in 1966 as a result of catching-up by other OECD countries.

Technology Intensity

It was precisely in the context of issues of international competitiveness that a new term – technology intensity – appeared, used to describe the same phenomenon. In the course of the debate on the technological gaps between Europe and the United States, the US government set up an interdepartmental committee to study the issue[34]. At the request of the (Hornig) committee, the Department of Commerce conducted one of the first surveys of American investments and operations in Europe. To the best of my knowledge, it is this survey that coined the term technology-intensive industries to document the structure of US direct investment in Western Europe[35]. According to the committee, 80% of all US direct investments in manufacturing in Western Europe were in technology-intensive industries, and Americans controlled large segments of the market in such technology-intensive products as computers.

As a follow-up to its report, the committee recommended that the Department of Commerce "conduct on a continuing basis in-depth analytical studies on the economic and technological questions related to technological disparities and to the international flow of technology, trade, and investments"[36]. The Department of Commerce responded with further studies and reports that brought onto the scene the concept of technology intensity, and the decline of the United

33 OECD (1970), Gaps in Technology, *op. cit*., p. 255.

34 B. Godin (2003), Technological Gaps, *op. cit*.

35 *Report of the Interdepartmental Committee on the Technological Gap*, Report submitted to the President, December 22, 1967, White House, p. 13-14.

36 *Ibid*., p. v.

States in technology-intensive industries. M. T. Boretsky, director of the Technological Gap Study Program (1967-69) at the Department of Commerce, launched the research program.

Until then, as we have seen above, "research-intensive industries" were defined as those that had a high R&D/sales ratio. Boretsky instead used three statistics (or criteria, as he called them) to construct what he called technology-intensive products (although he used industries as the unit, not products)[37]. These criteria were R&D, scientific and technical manpower, and the skill level of workers. The following industries were thus identified as belonging to the category: chemicals, non-electrical machinery, electrical machinery and apparatus (including electronics), transportation equipment (including automobiles and aircraft), and scientific and professional instruments and controls. The industries responsible for these products represented 14% of GDP in the United States, employed 60% of all scientific and engineering manpower, and performed 80% of non-defense industrial R&D.

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

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

should have been accorded to the United States rather than to the major countries of Europe, or to Japan", concluded M. Boretsky[38].

The Department of Commerce continued to develop and improve the indicator in the following years[39], and used the data to document America's competitiveness[40]. In fact, the 1980s was a time when the US government became obsessed with international competitiveness: "the United States is playing a relatively smaller role in the world economy", stated the report of the President on US competitiveness in 1980[41]. Indeed, in 1971, the US balance of trade turned to a deficit for the first time since 1893, and in 1986 the US trade performance in technology-intensive industries would dip into a $2.6 billion deficit for the first time. But now it was Japan rather than Europe that was the target: "Japan has joined the United States in having a comparative advantage in technology-intensive products (…)", warned the document[42]. In response, the US government set up a

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

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

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

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

42 Soon, every US organization would get into the discourse. See, for example: Office of Technology Assessment (1991), *Competing Economies: America, Europe, and the Pacific Rim*, Washington; National Research Council (1992), *Japan's Growing Capability: Implications for the US Economy*, Office of International Affairs, Washington: National

Commission on Industrial Competitiveness in 1983[43], then the Council on Competitiveness in 1986[44], and the Competitiveness Policy Council in 1992[45]. It also set up the Critical Technologies Institute in 1991 (renamed the Science and Technology Policy Institute in 1998), which periodically identified technologies critical for the future[46]. It was in this context that concepts like critical technologies, core technologies, basic technologies, advanced technologies, new technologies, strategic technologies and emerging technologies came onto the scene[47].

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

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Academy Press; National Science Foundation (1995), *Asia's New High-Tech Competitors*, NSF 95-309, Washington: National Science Foundation.

43 Global Competition: the New Reality, 1985.

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

45 Building a Competitive America, 1992, Washington.

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

47 National Research Council (1983), International Competition in Advanced Technology: Decisions for America, Washington: National Academy Press; US Department of Commerce (1987), The Status of Emerging Technologies: An Economic/Technological Assessment to the Year 2000, NBSIR 87-3671, Washington; H. Giersch (ed.) (1982), Emerging Technologies: Consequences for Economic Growth, Structural Change and Employment, Tubinger, Mohr; Science Council of Canada (1986), A National Consultation on Emerging Technologies, Ottawa; OECD (1985), Analytical Report of the Ad Hoc Group on Science, Technology and Competitiveness, SPT (84) 26; OECD (1988), New Technologies in the 1990s: A Socio-Economic Strategy, Paris.

Department of Labor,[48] the Bureau of Census,[49] and the National Science Foundation[50]. The Foundation's work in fact started soon after Boretsky's, and was intended to add new indicators to its recent *Science Indicators* series. The organization defined technology intensity using two criteria: R&D as a percentage of sales, and the number of scientists and engineers engaged in R&D.

From these efforts, the use of the indicator soon spread to other countries[51] and international organizations like the European Commission[52] and the OECD.

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

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

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

51 H. Legler (1987), West German Competitiveness of Technology Intensive Products, in H. Grupp (ed.), *Problems of Measuring Technological Change*, Koln: Verlag TUV Rheinland GmbH; OECD (1988), *La mesure de la haute technologie: méthodes existantes et améliorations possibles*, DSTI/IP/88.43, p. 10-14. For the United Kingdom, see: R. L. Butchart (1987), A New UK Definition of the High-Technology Industries, *Economic Trends*, 400, p. 82-88; For Canada, see: Ministry of State, Science and Technology (1978), *Canadian Trade in Technology-Intensive Manufactures, 1964-1976*, Ottawa.

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

HIGH TECHNOLOGY

In the mid-1980s, the term **high technology** began to be used concurrently or in place of technology intensity, as evidenced in the US Department of Commerce reports[53]. Nothing had changed with regard to the statistic, however, but a valued and prestigious label (high) was now assigned to it. The OECD was an important catalyst in the dissemination of this term.

As early as 1980, the OECD Committee for Scientific and Technological Policy (CSTP) set up an *ad hoc* group on science, technology and competitiveness to get a better understanding of international competitiveness and its relations to technology. The group delivered its analytical report in 1984. According to the group, "differences in R&D intensities are best interpreted as signifying, first that in some industries technology is more immediately geared to R&D than it is in others", and second that "such industries may also represent the technology base on which other industrial sectors rely and from which inter-sectoral transfers of technology must take place (…)"[54]. The main thesis of the report was therefore: "changes in the nature and location within industry of *core technologies* are probably associated with extensive economic and industrial changes of a structural type, both at the domestic and at the international level, many of which will bear directly on the competitiveness of firms and economies"[55].

The real impetus to work on high technology, however, came from the OECD Council of Ministers, which asked the Secretariat in 1982 to examine the problems that could arise in the trade of high-technology products. High-technology trade had now gained strategic

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

54 OECD (1985), Analytical Report of the Ad Hoc Group on Science, Technology and Competitiveness, *op. cit*. p. 11.

55 *Ibid*., p. 14.

importance in the economic and political context of the time, particularly in the United States (due to security reasons and economic concerns), but also in other OECD member countries: high-tech industries were expanding more rapidly than other industries in international trade, and were believed to be an important policy option for economic progress. The Industry Committee and the Committee for Science and Technology Policy of the Directorate for Science, Technology and Industry thus studied approaches to international trade theory[56], and conducted two series of analyses: six case studies of specific industrial technologies, plus some reflections on defining high technology in terms of five characteristics or criteria (which went beyond mere ratios of R&D expenditures to sales)[57]. It reported back to the Council in 1985[58].

The first international statistics were published in 1986 in the second issue of the OECD's *Science and Technology Indicators* series. The organization improved over previous works, in two senses. Firstly, it began using a new label systematically – high technology. Secondly, it broke down the statistics into subclasses. Up until then, there had been only one class of industries or products classified according to technology intensity. Others were simply forgotten or called non-technology-intensive. With the OECD, three categories of technology intensity were now constructed: high, medium and low (Table 10).

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56 OECD (1981), *Analysis of the Contribution of the Work on Science and Technology Indicators to Work on Technology and Competitiveness*, DSTI/SPR/81.21.

57 OECD (1984), Background Report on the Method of Work and Findings of the Studies Carried Out by the Industry Committee and the Committee for Scientific and Technological Policy, DSTI/SPR/84.1.

58 OECD (1985), An Initial Contribution to the Statistical Analysis of Trade Patterns in High Technology Products, DSTI/SPR/84.66.

Table 10. OECD Technology Intensity Levels (1986)

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

The source of this innovation is most probably economist Rupert W. Maclaurin from MIT. Maclaurin is an author totally forgotten today. One finds nothing in the literature on his biography, and neither is there anything on his role in the literature on innovation, except old citations[59]. Beginning in the early 1940s, he developed the first program of research on the economics of technological change[60]. He used Schumpeter's ideas, analyzing innovation as a process composed of several stages or steps, and proposed a theory of innovation, later called the linear model of innovation. From this research, he developed the first full-length discussion of the model,

59 R. R. Nelson (1959), The Simple Economics of Basic Scientific Research, *Journal of Political Economy*, 67, p. 297-306; E. Mansfield (1968), *The Economics of Technological Change*, New York: Norton, p. 12 (footnote 2), p. 34 (footnote 45).

60 B. Godin (2007), *In the Shadow of Schumpeter: W. Rupert Maclaurin and the Study of Technological Innovation*, Project on the History and Sociology of STI Statistics, INRS: Montreal, Forthcoming.

and suggested the first list of indicators for measuring innovation[61]. Then in 1954, Maclaurin suggested a measure of "technological progress" based on a three-stage classification (high, medium and low) and classified thirteen industries according to the volume of R&D expenditures, the number of patents issued and the number of scientists [62]:

Highest rate of progress

Chemical

Photographic

Airplane

Oil

High Progress

Radio and television

Electric light

Medium Progress

Automobile

Paper

Steel

Lower progress

Food processing

Cotton textile

Coal mining

House assembling

The classification was influential. In the following years, similar classifications appeared. In the late 1950s, C. F. Carter and B. R. Williams, respectively from Belfast and Keele universities, carried out a series of studies on innovation for the Science and Industry

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[61] W. R. Maclaurin (1953), The Sequence from Invention to Innovation and its Relation to Economic Growth, *Quarterly Journal of Economics*, 67 (1), p. 97-111.

[62] W. P. Maclaurin (1954), Technological Progress in Some American Industries, *American Economic Review*, 44 (2), p. 178-200.

Committee of the British Association for the Advancement of Science[63]. One of these studies looked at the characteristics of firms that make them "technically progressive", or innovative, defined as using science and technology, and capable of producing or adopting new products and processes[64]. The suggested classification for over 150 firms in their sample population was: progressive, moderately progressive and non-progressive. From their calculations, Carter and Williams measured a relationship between progressiveness and firms' performance, such as profits. Then, a three-level classification came to be used in several national reports, like the US Tariff Commission in 1973[65], and the Canadian Ministry of State for Science and Technology[66].

With its new classification, the OECD calculated that the R&D-intensive industries[67] were responsible for 51% of total industrial R&D of OECD countries during the period 1970-1980[68]. The organization also found that these industries have the highest growth, and show a positive correlation between R&D intensity and exports. The United States and Japan were at the forefront. In the next decade,

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63 C. F. Carter and B. R. Williams (1957), *Industry and Technical Progress: Factors Governing the Speed of Application of Science*, London: Oxford University Press; C. F. Carter and B. R. Williams (1958), *Investment in Innovation*, London: Oxford University Press; C. F. Carter and B. R. Williams (1959), *Science in Industry: Policy for Progress*, London: Oxford University Press.

64 C. F. Carter and B. R. Williams (1957), Industry and Technical Progress, *op. cit.*, p. 108-111, 177-188; C. F. Carter and B. R. Williams (1959), The Characteristics of Technically Progressive Firms, *Journal of Industrial Economics*, 7 (2), p. 87-104.

65 US Tariff Commission (1973), Implications of Multinational Firms for World Trade and Investment and for US Trade and Labor, Washington.

66 Ministry of State, Science and Technology (1978), Performance of Canadian Manufacturing Industries by Levels of Research Intensity, Background Paper, Ottawa.

67 The term R&D intensity is used in the OECD text despite the fact that the chapter dealt with technology intensity.

68 OECD, Science and Technology Indicators, Paris, p. 58-74.

all statistical analyses on competitiveness conducted by the Directorate showed the same patterns[69].

The early OECD analytical work on high technology was based on the US classification scheme[70]. The US Department of Commerce had developed a list of ten high-technology industries based on ratios of R&D expenditures to sales. The first OECD list of high-technology industries extrapolated the structure of American industry onto the entire area covered by the OECD, and was criticized for this reason[71]. The OECD consequently organized a workshop in 1983[72] in which the literature on international trade theory and its main concepts[73] were studied to learn how to develop high-technology trade indicators. The workshop concluded on the need for such indicators based on the following "fact": "direct investment or the sale of technology are as effective as exports in gaining control of markets"[74].

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69 OECD (1992), Technology and the Economy: the Key Relationships, Paris, chapter 11; OECD (1992), Science and Technology Policy Outlook, Paris, chapter 2; OECD (1996), Technology and Industrial Performance, Paris, chapter 5.

70 In fact, before the OECD Secretariat worked on the topic, no country had developed much work apart from the United States. See OECD (1993), Summary of Replies to the Questionnaire on Methodology, DSTI/EAS/IND/STP (93) 4.

71 OECD (1980), *International Trade in High R&D Intensive Products*, STIC/80.48; OECD (1983), Experimental Studies on the Analysis of Output: International Trade in High Technology Products – An Empirical Approach, *op. cit.*

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

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

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

In collaboration with the Fraunhofer Institute for Systems and Innovation Research (Germany), the OECD then developed a new classification based on a broader sample of eleven countries[75]. But there were still problems regarding the lack of sufficiently-disaggregated sectoral data: the list was based on industries rather than products[76]. All products from high-technology industries were qualified as high-tech even if they were not, simply because the industries that produced them were classified as high-tech. And conversely, all high-tech products from low-technology industries were qualified as low-tech. Another difficulty was that the indicator did not take technology dissemination into account, but only R&D. An industry was thus reputed to be high-technology intensive if it had high levels of R&D, even if it did not actually produce or use much in the way of high-technology products and processes. Finally, the data upon which the list was based dated from 1970-80[77], whereas high-technology products were known to be continuously evolving[78].

The list was therefore revised in the mid-1990s in collaboration with Eurostat[79] and following a workshop held in 1993[80]. It used much more recent data, and included a new dimension to take technology dissemination, as embodied technology (technology incorporated in

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

76 OECD (1978), Problems of Establishing the R&D Intensities of Industries, DSTI/SPR/78.44.

77 OECD (1988), La mesure de la haute technologie: méthodes existantes et améliorations possibles, *op. cit.*; OECD (1991) *High Technology Products: Background Document*, DSTI/STII (91) 35.

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

79 OECD (1994), *Classification of High-Technology Products and Industries*, DSTI/EAS/IND/WP9 (94) 11; OECD (1995), *Classification of High-Technology Products and Industries*, DSTI/EAS/IND/STP (95) 1; OECD (1997), *Revision of the High Technology Sector and Product Classification*, DSTI/IND/STP/SWP/NESTI (97) 1.

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

physical capital), into account. Two lists were in fact developed. The first concerned high-technology industries, and considered both direct (R&D)[81] and indirect[82] intensities[83]. Four groups of industries were identified, with medium technology being divided into high and low (Table 11). But limitations persisted: high-technology intensities were calculated on the basis of the principal activity of the firms that made up the industry, and there was a lack of disaggregated details. In addition, the OECD recognized that: "the classification of the sectors in three or four groups in terms of their R&D intensity is partly a normative choice"[84].

This led to the development of the second list, which was based on products rather than industries, and which was solely concerned with the high-technology category. All products with R&D intensities above the industry average, i.e.: about 3.5% of total sales, were considered high-tech. This list excluded products that were not high-tech, even if they were manufactured by high-tech industries. Furthermore, the same products were classified similarly for all countries. But there were and still remain two limitations. Firstly, the indicator was not totally quantitative: it was partly based on expert opinion. Secondly, the data were not comparable with other industrial data.

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[81] R&D expenditure-to-output ratios were calculated in 22 sectors of the 10 countries that accounted for more than 95% of OECD industrial R&D, then, using purchasing power parities, each sector was weighted according to its share of the total output.

[82] Input-output coefficients.

[83] For details on calculations, see OECD (1995), *Technology Diffusion: Tracing the Flows of Embodied R&D in Eight OECD Countries*, DSTI/EAS (93) 5/REV1; G. Papaconstantinou et al. (1996), *Embodied Technology Diffusion: An Empirical Analysis for 10 OECD Countries*, OECD/GD (96) 26.

[84] OECD (1995), Classification of High-Technology Products and Industries, DSTI/EAS/IND/STP (95) 1, p. 8.

Table 11. OECD List of Technology Industries (1997)

HIGH

Aircraft and Spacecraft (ISIC 353)
Pharmaceuticals (ISIC 2423)
Office, accounting and computing machinery (ISIC 30)
Radio, TV and communications equipment (ISIC 32)
Medical, precision and optical instruments (ISIC 33)

MEDIUM-HIGH

Electrical machinery and apparatus (ISIC 31)
Motor vehicles, trailers and semi-trailers (ISIC 34)
Chemicals excluding pharmaceuticals (ISIC 24 *less* 2423)
Railroad equipment and transport equipment (ISIC 352 + 359)
Machinery and equipment (ISIC 29)

MEDIUM-LOW

Coke, refined petroleum products and nuclear fuel (ISIC 23)
Rubber and plastic products (ISIC 25)
Other non-metallic mineral products (ISIC 26)
Building and repairing of ships and boats (ISIC 351)
Basic metals (ISIC 27)
Fabricated metal products, except machinery & equipment (ISIC 28)

LOW

Manufacturing; Recycling (ISIC 36-37)
Wood and products of wood and cork (ISIC 20)
Pulp, paper, paper products, printing and publishing (ISIC 21-22)
Food products, beverages and tobacco (ISIC 15-16)
Textiles, textile products, leather and footwear (ISIC 17-19)

Unlike other OECD science and technology indicators, the work of the organization on high technology never led to a methodological manual. Several times, among them during the fourth revision of the Frascati manual, a manual devoted to high technology was envisioned[85], but never written. Nevertheless, indicators on international trade in high technology industries were published regularly in *Main Science and Technology Indicators* from 1988.

CONCLUSION

How has the concept of high technology improved over the previous concepts? Certainly, one could argue with Kelly that: "research-intensity and technology-intensity are not necessarily the same concept. What one is really trying to measure [with technology intensity] is the degree of technical sophistication of products that gives them a competitive edge (…)"[86]. However, it should have become clear from the above analysis that both concepts are actually the same, according to their measurement. This is because, as Kelly himself admitted: "as in many areas of economics, proxies must be used as an indicator (…). [And we] chose the R&D intensity". The OECD technology intensity indicator is also based on R&D expenditures to sales ratios, and is frequently discussed in terms of R&D intensity rather than technology intensity.

When multiple criteria are used, they usually center around Boretsky's three criteria, to the point that "limited progress appears to have been made on the measurement of technology intensiveness since the original Boretsky paper"[87], except for rhetorical inventiveness. For example, a newly-coined concept appeared

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85 OECD (1991), Future Work on High Technology, DSTI/STII/IND/WP9 (91) 7; OECD (1991), High Technology Products, DSTI/STII (91) 35; OECD (1992), High Technology Industry and Products Indicators: Preparation of a Manual, DSTI/STII/IND/WP9 (92) 6; OECD (1993), Seminar on High Technology Industry and Products Indicators: Preparation of a Manual, DSTI/EAS/IND/STP (93) 2.

86 R. K. Kelly (1976), Alternative Measurements of Technology-Intensive Trade, *op. cit*. p. 8.

87 F. Chesnais and C. Michon-Savarit (1980), Some Observations on Alternative Approaches to the Analysis of International Competitiveness and the Role of Technology Factor, STIC/80.41, OECD, p. 14.

recently at the OECD in its work on the knowledge-based economy: **knowledge-based industries**[88]**.** Knowledge-based industries are defined as those that have the following three characteristics: 1) a high level of investment in innovation, 2) intensive use of acquired technology, and 3) a highly-educated workforce[89]. This is a perfect example of a variation on the high technology indicator.

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

Academics are no better[90]. What role have they played in all this? It is clear that the indicator originally came from official organizations. However, some precursors exist in the academic literature: W. R. Maclaurin, C. F. Carter and B. R. Williams. In general, however, academics (economists) have satisfied themselves with models correlating R&D with exports to assess the role of science in trade performances[91]. But they also acted as consultants to public

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88 See Chapter 8 below.

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

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

91 T. C. Lowinger (1975), The Technology Factor and the Export Performance of US Manufacturing Industries, *Economic Inquiry*, 13, p. 221-236; F. Wolter (1977), Factor Proportions, Technology and West German Industry's International Trade Patterns, *Weltwirtschaftliches Archiv*, 113, p. 250-267; H. Legler (1987), West German Competitiveness of Technology Intensive Products, in H. Grupp (ed.), *Problems of Measuring Technological Change*, Kohl: Verlag, p. 171-190; J. Fagerberg (1988), International Competitiveness, *The Economic*

organizations, helping to define indicators on technology intensity[92], and increasingly used the high-technology label and its indicators in the 1990s, or developed their own classifications[93]. Above all, academics were at the heart of the discourses on competitiveness[94].

Today, the indicator remains a highly-contested measure. The main criticism has to do with the basic statistics behind the indicator: R&D expenditures. Some authors therefore have suggested replacing R&D with patents[95], and others have argued for using several dimensions

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Journal, 98, p. 353-374; G. Dosi and L. Soete (1988), Technical Change and International Trade, in G. Dosi et al. (eds.), *Technical Change and Economic Theory*, London: Frances Pinter, p. 401-431.

92 C. Freeman (SPRU) for the OECD; T. A. Abbott (Rutgers University) for the US Bureau of Census; A. L. Porter and J. D. Roessner (Georgia Institute of Technology) for the NSF.

93 E. Papagni (1992), High-Technology Exports of EEC Countries: Persistence and Diversity of Specialization Patterns, *Applied Economics*, 24, p. 925-933; G. Amendola and A. Perrucci (1994), European Structures of Specialization in High-Technology Products: A New Approach, *STI Review*, 14, p. 163-191; H. Grupp (1995), Science, High Technology and the Competitiveness of EU Countries, *Cambridge Journal of Economics*, 19, p. 209-223; P. Guerrieri and C. Milana (1995), Changes and Trends in the World Trade in High-Technology Products, *Cambridge Journal of Economics*, 19, p. 225-242; J. D. Roessner et al. (1996), Anticipating the Future High-Tech of Nations: Indicators for 28 Countries, *Technological Forecasting and Social Change*, 51, p. 133-149; A. L. Porter et al (1996), Indicators of Technology Competitiveness of 28 Countries, *International Journal of Technology Management*, 12 (1), p. 1-32; A. L. Porter et al., (1999), *Indicators of Technology-Based Competitiveness of 33 Countries*, TPAC, Georgia Institute of Technology, Atlanta; A. L. Porter et al. (2001), Changes in National Technological Competitiveness, *Technology Analysis and Strategic Management*, 13, p. 477-496; D. Roessner et al. (2002), A Comparison of Recent Assessments of High-Tech Competitiveness of Nations, *International Journal of Technology Management*, 23, p. 536-537.

94 M. E. Porter (1990), The Competitive Advantage of Nations, New York: Free Press.

95 L. Soete (1987), The Impact of Technological Innovation on International Trade Patterns: The Evidence Reconsidered, Research Policy, 16, p. 101-130.

and statistics to define the indicator[96]. A second frequently-voiced criticism has to do with the fact that a firm may be considered technology-intensive not only because it conducts R&D, but also if it adopts and uses advanced technologies in its activities and employs highly-trained workers[97]. In this sense, low-tech and medium-tech industries are in a close, symbiotic relationship with high-tech industries, and constitute a market for the latter[98]. A third criticism refers to the fact that there is no standardization yet, and therefore organizations and authors produce different results. T. A. Abbott, for example, has documented how a trade surplus of $3.5 billion (1985-88) is measured when products are used as units, and a deficit ($17 billion) appears when the measurement is based on industries[99].

Certainly, the indicator brought simplification to statistical analyses. Before high-technology groups appeared, analysis of R&D and trade was conducted according to individual industrial classes or

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

[97] K. S. Palda (1986), Technological Intensity: Concept and Measurement, *Research Policy*, 15, p. 187-198; J. R. Baldwin and G. Gellatly (1998), *Are There High-Tech Industries or Only High-Tech Firms? Evidence From New Technology-Based Firms*, Research Paper series, No. 120, Statistics Canada.

[98] N. von Tunzelmann and V. Acha (2005), Innovation in "Low-Tech" Industries, in J. Fagerberg, D. C. Mowery and R. R. Nelson (eds.), The Oxford Handbook of Innovation, Oxford: Oxford University Press, 407-432. See also the contributions to the PILOT Project's conference on "Low-Tech as a Misnomer: the Role of Non-Research-Intensive Industries in the Knowledge Economy", Brussels, 29-30 June 2005. http://www.pilot-project.org/conference.html.

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

products[100]. The high-technology indicator reduced the classification to only three groups. But the indicator also highlighted statistical discrepancies between studies. As the OECD itself argued, each author, organization or country has its own idea of what constitutes high technology, and each uses its own vocabulary[101]. The OECD was only partly right, however, when it suggested that "the concept of high technology became part of our everyday vocabulary before economists and scientists had even managed to produce a precise and generally-accepted definition of the term"[102]. Very early on, official economists (and statisticians) invented the concept and constructed a measurement – which more or less focused on R&D data. The problem stems rather from the political obsession to which it was applied – competitiveness[103] – and the urge to support the case quantitatively.

[100] For example, see: Leontief (1953), *op. cit*; B. Balassa (1962), Recent Developments in the Competitiveness of American Industry and Prospects for the Future, in Joint Economic Committee, Factors Affecting the United States Balance of Payments, *op. cit*, p. 27-54; W. H. Branson and H. B. Junz (1971), Trends in US Trade and Comparative Advantage, *Brooking Papers on Economic Activity*, 2, p. 285-345.

[101] OECD (1993), *Summary of Replies to the Questionnaire on Methodology*, DSTI/EAS/IND/STP (93) 4.

[102] OECD (1988), *La mesure de la haute technologie: méthodes existantes et améliorations possibles*, DSTI/IP/88.43, p. 3.

[103] To get an idea of the reports produced in several countries in the early 1990s, see: OECD (1995), *Competitiveness: An Overview of Reports Issued in Member Countries*, DSTI/IND (95) 15. For the OECD program of work on competitiveness in the 1990s, see: OECD (1993), *Framework Conditions for Industry: A New Policy Paradigm*, DSTI/IND (93) 31.

CHAPTER SIX

THE POLITICAL AGENDA ON GLOBALIZATION, ITS FRAMEWORK AND MEASUREMENT

As the previous chapter documented, industrial competitiveness, or the capacity of firms to produce and sell goods and services, was on every government's lips in the 1990s[1]. The OECD was no exception, and conducted several studies on industrial competitiveness. What was characteristic of these works was that, with time, they increasingly came to be linked to a narrative on globalization: "The concern with competitiveness is not new (…). However, within the current context of the globalization of product and capital markets and the rapid diffusion of know-how, meeting the competitiveness agenda has assumed greater urgency"[2].

According to every analyst, the competitiveness of a nation is much more difficult to define than that of a firm[3]. Broadly defined, however, national competitiveness refers to at least three elements. First, to the capacity of a country to sell its products and services in other countries. Here international trade is the traditional indicator for assessing the countries' competitiveness, and early on, the OECD Directorate for Science, Technology and Industry developed indicators on high technology trade. The second way to compare countries according to competitiveness is by looking at productivity. Again, the Directorate conducted a whole program of work in the

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1 For an overview of national reports on industrial competitiveness, see: OECD (1996), *Industrial Competitiveness,* Paris.

2 OECD (1995), *High Level Forum on Industrial Competitiveness: Draft Synthesis of the Discussions*, DSTI/IND (95) 18, p. 3.

3 P. Krugman (1997), *Pop Internationalism*, Cambridge (Mass.), MIT Press.

1990s that compared the productivity of OECD member countries and tried to explain the differences as being attributable to technology. Third, the competitiveness of countries refers to the factors, or the national environment, that are the major determinants of the location and of the investment decisions of firms[4]:

> In all OECD countries, a major impact of globalization on government policy has been to focus policymakers' attention to the importance of the framework conditions for business activity. In global competition in product and capital markets, and ensuing mobility of production capacity in trade exposed sectors, domestic level of investment, employment and earnings are heavily influenced by the framework parameters that affect local firms' productivity, cost-effectiveness and innovativeness. These factors make the national business sector more or less attractive to internationally mobile investment capital, and to localization decisions by multinational corporations.

In 1994, the OECD embarked on a project using benchmarking indicators precisely for comparing the characteristics, strengths and weaknesses of domestic business environments, that is, the "framework conditions" of OECD countries[5]. Eight variables were finally chosen to define competitiveness and to benchmark countries: research and development (R&D) infrastructure, educational profile of the labour force, corporate governance environments, employment

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4 OECD (1996), Framework Conditions for Industrial Competitiveness: Past Progress and Next Steps, DSTI/IND (96) 14, p. 2.

5 OECD (1993), Framework Conditions for Industry: A New Policy Paradigm, DSTI/IND (93) 31; OECD (1994), Framework Conditions for Industrial Competitiveness: the OECD Industry Committee Project, DSTI/IND (94) 4; OECD (1994), Cadre des activités industrielles: résumé et conclusions de la reunion "méthodologie et plan de travail", DSTI/IND (94) 11.

regulations, labour costs, corporate taxation, energy costs, telecommunication costs and infrastructures. The results were published under the umbrella of globalization in 1997[6]. To the OECD, these factors were framework conditions for decisions of firms to globalize: "in rapidly globalizing OECD economies, differences in framework conditions for industry are having an increasing impact (…)"[7].

But what is globalization? And how should we measure it? This chapter looks at the efforts of the OECD to define globalization, a concept that still remains fuzzy today, and to develop standardized indicators. It develops the thesis that globalization is not a new phenomenon but rather reflects policy-makers and statisticians' new interest in globalization. The first part discusses the conceptual framework that the OECD developed in the 1990s to analyze the globalization of economies. The framework centered on foreign direct investment as the main characteristic of globalization. The second part analyzes the impact of both globalization and OECD work on science and technology statistics. As technology was identified as the second characteristic of globalization, several science, technology and innovation statistics came to be revised or reconsidered to introduce the dimension of globalization. The last section discusses the empirical results emerging from the OECD work.

THE GLOBALIZATION FRAMEWORK

The current statistical work of the OECD Directorate for Science, Technology and Industry owes its orientation partly to the Technology and Economy Program of the early 1990s, which

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6 OECD (1997), Industrial Competitiveness: Benchmarking Business Environment in the Global Economy, Paris.

7 OECD (1994), Framework Conditions for Industrial Competitiveness: the OECD Industry Committee Project, op. cit. p. 4.

identified globalization as one of the eight topics that should be extensively studied. In fact, the conference that launched the Technology and Economy Program concluded that the concept of globalization was fuzzy, subjective, badly defined and a hodge-podge of ideas[8]. Years later, globalization was still qualified as a "fairly vague and imprecise concept"[9]. Certainly, international trade has grown by a factor of 16 in real terms since 1950, and foreign direct investment by 25 times since 1970[10]. But, "none of these components of economic globalization is actually new", admitted the OECD; "rather, it is their intensity and multiplicity, which gathered pace in the 1980s and 1990s, that are creating a new world-wide economic system"[11]. Internationalization has taken new forms, and it was to these new forms that the OECD applied the term globalization: "International trade can no longer be considered as being virtually the sole vector for the penetration of foreign markets: international investments and transfers of technology now play important parts in this process"[12]. For the OECD, a distinctive feature of globalization is the division of firms' operations into separate segments carried out in different countries. The most prominent features of globalization are foreign direct investment, various aspects of international trade, and international inter-firm collaboration[13].

In the view of the OECD, these new forms of internationalization were not being appropriately measured. "Until [the 1990s], all indicators of competitiveness were based exclusively on international

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8 OECD (1992), Technology and the Economy: The Key Relationships, Chapter 10, Paris, p. 232.

9 OECD (1996), Possibility of Preparing a Manual on Globalization Indicators, DSTI/EAS/IND/WP9 (96) 8, p. 2.

10 OECD (1998), Globalization and Industry Performance, DSTI/IND (98) 11.

11 OECD (2001), Manual on Economic Globalization Indicators: Chapter 1, DSTI/EAS/IND/SWP (2001) 1, p. 4.

12 OECD (1992), Indicators of the Globalization of Industrial Activities, DSTI/STII/IND/WP9 (92) 1; OECD (1996), Globalization and Competitiveness: Relevant Indicators, OCDE/GD (96) 43.

13 OECD (1996), Globalization of Industry, Paris, p. 15.

trade"[14] and "were proving a less effective guide to policymaking"[15]. "Many aspects of globalization will only be understood through collection and examination of new internationally comparable data and case studies", declared the OECD.[16] But there was a great deal of data for which international comparability was not satisfactory and required harmonization[17].

These two limitations – the fuzziness of the concept and the inadequacy of the indicators – required coordination of the then-current studies to pull the work together into a more coherent whole[18]. Above all, what was needed was a framework, as suggested by the US delegate: "work has been underway in a number of OECD committees studying the impact of a range of domestic policies on globalization. The US believes these crosscutting proposals require coordination", that is, a framework including sectoral studies and horizontal statistical analysis[19].

The OECD's program of work on globalization started in the early 1990s with the following definition: "Globalization is the outcome of the progressive international expansion of firms since World War II. Firms strategies have shifted from exporting, through local sales networks and local assembly, to fully integrated foreign operations

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14 OECD (1992), Indicators of the Globalization of Industrial Activities, *op. cit*. p. 5.

15 OECD (2000), *Manual on Economic Globalization Indicators: General Presentation*, DSTI/IND (2000) 16, p. 2.

16 OECD (1992), *Industrial Policy in OECD Countries: Annual Review 1992*, Paris, p. 195.

17 OECD (1996), Possibility of Preparing a Manual on Globalization Indicators, *op. cit*. p. 3. See also: OECD (1998), *Database on the Activity of Foreign Affiliates in OECD Countries and National Firms' Affiliates Abroad*, DSTI/EAS/IND/SWP (98) 15.

18 OECD (1992), *Globalization of Industrial Activities: Globalization Framework*, DSTI/IND (92) 45, p. 3.

19 OECD (1992), *Globalization of Industrial Activities: Globalization Framework*, DSTI/IND/WP9 (92) 6/07, p. 3.

with local headquarters functions and networks of suppliers and co-operating firms"[20].

The OECD identified two sets of reasons for studying the phenomenon. First, policy issues: "Lasting solutions to many problems facing governments can now only be found at the world level: environment, trade, technology, financial markets, capital flows, foreign direct investment"[21]. According to the OECD, policy issues concerned the concentration of economic power within a few companies, the low level of local sourcing and linkages between foreign firms and national suppliers, the subsidization of foreign investment and constraints on inward investment, the impact on small businesses, and intellectual property rights. In fact, for years, fears had been expressed concerning multinationals and foreign takeovers. As the US National Research Council's Committee on Foreign Participation in US R&D reminded its readers: foreign participation in US R&D may weaken the nation's technology base, increase US dependence on foreign sources of technology, undermine military strength, or shift jobs and profits away from the United States[22].

Apart from the above policy issues, however, imperatives on economic growth came to dominate the rhetoric in the mid 1990s: "Industries which are globalizing faster perform better in a measurable way than industries which are less exposed to globalization"[23]. Briefly stated, the OECD thought that globalization had a significant impact on economic growth, productivity and competitiveness.

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20 OECD (1992), Globalization of Industrial Activities: Overview of Work, DSTI/IND (92) 28, p. 4.

21 OECD (1991), Indicators of the Internationalization of Industrial Activities, DSTI/STII/IND/WP9 (91) 3, p. 3.

22 P. P. Reid and A. Schriesheim (eds.) (1996), Prospering in a Global Economy: Foreign Participation in US R&D: Asset or Liability, Washington: National Academy Press, p. V.

23 OECD (1998), Globalization and Industry Performance, op. cit. p. 4.

In 1991, the OECD Industry Committee asked its working party on industrial statistics to include the development of new indicators on the "globalization of industrial activities" in its program of work. In fact, "most of the indicators currently available are purely national in conception (…)"[24]. Work was suggested on the following indicators: foreign investments in production and trade, mergers and acquisitions, agreements and alliances, concentration, intra-branch and intra-product trade, patents, technological balance of payments, and location of R&D centers.

To launch this work program, a workshop on Globalization Indicators was held in June 1993, and from then on, the working party held a special annual session on globalization[25]. Within the working party, foreign direct investment was identified as a priority for measurement, particularly the activity of foreign affiliates. Two main projects came out of the workshop. First was a databank on foreign affiliates. The first OECD survey on the activities of foreign affiliates had already been conducted in 1989, and an analysis had been published in 1994 (*The Performance of Foreign Affiliates in OECD Countries*). The working party extended the databank with a survey of the activities of affiliates of national firms abroad (multinationals) (*Activities of Foreign Affiliates in OECD Countries*, 1997). The databank now includes 18 variables, among them R&D, and is concerned with inward[26] and outward[27] investments, for both manufacturing and services (*Measuring Globalization*, 2001). The databank was also made compatible with data from industrial surveys.

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[24] OECD (1991), Indicators of the Internationalization of Industrial Activities, *op. cit*. p. 3.

[25] OECD (1993), *Workshop on Globalization Indicators*, DSTI/EAS/IND/WP9 (93) 5; OECD (1993), *Workshop on Globalization Indicators*, DSTI/IND/RD (93) 5.

[26] Activities of foreign affiliates within each country.

[27] Affiliates of national firms abroad.

The second output from the workshop was related to a suggestion to develop methodological guidelines on Flows of Direct Investments[28]. The suggestion gave rise to the idea of a manual on economic globalization indicators in 1996[29]. Five areas were suggested for measuring globalization and for harmonizing national statistics: a definition of the concept itself, trade, direct investment, employment and technology. Employment was later deleted.

The manual, now called a handbook[30], made available in 2004[31], defined globalization as follows: a "phenomenon in which markets and production of different countries become increasingly interdependent through the changes induced by the dynamics of trade, capital and technology flows – changes of which the primary vehicles are multinational enterprises. Thanks to information and communication technologies, such firms are organized into transnational networks in a context of intense international competition which also extends to local firms, as well as to other spheres of each country's economic and social life"[32].

The handbook developed three sets of indicators: *trade* in goods and services, foreign direct *investment* by multinational firms, and internationalization of *technology*. Three sets of indicators were also suggested for measuring the internationalization of technology: R&D expenditures, technology receipts and payments, and high technology products.

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28 OECD (1993), Workshop on Globalization Indicators, *op. cit.*

29 OECD (1996), Possibility of Preparing a Manual on Globalization Indicators, *op. cit.*

30 In the end, "manual" was changed to "handbook" because the OECD judged the document not mature enough. The term manual, however, remains in the French version. Personal conversation with T. Hatzichronoglou, 21 May 2004.

31 OECD (2004), *Handbook on Economic Globalization Indicators*, DSTI/EAS/IND/SWP (2004) 1.

32 OECD (2001), Manual on Economic Globalization Indicators, *op. cit*. p. 4.

THE GLOBALIZATION OF TECHNOLOGY

The OECD narrative identified three phases in the process leading to globalization[33]. The first was concerned with trade in products and services. This phase is called internationalization. The second, called multinationalization, was concerned with the increased use of direct investment as a strategy by firms to expand. The last is globalization proper. It is characterized, among other things, by the relocation of R&D centers[34].

To the OECD, technology was an important factor explaining globalization: "Technology is one of the main driving forces behind globalization, thanks in particular to the growth in and acceleration of the dissemination of new information and communication technologies"[35]. "Probably the most important change in firm strategies to improve competitiveness is their emphasis on investment in intangible assets; this shift is part of the larger move towards a more knowledge-based economy"[36]. The rhetoric goes back to the Technology and Economy Program Conference, which insisted that technology played a role in the globalization process[37].

The early draft version of the handbook on globalization originally covered five forms of globalization with regard to technology[38]:

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33 OECD (1992), Globalization of Industrial Activities: Four Case Studies, Paris; T. Hatzichronoglou (1999), The Globalization of Industry in OECD Countries, STI Working Papers 1999/2, DSTI/DOC (99) 2.

34 For variations on such taxonomies, see: D. Hamdani (2003), Global or Multinational: It Matters for Innovation, Innovation Analysis Bulletin, Statistics Canada, 88-003, p. 3-4.

35 OECD (1996), Possibility of Preparing a Manual on Globalization Indicators, op. cit.

36 OECD (1997), Industrial Performance and Competitiveness in an Era of Globalization and Technological Change, DSTI/IND (97) 23, p. 3.

37 OECD (1991), TEP: International Conference Cycle, Paris; OECD (1992), Technology and the Economy: The Key Relationships, Chapter 10, op. cit.

38 OECD (1999), *Manual on Globalization Indicators*, DSTYI/IND/STP/SWP/NESTI (99) 1.

R&D, patents, trade in disembodied technology (technology payments and receipts), international technology alliances between firms, and high-technology products. It finally centered around three[39]: R&D, technology diffusion (payments and receipts), and high-technology trade. The rationale for deleting the other two series of indicators was one that was offered as early as 1993 at the workshop on globalization, which suggested dropping work on collection of international data on mergers and acquisitions and collaboration agreements between firms because these data "are collected mainly by private sources without any involvement of official statistical services"[40]. The handbook on globalization added that such data require further methodological analysis, but also stated that these areas "would raise some problems because most of the basic data have until now been collected by private sources. Consequently, the harmonization of data, which is one of the main objectives of this manual, becomes more difficult"[41].

While this argument is true for technological alliances between firms, it is not for patents. Data on patents come from public patent offices. Furthermore, the Directorate for Science, Technology and Industry recently launched a whole program of work on patents, based on patent families[42], which owes its existence partly to the globalization framework[43]. Since 2002, the indicators on patent families have been judged sufficiently developed to be included in *Main Science and Technology Indicators*. The same is true for the other deleted

39 OECD (2002), Manual on Economic Globalization Indicators, *op. cit*.

40 OECD (1993), Workshop on Globalization Indicators, *op. cit.*, p. 17.

41 OECD (2002), Manual on Economic Globalization Indicators, *op. cit*. p. 3.

42 OECD (2000), *Counting Patent Families: Preliminary Findings*, DSTI/EAS/STP/NESTI/RD (2000) 11; OECD (2001), *Patent Families: Methodology*, DSTI/EAS/STP/NESTI (2001) 11.

43 OECD (1999), The Internationalization of Technology Analyzed with Patent Data, DSTI/EAS/STP/NESTI (99) 3.

statistics: their lacunae never prevented the OECD from using the statistics and conducting whole analyses based on them[44].

Be that as it may, the handbook was the occasion for the Directorate for Science, Technology and Industry to review its science, technology and innovation statistics at three levels, to which we now turn: redefining GERD (Gross Expenditures on R&D), resuscitating the technological balance of payments indicator, and revising statistics on government funding of R&D[45].

Measuring the Internationalization of R&D

In 1993, the workshop on globalization suggested that the "detailed data reveal that [the recent R&D] decline may be attributed to the decision by several major companies to relocate their R&D laboratories abroad. These companies have also acquired a number of foreign R&D laboratories through mergers and acquisitions"[46]. There was therefore a need to redefine the concept of the national R&D effort in the context of globalization: "Until now the attention of the authorities in every country has focused essentially on research carried out inside their own borders. However (…) it is important to take into account that a significant portion of R&D carried out inside a country's national borders is intended for foreign markets and,

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44 See, for example: OECD (2000), Changing Patterns of Industrial Globalization: International Strategic Alliances, DSTI/IND (2000) 2; Nam-Hoon Kang and S. Johansson, Cross-Border Mergers and Acquisitions: Their Role in Industrial Globalization, DSTI/DOC (2000) 1; OECD (2001), Science, Technology and Industry Scoreboard, Paris; OECD (2002), Industrial Globalization and Restructuring, in Science, Technology and Industry Outlook, Paris, p. 203-227.

45 Indicators on high technology were already well developed, and nothing new, with regard to globalization, was suggested in the manual on economic globalization.

46 OECD (1992), Indicators of the Globalization of Industrial Activities, op. cit. p. 5.

conversely, that a share of the R&D carried out abroad is intended for the domestic market"[47].

The working party suggested working together with the Group of National Experts on Science and Technology Indicators (NESTI) to improve the indicators on R&D activities of foreign firms in domestic markets, and of domestic firms abroad. To date, multinational firms have never been considered as a distinct category of firm, neither in national R&D surveys nor in the Frascati manual. The R&D expenditures of a country's industry (Business Expenditures on R&D, or BERD) is currently defined as the sum of the R&D expenditures by nationally-controlled firms in that country, plus R&D expenditures by affiliates owned by firms from other countries for R&D carried out in the country in question. The handbook on economic globalization indicators suggested that a firm's nationality take precedence, rather than the country in which its research activities are carried out. Using this approach, a country's business R&D effort would consist of the research conducted on its territory by domestically-controlled firms and by affiliates of those firms abroad, excluding research done locally by foreign-owned firms. The handbook therefore suggested a series of appropriate indicators: R&D activities of foreign affiliates in each country (inward investment), R&D activities of affiliates of national firms abroad (outward investment), and R&D activities of parent companies in their home countries.

The survey and the databank on the Activities of Multinational Firms were the envisaged sources of data for the indicators, since they include R&D expenditures of affiliates of national firms abroad since the mid 1990s – to which R&D activities by parent company have recently been added. However, another source of data came to be available: the OECD agreed to modify its international survey on

[47] OECD (2004), The Internationalization of Industrial R&D: Policy Issues and Measurement Problems, DSTI/EAS/STP/NESTI (2004) 24, p. 3.

R&D[48]. For years, the survey collected data on funding of R&D to and from other countries, but no distinction was made between national firms and foreign affiliates. In the case of external funding of industrial R&D, a distinction is now made in the survey between BERD (domestic business expenditures on R&D) and NBERD (national business expenditures on R&D). Furthermore, the most recent edition of the Frascati manual included in its sectoral classification of private enterprise a distinction among “enterprises not belonging to any group, enterprises belonging to a national group and enterprises belonging to a foreign multinational group”. [49] The challenge remains that of persuading countries to collect such information[50].

Renewed Interest in the Technological Balance of Payments

The technological balance of payments has always been a criticized indicator. The problems are in fact many, but the main ones involve methodological concerns (limited international comparability of the data and heterogeneous sources) and interpretation (a negative balance, for example, can be a positive sign for a country’s economy). It is therefore surprising to find the technological balance of payments selected as an indicator for measuring globalization.

In fact, according to the OECD, globalization provided an opportunity – a framework – for interpreting technological payments

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48 OECD (1996), Collection of R&D Data in Connection with Work on Globalization, DSTI/EAS/STP/NESTI (96) 11; OECD (1998), Internationalization of Technology: Discussion Paper, DSTI/EAS/STP/NESTI (98) 9; OECD (1999), Data Collection on the Internationalization of Industrial R&D, DSTI/EAS/STP/NESTI (99) 8.

49 OECD (2002), The Measurement of Scientific and Technological Activities: Proposed Standard Practice for Surveys on Research and Experimental Development, Paris, p. 61.

50 On the availability of data in member countries, see: OECD (2004), The Internationalization of Industrial R&D: Policy Issues and Measurement Problems, op. cit.

and receipts by putting the indicator in a *systemic* perspective, that is, combining technological indicators (embodied technology flows like inter-industrial flows, high-technology flows and trade by foreign affiliates) and non-technological indicators (like the technological balance of payments). According to the OECD, the concept of globalization makes possible a different (sequential) vision of economic phenomena: direct investment flows generate exports from the investing countries (and imports from the host country) which are accompanied by transfers of technology and know-how, and by capital movements[51].

Despite the usefulness of the indicator for the globalization framework, the OECD has yet to publish any analyses on technology flows. In the past, the OECD conducted very few analyses on technological payments and receipts, only including some tables in *Main Science and Technology Indicators*. It remains to be seen whether the organization is serious about its new rationale on globalization. If investment flows, rather than trade, characterize globalization, then technological flows (payments and receipts) should figure prominently in any analyses of globalization.

Other Impacts of Globalization on S&T Statistics

In the early 1990s, some people began to wonder whether increasing internationalization of R&D activities might not have resulted in an incomplete picture of public R&D funding. In fact, the share of Gross Expenditures on R&D (GERD) financed by government declined from one-half in 1975 to about one-third in 1995. The reasons were many – a decline in defense R&D, increased use of fiscal incentives instead of direct financing – but the OECD *Technology, Productivity and Jobs* project identified the internationalization of R&D as having a major impact on the traditional measure of the government

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51 OECD (1996), Technology Balance of Payments Indicators within the Framework of the Activity on Globalization, DSTI/EAS/STP/NESTI (96) 10, p. 5.

contribution to R&D[52]. Greater use was being made of international programs and facilities abroad, and these were incompletely measured.

Government R&D financing can be measured in three ways: 1) from GBAORD (Government Budget Appropriations or Outlays for R&D) derived from budgetary documents, 2) from the GERD (where statistics on government R&D come from a specific survey), and 3) from the GNERD (Gross National Expenditures on R&D), which measures the total amount of R&D financed by national sources. GNERD comprises R&D performed in the country and financed by national sources (GERD minus funds from abroad), plus extramural payments by national sources for R&D performed abroad.

The problem identified by the OECD was that government payments to international organizations were not included in R&D performed abroad. European countries, for example, included neither the estimated R&D content of their contribution to the European Community budget (Framework program, CERN, ESA), which amounted to 14% of GERD in 1995, nor their receipts from abroad, as government R&D. Although the latter was of little statistical consequence in countries with large R&D efforts, its effects were much more strongly felt in small R&D-intensive countries, and in fact were twice as intense in countries like Greece and Ireland than others[53].

In the end, the OECD concluded that statistics on government financing of R&D were not lower because greater use was being made of programs and facilities abroad, but because, according to some countries (European countries and Canada), they merely provide an incomplete picture of government funding. The

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52 OECD (1998), Technology, Productivity and Job Creation: Best Policy Practices, Paris, Chapter 3.

53 OECD (1997), Treatment of European Commission Funds in R&D Surveys: Summary of National Practices, DSTI/EAS/STP/NESTI/RD (97) 3; OECD (1998), Measuring the Internationalization of Government Funding of R&D, DSTI/EAS/STP/NESTI (98) 3.

discrepancies led the OECD to construct new estimates and suggest standards[54], and circulate a *Sources and Methods* paper documenting national statistics on public funding of R&D[55].

WHAT DID THE NUMBERS SAY?

To date, the OECD has made very few uses of its new statistics on globalization. First, very few countries provide data on NBERD (national business expenditures on R&D). Second, the database on the Activities of Foreign Affiliates in OECD Member Countries is limited by "the availability of data, which suffers from small samples, short time series and a lack of information on a broader range of countries and industrial sectors"[56]. Nevertheless, two kinds of output on science and technology came from a decade of efforts: analytical studies and indicators (Table 12).

Table 12. OECD Publications on Globalization

Trade, Investment and Technology in the 1990s, 1991.
International Direct Investment, 1992.
Globalization of Industrial Activities: Four Case Studies, 1992.
International Direct Investment: Policies and Trends, 1993.
The Performance of Foreign Affiliates in OECD Countries, 1994.
Globalization of Industry: Overview and Sector Reports, 1996.
Globalization and SMEs, 1997.
Towards a New Global Age: Challenges and Opportunities, 1997.
Activities of Foreign Affiliates in OECD Countries, 1997.
Internationalization of Industrial R&D: Patterns and Trends, 1998.

54 OECD (1998), Measuring the Internationalization of Government Funding of R&D, *op. cit*.

55 OECD (1998), *Measuring the Internationalization of Government Funding: Sources and Methods*, DSTI/EAS/STP/NESTI/RD (98) 2.

56 OECD (1997), *Globalization of Industrial Research: Background Paper*, DSTI/STP/TIP (97) 6, p. 6.

Measuring Globalization: the Role of Multinationals in OECD Economies, 2001. Manual on Economic Globalization, 2003. OECD Economic Globalization Indicators, 2005.

There have always been analyses of globalization in the *Science, Technology and Industry Outlook* series (started in 1992), but these were very brief and used non-standardized data[57]. The first standardized empirical analysis appeared in a short chapter titled *The Role of Technology* in *The Performance of Foreign Affiliates in OECD Countries* published in 1994. In the view of the OECD, setting up laboratories outside the country of origin and the extension of co-operation agreements and alliances (technoglobalism) were the decisive elements among the technological changes that took place in the 1980s[58]. The publication reported that the proportion of R&D carried out by foreign affiliates tended to increase steadily, but was generally smaller than that of their turnover or production[59]. The R&D intensity of foreign affiliates was generally low, except in the United States, which was twice as great as the national average in pharmaceuticals, three times as great in chemicals and four times as great in mechanical engineering[60].

The study was followed two years later by a second one. However, *Globalization of Industry* (1996) was not devoted to R&D, but

[57] OECD (1992), *Science and Technology Policy: Review and Outlook*, Paris, p. 36-38, 87-100; OECD (1996), *Science, Technology and Industry Outlook*, Paris, p. 61-71; OECD (2000), *Science, Technology and Industry Outlook*, Paris, p. 41-49; OECD (2002), *Science, Technology and Industry Outlook*, Paris, p. 45-50, 81-85, 203-225.

[58] OECD (1994), *The Performance of Foreign Affiliates in OECD Countries* , Paris, p. 61.

[59] *Ibid*., p. 63.

[60] *Ibid*., p. 65.

science and technology figured regularly in the analysis. The study started by defining globalization as follows[61]:

> Globalization of industry refers to the trans-border operations of firms undertaken to organize their development, production, sourcing, marketing and financing activities (…). Historically, international expansion was mainly through trade, followed in the 1980s by a major increase in international direct investment and inter-firm collaboration. What has changed recently is that firms have used new combinations of international investment, trade and international collaboration to expand internationally and achieve greater efficiencies. International strategies of the past, based on exports, and multi-domestic strategies based on sales in separate foreign markets, are giving way to new strategies based on a mixture of cross-border operations – foreign investment, exports and sourcing, and international alliances (…). At the macroeconomic level, the term globalization refers to the emergence of new patterns in the international transfer of products and knowledge by three main routes: international trade, international direct investment, and international collaboration agreements.

The study then looked at a series of indicators that revealed the following trends:

- International trade now represented 20% of GDP. The greatest growth was observed in Europe and Asia, and in transportation equipment and materials. OECD member countries were shown to concentrate their efforts in high technology sectors. Trade in intermediary goods was also on

61 OECD (1996), *Globalization of Industry*, Paris: OECD, p. 19-20.

the increase, mainly for products with high R&D efficiency ratios.

- Intra-firm exchanges (data for the United States and Japan only): a third of exchanges were between firms of the same group, and in sectors of high R&D intensity.
- Direct investment: foreign direct investment increased more rapidly than GDP or trade between 1970 and 1990. The destination was initially the United States, but Europe had now become the preferred location. Flows of Direct Investments (FDI) concerned primarily manufacturing (30-45%), and were often achieved through mergers and acquisitions.
- Foreign Affiliates: foreign affiliates were responsible for a growing share of production in many industrial sectors, and had better economic performance than national firms: production, value-added employment, productivity and salaries. However, their R&D intensity was lower than national firms, except in small countries like Canada (where it was almost equal) or the United States (where it was higher).
- Inter-firm agreements: Collaborative agreements had increased by 10% annually since the 1980s. These occurred mainly in high-technology sectors, and concerned mainly big firms (except for pharmaceuticals and biotechnology).
- Small and Medium-sized Enterprises (SMEs) had not yet globalized. Only about 25% had, versus 50-66% for larger firms. When SMEs did globalize, they did so mainly through trade.

The first real study entirely devoted to the internationalization of R&D was published in 1998. The Directorate for Science, Technology and Industry estimated that R&D handled by foreign affiliates accounted globally for about 11 per cent of industrial R&D

in the mid 1990s[62]. This varies, however, by country, from 5% in Japan to 60% in Ireland. It also varies by industrial sector: those most likely to globalize were high-technology industries[63].

Despite these results, the study admitted that it underestimated the level of internationalization, because a large number of countries have data on the R&D activities of foreign affiliates in their own countries, but not on their domestic companies' affiliates:

In view of the fact that, until now, most firms' laboratories have been located in OECD Member countries, the available data should give some indications of the level of internationalization of R&D functions. Over the last few years, however, more and more firms have been setting up R&D centers outside the OECD Member countries. This means that the information available underestimates the real level of R&D internationalization. In addition, the available data for all but a few of the largest countries only cover a relatively short period, and cannot really reflect the magnitude of these changes.

Nonetheless, the year 2001 saw the introduction of two innovations in science, technology and innovation indicators with regard to globalization. First, regular indicators on globalization started to be included in *Main Science and Technology Indicators*. To the data on GERD financed from abroad (published since the 1990 edition), tables were added on the R&D expenditures of foreign affiliates. Second, the 2001 edition of the *Scoreboard of Science, Technology and Industry Indicators* included a whole section of indicators on globalization, some of which were concerned with science and technology (Table 13).

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62 OECD (1998), Internationalization of Industrial R&D: Patterns and Trends, Paris, 1998. See also: OECD (1998), Globalization of Industrial R&D: Policy Implications, DSTI/STP/TIP (98) 4.

63 OECD (1997), Globalization of Industrial Research: Background Paper, op. cit.

More recently, the OECD started publishing a new series titled *OECD Economic Globalization Indicators*. But the work on globalization has yet to really bear fruit with regard to science and technology. This can be explained by two factors. First, the work on globalization illustrates the lag between a concept and policy demands on one hand, and the response of statisticians on the other. It takes at least ten years, or more, to develop appropriate and reliable statistics and indicators. Second, the concept (globalization) competes with others when it comes to developing and organizing statistics into conceptual frameworks for policy purposes: national systems of innovation, the knowledge-based economy and the new economy. The latter two, as we will now see, came to dominate the OECD work in the mid 1990s.

Table 13. Globalization Indicators (OECD Science, Technology and Industry Scoreboard 2001)

Global Integration of Economic Activity
International trade
Exposure to international trade competition by industry
Foreign direct investment flows
Cross-border mergers and acquisitions
Activity of foreign affiliates in manufacturing
Activity of foreign affiliates in services
Internationalization of industrial R&D
International strategic alliances between firms
Cross-border ownership of inventions
International cooperation in science and technology
Technology balance of payments
Economic Structure and Productivity
International trade by technology intensity
International trade in high-technology and medium high-technology industries

CONCLUSION

In the 1980s, economists and statisticians began measuring an increase in international trade among OECD member countries. Trade was only one facet of internationalization, however. In fact, several authors admitted that internationalization was badly measured. The OECD gave itself the task of developing standardized methodological rules for three aspects of measuring internationalization: trade, flows of direct investments and technology. With regard to technology, three sets of indicators were suggested: R&D, technological balance of payments and high technology.

Globalization is a term or label assigned to the growth of internationalization and to its new forms. It is above all a rhetorical concept. Many authors admit that nothing really new defines globalization. The OECD itself seems to agree. After characterizing the global economy using elements different from the previous period, where international trade was the driving force, the OECD continues: "trade is still the most substantial form of integration into the global economy"[64]. In fact, as we will see below, the same rhetoric defines other popular concepts at the OECD, like the knowledge-based economy. One characteristic of the discourses on the knowledge-based economy was that the phenomenon was not new, but simply more present.

What, then, is the function of such labels? They help to place an issue on the policy agenda and to capture political attention – and consequently give statisticians further topics to work on. The whole process works as follows. In general, work proposals come either from the OECD Secretariat (and/or committees) or from the ministers (often under the influence of a specific country). Studies are then conducted by the Secretariat, with a view to presenting to a ministerial conference. The conference, in turn, generally with the

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64 OECD (2001), Manual on Economic Globalization Indicators, *op. cit*. p. 17.

advice of the OECD officials themselves, asks for more work. This is how projects extend and build on previous ones. In 1998, for example, the meeting of the Industry Committee at the ministerial level was presented with work done to date, and recommended that the OECD advance the analysis of globalization, determine its implications for firm and sector performance, and determine how governments can pursue policies whereby the benefits of globalization are fully realized. This was a necessary step for consolidating the work on globalization and continuing its development.

Nevertheless, one should not be too cynical. The concept of globalization has allowed the OECD to develop new indicators, and to initiate studies on new dimensions of science and technology. R&D performed by foreign affiliates was one example, as was its work in progress on patent families, and on the migration of highly-qualified personnel.

PART II

CHAPTER SEVEN

NATIONAL INNOVATION SYSTEM: THE SYSTEM APPROACH IN HISTORICAL PERSPECTIVE

In the late 1980s, a new kind of conceptual framework appeared in the science, technology and innovation studies: the National Innovation System. The National Innovation System framework suggests that the research system's ultimate goal is innovation, and that the system is part of a larger system composed of sectors like government, university and industry and their environments. The framework also emphasized the relationships between the components or sectors as the "cause" explaining the performance of innovation systems.

Where does the idea of the National Innovation System come from? Most authors agree that it came from researchers like C. Freeman, R. Nelson and B.-A. Lundvall[1]. In this chapter, I go back further back in

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[1] C. Freeman (1987), Technology Policy and Economic Performance, London: Pinter; G. Dosi et al. (1988), Technical Change and Economic Theory, Part V: National Innovation Systems, London: Pinter; B.-A., Lundvall (ed.) (1992), National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning, London: Pinter; R. R. Nelson (ed.) (1993), National Innovation Systems: A Comparative Analysis, Oxford: Oxford University Press. See also: C. Edquist (ed.) (1997), Systems of Innovation: Technologies, Institutions and Organizations,

time and show what the "system approach" owes to the OECD and its very early works from the 1960s. This chapter is not a study of the concept of the National Innovation System itself, and neither is it a critical analysis of its main rationale. R. Miettinen has conducted a very enlightened analysis that serves this purpose[2]. Rather, I develop the idea that a system approach was fundamental to OECD work and that, although it did not use the term National Innovation System as such, the organization considerably influenced the above authors (as much as they influenced the organization).

The first part of the chapter presents the emergence of the National Innovation System framework in the OECD literature of the 1990s[3], and its relationship to one of its competitors, the Knowledge-Based Economy framework. Two of the National Innovation System's limitations, as discussed in the OECD literature, are presented: lack of substance and statistics. The first criticism is a severe one, and should be addressed, if true, with regard to the entire system approach. The second criticism is real, at least as opposed to the early system approach. The second part of the chapter goes back in history to trace the emergence of a system approach at OECD from the early 1960s onward. Three major documents in this regard are *Gaps in Technology* (1968-70), the Salomon report titled *The Research System*, which was published in three volumes between 1972 and 1974, and *Technical Change and Economic Policy* (1980). The third part looks at how a system approach entered into early statistics on science, via the Frascati manual.

London: Pinter; B. Amable, R. Barré and R. Boyer (1997), Les systèmes d'innovation à l'ère de la globalisation, Paris: Economica.

2 R. Miettinen (2002), National Innovation System: Scientific Concept or Political Rhetoric, Helsinki: Edita. See also N. Sharif (2006), Emergence and Development of the National Innovation System Concept, Research Policy, 35 (5), p. 745-766.

3 On the system approach and its use at the European policy level, see the following publication, as well as the subsequent strategies of the European Commission: L. Soete and A. Arundel (eds.) (1993), *An Integrated Approach to European Innovation and Technology Diffusion Policy*, EIMS Series, Publication no. 15090, European Commission.

NATIONAL INNOVATION SYSTEM AT OECD

For several decades, (neo-classical) economists have been criticized for their failure to integrate institutions into their theories and econometric models[4]. Partly as a response to this situation, scholars in the field of science, technology and innovation studies invented the concept of a National Innovation System. However, the concept also owes a large debt to the old debate (1960s) on technological gaps and competitiveness, as illustrated in the paper by Freeman (1987) with its analysis of the Japanese system[5]. Since World War II, Europeans have always been fascinated with the disparities in technological and economic performance between Europe on one hand and the United States and Japan on the other[6]. The National Innovation System, with its emphasis on the ways institutions behave and relate to each other, offered a new rationale to explain these gaps.

According to R. R. Nelson, a National Innovation System "is a set of institutions whose interactions determine the innovative performance of national firms"[7]. To B.-A. Lundvall, it "is constituted by elements and relationships which interact in the production, diffusion and use of new, and economically useful, knowledge"[8]. These elements or institutions are firms, public laboratories and universities, but also financial institutions, the educational system, government regulatory bodies and others that interact together.

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4 R. R. Nelson (1981), Research on Productivity Growth and Productivity Differences: Dead Ends and New Departures, *Journal of Economic Literature*, 19, p. 1029-1064; R. R. Nelson and S. G. Winter (1977), In Search of a Useful Theory of Innovation, *Research Policy*, 6, p. 36-76.

5 C. Freeman (1987), Technology Policy and Economic Performance, *op. cit*.

6 B. Godin (2002), Technological Gaps: An Important Episode in the Construction of Science and Technology Statistics, *op. cit*.

7 R. R. Nelson (ed.) (1993), National Innovation Systems: A Comparative Analysis, *op. cit*. p. 4.

8 B.-A. Lundvall (1992), Introduction, in B.-A., Lundvall (ed.), National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning, *op. cit*. p. 2.

There are two families of authors in the National Innovation System literature: those centering on the analysis of institutions (including institutional rules) and describing the ways countries have organized their National Innovation Systems[9], and those who are more conceptual, focusing on knowledge and the process of learning itself: learning-by-doing, learning-by-using, etc.[10]. From the latter group, the concept of the knowledge economy, first suggested in the early 1960s, re-emerged in the 1990s.

It was to Lundvall – nominated deputy director of the OECD Directorate for Science, Technology and Industry (DSTI) in 1992 (until 1995) – that the OECD Secretariat entrusted its program on National Innovation Systems. In fact, the OECD always looked for conceptual frameworks to catch the attention of policy-makers. In the early 1990s, it was the National Innovation System that was supposed to do the job: getting a better understanding of the significant differences between countries in terms of their capacity to innovate, and looking at how globalization and new trends in science and technology affect national systems[11]. However, the program did not have the expected impact on policies. In a recent review paper, the OECD admitted: "there are still concerns in the policy making community that the National System of Innovation approach has too little operational value and is difficult to implement"[12].

Too little operational value, but also a lack of substance, according to some authors. To D. Foray (France), the individual behind the resurgence of the concept of the knowledge-based economy[13], the

9 R. R. Nelson (ed.) (1993), National Innovation Systems, *op. cit*.

10 B.-A. Lundvall (ed.) (1992), National Systems of Innovation, *op. cit.*

11 OECD (1992), *National Systems of Innovation: Definitions, Conceptual Foundations and Initial Steps in a Comparative Analysis*, DSTI/STP(92)15; OECD (1994), *National Innovation Systems: Work Plan for Pilot Case Studies*, DSTI/STP/TIP(94)16; OECD (1996), *National Innovation Systems: Proposals for Phase II*, DSTI/STP/TIP(96)11.

12 OECD (2002), *Dynamising National Innovation Systems*, Paris, p. 11.

13 D. Foray (2000), L'économie de la connaissance, Paris: La Découverte.

OECD work on the concept of National Innovation Systems is "neither strikingly original, nor rhetorically stirring"[14], and places too much emphasis on national institutions and economic growth, and not enough on the distribution of knowledge itself. However, Foray (and P. David) concluded similarly to Lundvall on a number of points, among them: "an efficient system of distribution and access to knowledge is a *sine qua non* condition for increasing the amount of innovative opportunities. Knowledge distribution is the crucial issue"[15].

Thus, it seems that a central characteristic of a National Innovation System is the way knowledge is distributed and used. As K. Smith, author of the OECD methodological manual on innovation, put it: "The overall innovation performance of an economy depends not so much on how specific formal institutions (firms, research institutes, universities, etc.) perform, but on how they interact with each other"[16]. Indeed, according to others, "knowledge is abundant but the ability to use it is scarce"[17].

Another consensual view of authors on National Innovation Systems was that statisticians simply did not have the appropriate tools to measure the concept. To Smith, the "system approaches have been notable more for their conceptual innovations, and the novelty of their approaches, rather than for quantification of empirical description"[18]. "There are no straightforward routes to empirical system mapping: we have neither purpose-designed data sources, nor any obvious methodological approach. The challenge, therefore, is to

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14 P. David and D. Foray (1995), Assessing and Expanding the Science and Technology Knowledge Base, STI Review, 16, p. 14.

15 *Ibid*., p. 40.

16 K. Smith (1995), Interactions in Knowledge Systems: Foundations, Policy Implications and Empirical Methods, STI Review, 16, p. 72.

17 B.-A. Lundvall and B. Johnson (1994), The Learning Economy, op. cit. p. 31.

18 K. Smith (1995), Interactions in Knowledge Systems: Foundations, Policy Implications and Empirical Methods, *op. cit*. p. 81.

use existing indicators and methods"[19]. To Lundvall, "the most relevant performance indicators of a National Innovation System should reflect the efficiency and effectiveness in producing, diffusing and exploiting economically useful knowledge. Such indicators are not well developed today"[20]. Similarly, David and Foray suggested: "A system of innovation cannot be assessed only by comparing some absolute input measures such as research and development (R&D) expenditures, with output indicators, such as patents or high-tech products. Instead innovation systems must be assessed by reference to some measures of the use of that knowledge"[21]. "The development of new quantitative and qualitative indicators (or the creative use of existing ones) is an urgent need in the formation of more effective science and technology policies"[22].

The OECD project on the National Innovation System flirted with the idea of knowledge distribution and use, having even temporarily redefined the initial objectives of the project around knowledge access and distribution, whereas the original aims concerned institutional factors explaining the efficiency of National Innovation Systems[23]. The National Innovation System project also flirted with indicators on knowledge distribution, but rapidly concluded, "it has proved difficult to produce general indicators of the knowledge distribution power of a national innovation system"[24].

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19 *Ibid*., p. 70.

20 B.-A. Lundvall (1992), Introduction, *op. cit*. p. 6.

21 P. David and D. Foray (1995), Assessing and Expanding the Science and Technology Knowledge Base, *op. cit*. p. 81.

22 *Ibid*., p. 82.

23 Compare OECD (1993), Work on National Innovation Systems: Road Map, *op. cit*. with OECD (1994), National Innovation Systems: Work Plan for Pilot Case Studies, *op. cit.*

24 OECD (1996), National Innovation Systems: Proposals for Phase II, DSTI/STP/TIP(96)11, p. 3.

From the start, the OECD project identified the construction of indicators for measuring National Innovation Systems as a priority[25], and indeed early on suggested a list of indicators to this end (see Appendix 4)[26]. But the decision to build on existing work because of budgetary constraints[27] considerably limited the empirical novelty of the studies. Nevertheless, the project, conducted in two phases between 1994 and 2001, produced several reports that looked at flows and forms of transactions among institutions, among them: networks, clusters and mobility of personnel (Table 14)[28].

Table 14. OECD Publications on National Innovation Systems

1995	*National Systems for Financing Innovation*.
1997	*National Innovation Systems*.
1999	*Managing National Innovation Systems*.
1999	*Boosting Innovation: The Cluster Approach.*
2001	*Innovative Networks: Co-Operation in National Innovation Systems*.
2001	*Innovative Clusters: Drivers of National Innovation Systems*.
2001	*Innovative People: Mobility of Skilled*

[25] OECD (1993), Work on National Innovation Systems: Road Map, DSTI/STP(93)8.

[26] OECD (1997), National Innovation Systems, Paris, p. 45.

[27] OECD (1992), National Systems of Innovation: Definitions, Conceptual Foundations and Initial Steps in a Comparative Analysis, op. cit. p. 10.

[28] OECD (1995), National Systems for Financing Innovation, Paris; OECD (1997), National Innovation Systems, op. cit.; OECD (1999), Managing National Innovation Systems, Paris; OECD (1999), Boosting Innovation: The Cluster Approach, Paris; OECD (2001), Innovative Networks: Co-Operation in National Innovation Systems, Paris; OECD (2001), Innovative Clusters: Drivers of National Innovation Systems, Paris; OECD (2001), Innovative People: Mobility of Skilled Personnel in National Innovation Systems, Paris; OECD (2002), Dynamising National Innovation Systems, op. cit; OECD (2005), Governance of Innovation Systems, 3 volumes, Paris.

	Personnel in National Innovation Systems.
2002	*Dynamising National Innovation Systems*.
2005	*Governance of Innovation Systems*.

THE SYSTEM APPROACH

The OECD has been very influential on the development of science policy among member countries[29]. The interest of the organization in these matters goes back to the OEEC[30], the predecessor to the OECD. In 1958, the Council of Europe asked a working party (WP26) to examine the activities of the European Productivity Agency, where the main activities for science were conducted. To the Council, there was a "scientific research crisis in Europe":

> Between the highly developed, science-based industries of the United States and the explosive development of Russian technology, Europe sits uneasily. (…) True, Europe has the great advantage of the tradition and maturity of its scientific institutions, and particularly those for fundamental research. (…) But this is not enough. (…) Europe has, as a region, been slow to exploit in production the discoveries of its laboratories[31]. It is no longer possible for each of its constituent countries to undertake the amount of research necessary for its security and prosperity[32]. [But] most of our governments have evolved little in the way of a coherent national science policy, while the concept of scientific research and development as an

29 J. J. Salomon (2000), L'OCDE et les politiques scientifiques, *Revue pour l'histoire du CNRS*, 3, 40-58.

30 Organization for European Economic Co-operation.

31 OEEC (1959), A Programme for European Co-operation in Science and Technology, C/WP26/W/4, p. 2.

32 *Ibid*., p. 2-3.

> important and integral feature of company investment is foreign to the thought of most of European industry[33].

Following the working party report, Dina Wilgress was asked by the Secretary-General to visit member countries to discover their approaches to science and technology. He reported, "It is in Western Europe that most of the great scientific discoveries have taken place (…) but in the race for scientific advance, the countries on the Continent of Europe stood comparatively still for more than two decades while the Soviet Union and North America forged ahead"[34]. The sources of the problem were many: the educational system was "better fitted for turning out people trained in the liberal arts than in science and technology"; there were prejudices against those who work with their hands, and few applications of the results of science; there were also a lack of resources for science, too great an emphasis on short-run profits and not enough on investment for the future, small-sized firms that were not so science-minded, and inadequacy of university facilities and technical training. Briefly stated, the components of the research system were not adapted to the then-new situation, nor well related to each other, nor oriented towards a common goal.

It was in this context that the newly created OECD (1961), via a Directorate for Scientific Affairs, turned to the promotion of national science policies. From its creation in 1961 to the emergence of the literature on National Innovation Systems, the OECD produced several policy papers, and most of them carried a system approach (Table 15). This approach consisted of emphasizing the institutional and contextual aspects of research. To the OECD, research was a system composed of four sectors, or components, and embedded within a larger environment:

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33 *Ibid*., p. 3.

34 OECD (1959), Co-operation in Scientific and Technical Research, C (59) 165, p. 14. Officially published in 1960.

- Sectors: government, university, industry and non-profit.
- Economic environment.
- International environment.

The view that the research system is composed of four main sectors goes back to the very first analyses on science, as conducted by J. D. Bernal in the United Kingdom (1939)[35] and V. Bush and others in the United States in the 1940s[36]. Organizations and organized research (laboratories) were seen as the main drivers of growth, and were analytically classified into economic sectors. The same sectors, except for the university sector, were also used in the main classification of the System of National Accounts. The classification was soon conventionalized into statistics on R&D – as discussed below.

According to the OECD, science policy is concerned with the issues and problems of each of these sectors, and with the relationships between the sectors. As the Piganiol committee (1963), set up by the Secretary-General to define the agenda of the organization in science policy matters, stated: "Science is not an autonomous activity but contributes to national safety, physical health, adequate nutrition, economic growth, improved living standards, and more leisure for the populations of the world"[37]. "The scientist (…) has the opportunity to cooperate with the educator, the economist, and the political leader in deciding how science as a social asset can be furthered, and how a

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35 J. D. Bernal (1939), *The Social Function of Science*, Cambridge (Mass.): MIT Press, 1973.

36 V. Bush (1945), *Science: The Endless Frontier*, North Stratford: Ayer Co., 1995, p. 85-89 President's Scientific Research Board (1947), *Science and Public Policy*, President's Scientific Research Board, Washington: USGPO.

37 OECD (1963), Science and the Policies of Government, Paris, p. 14.

nation and the human community can best benefit from its fruits. Science, in a word, has become a public concern"[38].

Table 15. OECD Major Publications On science and Technology

Before the National Innovation System Series (1960-1992)

1960	*Co-Operation in Scientific and Technical Research* (Wilgress report).
1963	*Science and the Policies of Governments* (Piganiol report).
1963	*Science, Economic Growth and Government Policy* (C. Freeman, R. Poignant, I. Svennilson).
1966	*Fundamental Research and the Policies of Governments*.
1966	*Government and the Allocation of Resources to Science*.
1966	*Government and Technical Innovation*.
1966	*The Social Sciences and the Politics of Governments*.
1968	*Fundamental Research and Universities* (B. David).
1968-70	*Gaps in Technology*.
1971	*The Conditions for Success in Technological Innovation* (K. Pavitt).
1972	*Science, Growth and Society* (Brooks report).
1972-74	*The Research System* (Salomon report).
1980	*Technical Change and Economic Policy* (Delapalme report).
1981	*Science and Technology Policy for the 1980s*.
1988	*New Technologies in the 1990s: a Socio-economic Strategy* (Sundqvist report).
1991	*Choosing Priorities in Science and*

38 Ibid., p. 15.

	Technology.
1991	*Technology in a Changing World*.
1992	*Technology and the Economy: the Key Relationships*.

Over the period 1960-1992, the OECD study that most explicitly carried a system approach was *The Research System*, published in three volumes between 1972 and 1974 under the direction of Jean-Jacques Salomon. The study looked at the research system in ten countries, large and small: organization, financing, application of science (or innovation), government research, university-industry relations, international dimensions, foundations[39]. Because research is not an autonomous system, so said the authors, the document "put emphasis on the institutional context in which research is conducted. One of the most delicate problem of science policy is how to influence the process by which scientific discoveries are transformed into useful applications and how to contribute, in some way or another, towards bringing the supply of science into closer harmony with the demand of society[40]. "The whole problem of university research consists in the break-up of its institutional framework (…)"[41].

The study framed the central issue of the system approach in terms of science policy, and contrasted two periods as defined in the OECD report known as the Piganiol report[42]: the policy for science period, as the expansion of research *per se*, versus the science for policy period, where "developing national research potential [is] generally regarded as synonymous with national innovation potential"[43]. In the words of the Salomon report:

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39 Volume 1: France, Germany, United Kingdom; Volume 2: Belgium, Netherlands, Norway, Sweden, Switzerland; Volume 3: Canada, United States.

40 OECD (1972), The Research System, Volume 1, Paris, p. 16.

41 *Ibid*., p. 17-18.

42 OECD (1963), *Science and the Policies of Government*, Paris: OECD, p. 18, See also the OECD Brooks report OECD (1972), *Science, Growth and Society*, Paris: OECD, p. 37. A. Elzinga and A. Jamison (1995), Changing Policy Agenda in Science and Technology, in S. Jasanoff et al. (eds.), *Handbook of Science and Technology Studies*, Thousand Oaks (Calif.): Sage, p. 572-597.

43 OECD (1974), *The Research System*, Volume 3, Paris, p. 168.

> The needs of fundamental research depend primarily on the talent available and the fields opened up by the unsolved (or unformulated) problems of science itself. The needs of applied research and development, on the other hand, depend primarily on the problems which the industrial system sets itself. There is no hermetic seal between the first type of problem and the second, the terms of each being renewed or changed by the progress made by the other on the basis of a certain degree of osmosis between the university and industry and that is precisely why it is better to speak of a "research system" rather than a juxtaposition or hierarchy of different forms of research[44].

In the words of the report, again, "fundamental research will be required to respond more closely to the imperatives of selectivity dictated by the social, political and industrial context"[45]. "The new links which are now taking shape between science and society will no doubt be reflected in the long term in new patterns of organization"[46].

As a major conclusion from the study, *The Research System* suggested: "Scientific and technological research, viewed from an institutional approach, cannot be separated from its political, economic, social and cultural context"[47]. "There is no single model, and each country must seek its own solutions"[48].

Another influential report with regard to systemic conclusions at the OECD was *Gaps in Technology*, published in 1968-1970. In the 1960s, there were concerns in Europe that the continent was lagging

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44 OECD (1972), The Research System, Volume 1, *op. cit.* p. 20.
45 *Ibid.*, p. 21.
46 *Ibid.*, p.22.
47 OECD (1974), The Research System, Volume 3, *op. cit.* p. 197.
48 *Ibid.*, p. 199.

behind the United States in term of technological potential[49]. As the analysis of the first international survey on R&D concluded: "There is a great difference between the amount of resources devoted to R&D in the United States and in other individual member countries. None of the latter spend more than one-tenth of the United States' expenditure on R&D (…) nor does any one of them employ more than one-third of the equivalent United States number of qualified scientists and technicians"[50].

The OECD conducted a two-year study, collecting many statistics on the scientific and technological activities of European countries and of the United States. In the end, none of the statistics appeared conclusive in explaining economic performance. The OECD suggested that the causes of the gaps were not R&D *per se*: "scientific and technological capacity is clearly a prerequisite but it is not a sufficient basis for success"[51]. The organization rather identified other factors in the "innovation system" as causes: capital availability, management, competence, attitudes, entrepreneurship, marketing skills, labour relations, education and culture.

The conclusions of this OECD study were reinforced by a second study contracted to Joseph Ben-David[52]. Using several indicators, Ben-David documented a gap in the development of (applied and) fundamental research between Europe and the United States, and suggested that the origins of the gap went back to the beginning of the twentieth century: to the failure in Europe to develop adequate research organizations and effective entrepreneurship in the

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49 B. Godin (2002), Technological Gaps: An Important Episode in the Construction of S&T Statistics, *op. cit.*

50 OECD (1967), The Overall Level and Structure of R&D Efforts in OECD Member Countries, Paris, p. 19.

51 OECD (1968), Gaps in Technology: General Report, Paris; OECD (1970), Gaps in Technology: Comparisons Between Countries in Education, R&D, Technological Innovation, International Economic Exchanges, Paris, p. 23.

52 OECD (1968), Fundamental Research and the Universities: Some Comments on International Differences, Paris.

exploitation of science for practical purposes. Briefly stated, European universities were not oriented enough toward economic and social needs: academics still considered science essentially as a cultural good. To change the situation would, according to Ben-David, require long-term policies involving structural changes.

Now, what were the relationships essential to an effective research system? According to the OECD, there were five types of relationships. The first is between economic sectors, above all: government, university and industry. Here, a recurrent focus or target of policy proposals was the industrial sector as a source of innovation and economic growth. The early literature was concerned with putting industrial research activities at the center of policies and arguing for devoting government funding extramurally, namely to firms, and for orienting fundamental research. Then, the organization put the emphasis on university-industry relationships for cross-fertilization of research. This was the 1980s. Finally, the organization urged universities to enter the marketplace and commercialize their inventions. From this emphasis on the industrial sector and the contribution of other sectors to innovation and economic growth, we can see that the research system at OECD was really an innovation system.

The second type of relationship in the "innovation system" was between basic and applied research, and here many OECD documents rejected the idea of innovation as a linear process starting with basic research and ending with commercialization. As the background document to the first ministerial conference on science (1963) stated: there is no natural boundary between basic and applied research. "The real problem is that of linking these two types of research activity"[53]. Similarly, in the words of *The Research System,* it is "progressively more difficult to trace the line of demarcation between what is deemed to be fundamental and what is oriented or

[53] OCDE (1963), Science, Economic Growth, and Government Policy, Paris, p. 63.

applied"[54]. Science and technology are intimately linked together. This was, in fact, the main reason the report gave for adopting a system approach[55]: "the special characteristic of modern scientific research is that it is developing in institutions which are no longer confined to the university environment"[56]. "Scientific research is a continuous process (...) whose different element are so many links in a continuous and retro-active feed *system*"[57].

The third type of relationship in the "innovation system" regards policy itself. According to the OECD, policy was too fragmented and uncoordinated. As the Piganiol report stated in 1963: "There is a great need for studies of the several fields and ways in which science and policy interact, and there is a need above all for a continuing and intimate working relationship between officials responsible for science policy and other policy makers"[58]. To the OECD, "national policies in other fields must take account of the achievements and expectations of science and technology": economic policy, social policy, military policy, foreign policy and aid policy[59]. To this end, the Piganiol report recommended the creation in each country of a national science office which would take on the tasks of formulating a national policy, co-coordinating the various scientific activities, and integrating science policy with general policy[60].

"A more comprehensive approach", namely "science policy as an integral factor in overall public policy"[61], was also the message of the Brooks report (1972), centered around social issues in science. To the OECD committee of experts, "purely economic solutions are

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54 OECD (1972), The Research System, Volume 1, op. cit. p. 11.

55 This was also the rationale already offered by Jean-Jacques Salomon (1970) in Science et politique, Paris: Seuil.

56 OECD (1972), The Research System, Volume 1, op. cit., p. 12.

57 *Ibid*., p. 12-13.

58 OECD (1963), Science and the Policies of Government, *op. cit*. p. 26-27.

59 *Ibid*., p. 26.

60 *Ibid*., p. 34.

61 OECD (1972), *Science, Growth and Society*, Paris, p. 12.

insufficient"[62]. "Science policy must be much more broadly conceived than in the past (…)"[63]:

> First, the different elements of science policies were usually treated independently of each other; second, science policies themselves were often treated in relative isolation from other policy decisions[64]. [Now], science and technology are an integral part of social and economic development, and we believe that this implies a much closer relationship between policies for science and technology and all socio-economic concerns and governmental responsibilities than has existed in the past[65].

Again in 1980, in *Technical Change and Economic Policy*, concerned with the economic situation at the time in OECD countries, the Delapalme committee recommended a "better integration of the scientific and technical aspects of public policy, and the social and economic aspects"[66], and "much closer links regarding such government functions as providing for national defence, agricultural productivity, health, energy supply, and protecting the environment and human safety"[67]. To the OECD, "the organizations that propose and carry out science and technology policies tend to stand separate from offices at a comparable level concerned with the more legal and economic aspects of policy"[68].

The fourth type of relationship in the "innovation system" stressed by the OECD concerns the economic environment. From its very

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62 *Ibid*., p. 30.
63 *Ibid*., p. 36.
64 *Ibid*., p. 47.
65 *Ibid*., p. 96.
66 OECD (1980), *Technical Change and Economic Policy*, Paris, p. 96.
67 *Ibid*.
68 *Ibid.*

beginning, science policy at the OECD was definitely oriented toward innovation and economic progress[69]. This was the message of the Piganiol report[70] and of the background document to the first ministerial meeting on science. In the words of the latter, "the relationship between a national policy for economic development and a national policy for scientific research and development is one of the essential subjects for study (…)"[71]. What was needed was a dialogue between those responsible for economic policy and those responsible for science policy[72].

From 1980 on, the economic environment therefore became the central concern to the OECD. Because "science and technology policies have usually been defined and implemented independently of economic policies"[73], *Technical Change and Economic Policy* recommended that science and technology policies be better integrated with economic and social policies:

> If there is little justification for assuming limits to science and technology, there are limitations imposed by political, economic, social and moral factors which may retard, inhibit or paralyze both scientific discovery and technical innovation[74]. The most intractable problems lie not in the potential of science and technology as such, but rather in the capacity of our economic systems to make satisfactory use of this potential[75].

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69 B. Godin (2005), *Measurement and Statistics on Science and Technology: 1920 to the Present*, London: Routledge.

70 "A growing opportunity for science and technology lies in the field of economic development" (p. 16).

71 OECD (1963), Science, Economic Growth and Government Policy, *op. cit.*, p. 52.

72 *Ibid*., p. 69-73.

73 OECD (1980), Technical Change and Economic Policy, *op. cit*., p. 12.

74 *Ibid.*, p. 93.

75 *Ibid*.

The last type of relationship in the "innovation system" was international cooperation. This was the object of the very first policy document produced by the OECD (or OEEC at the time). International cooperation was, in fact, the *raison d'être* of the organization: "While scientists have co-operated on a regular basis without regard to national boundaries, there are few co-operations between governments in science and technology"[76]. "Each European country has an interest in assuring that Western Europe as a whole does not fall behind in the race for scientific advance between North America on the one hand and Russia and China on the other"[77]. "The OEEC is the only international organization that is in the position to develop co-operation between the countries of Europe (...)"[78].

In summary, the OECD documents produced since the early 1960s were concerned with developing a system approach to science policy. The research system was composed of several institutional sectors in relationship to each other and all oriented toward technological innovation. The industrial sector was embedded in an economic environment. The government sector was composed of different departments with policies that were related, but were badly coordinated. The university sector had to orient its research potential more toward applied or oriented research and develop relationships with industry. On top was the OECD as a forum where countries collaborated to create a new object: science policy.

MEASURING THE RESEARCH SYSTEM

Unlike the National Innovation System framework, the system approach has the advantage of benefiting from statistics from its very beginning. As early as 1962, the OECD published the Frascati

76 OECD (1960), *Co-Operation in Scientific and Technical Research*, Paris, p. 12.

77 *Ibid*.

78 *Ibid*., p. 38.

manual, which offered national statisticians methodological rules for surveys on R&D expenditures and manpower[79]. One of the main concepts of the manual was GERD (Gross Expenditures on R&D), defined as the sum of the expenditures from the four main sectors of the economy: government, university, industry and non-profit[80]. Each sector was measured, and the results aggregated to construct a national budget for research. But the statistics also served to analyze how each sector performed in terms of R&D activities, and to measure the relationships as flows of funds between the sectors of the system. To this end, a matrix was suggested crossing sectors as sources of funds and sectors as performers of research activities, and identifying the transfers of funds between them.

The matrix is not directly the result of a system approach[81], but it fit the approach perfectly well. As we saw in Chapter 2, the idea of a matrix comes from the US Department of Defense and its very first measurement of research funds in the United States in 1953[82], and the US National Science Foundation developed the idea further[83]. The organization constructed a matrix of financial flows between the sectors, as both sources and performers of R&D (see Chapter 2, Table 1).

The National Science Foundation matrix became an international standard with the adoption of the OECD Frascati manual by member countries in 1963. The manual, written by C. Freeman after visiting

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79 B. Godin (2007), The Making of Statistical Standards: OECD and the Frascati Manual, 1962-2002, Accounting, Organization, and Society, forthcoming.

80 OECD (1962), Proposed Standard Practice for Surveys of Research and Development, Paris, p. 34-35.

81 Although economic input-output tables (or matrices), as originally developed by W. Leontief, and part of the System of National Accounts, are of a systemic nature and may have influenced the statistics on R&D.

82 Department of Defense (1953), *The Growth of Scientific R&D,* Office of the Secretary of Defense (R&D), RDB 114/34, Washington.

83 National Science Foundation (1956), Expenditures for R&D in the United States: 1953, *Reviews of Data on R&D,* 1, NSF 56-28, Washington.

countries where measurement was conducted, suggested collecting data on sectors for both intra-mural[84] and extra-mural activities[85], and breaking down R&D data according to funder and performer. The matrix was suggested as a useful way to determine the flows of funds between sectors[86]. From then on, the OECD produced regular studies analyzing the sectors and their performances[87].

In sum, the statistics on R&D served as the first tool to measure the "innovation system", the interrelationships between its components and its links to the economy. Later, these statistics appeared limited for measuring the diversity and complexity of National Innovation Systems, and new ones were developed, among them the innovation survey. But few of the new statistics had the "rigour" of the R&D statistics for "objectifying" the framework[88]. At the same time, the conceptual framework on National Innovation Systems itself came to be challenged by other frameworks.

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84 Intra-mural expenditures include all funds used for the performance of R&D *within* a particular organization or sector of the economy, whatever the sources of finance.

85 Extra-mural expenditures include all funds spent for the performance of R&D *outside* a particular organization or sector of the economy, including abroad.

86 OECD (1962), Proposed Standard Practice for Surveys of Research and Development, *op. cit*. p. 35-36.

87 OECD (1967), The Overall Level and Structure of R&D Efforts in OECD Member Countries, *op. cit*.; OECD (1971), *R&D in OECD Member Countries: Trends and Objectives*, Paris; OECD (1975), *Patterns of Resources Devoted to R&D in the OECD Area, 1963-1971*, Paris; OECD (1975), *Changing Priorities for Government R&D: An Experimental Study of Trends in the Objectives of Government R&D Funding in 12 OECD Member Countries, 1961-1972*, Paris; OECD (1979), *Trends in Industrial R&D in Selected OECD Countries, 1967-1975*, Paris; OECD (1979), *Trends in R&D in the Higher Education Sector in OECD Member Countries Since 1965 and Their Impact on National Basic Research Efforts*, SPT (79) 20 (unpublished).

88 By strength I mean 1) a consensus among countries, and 2) a historical series of data.

CONCLUSION

Recently, B.-A. Lundvall unearthed an earlier paper from Chris Freeman as being the first written contribution on the concept of National Innovation Systems. The paper was produced for the OECD in 1982, but never published[89]. We have seen above that a system approach originated at the OECD thirty years before the literature on National Innovation Systems. Equally, in the 1960s, system dynamics, among social scientists[90], and system analysis were both quite popular, the latter particularly in the United States at RAND[91]. Many researchers, particularly from management, began to use a system approach to study decisions and choices regarding science, technology and innovation[92]. This was also the approach of the

89 C. Freeman (1982), *Technological Infrastructure and International Competitiveness*. Published with a foreword by Lundvall in *Industrial and Corporate Change*, 13, 3, 2004, p. 541-569. The history of the concept, according to Lundvall, goes back to F. List (1841), then jumps hundred and fifty later to C. Freeman.

90 On system dynamics, see the works of J. W. Forrester in the late 1960s. For an influential application, see: D. L. Meadows et al. (1972), *The Limits to Growth*, New York: Universe Books.

91 See: A. C. Hughes and T. P. Hughes (2000), *Systems, Experts, and Computers: the System Approach in Management and Engineering, World War II and After*, Cambridge (Mass.): MIT Press. For a sample of RAND's published analyses, see: C. Hitch (1955), An Appreciation of Systems Analysis, *Journal of the Operations Research Society of America*, November, p. 466-481; C. Hitch (1958), Economics and Military Operations Research, *Review of Economics and Statistics*, 40 (3), p. 199-209; B. Klein and W. Meckling (1958), Application of Operations Research to Development Decisions, *Operations Research*, 6 (3), p. 352-363; E. S. Ouade (1969), *The Systems Approach and Public Policy*, Santa Monica (California): RAND Corporation.

92 M. H. Halbert and R. L. Ackoff (1959), An Operations Research Study of the Dissemination of Scientific Information, in National Academy of Sciences/National Research Council, *Proceedings of the International Conference on Scientific Information*, Washington, Volume 1, p. 97-130; R. E. Gibson (1964), A Systems Approach to Research Management, in J. R. Bright (ed.), *R&D and Technological Innovation*, Homewood (Illinois): R. D. Irwin, p. 34-49; G. A. Lakhtin (1968), Operational Research Methods in the Management of Scientific Research, *Minerva*,

experts composing the OECD committees. Here, the system approach meant (or was transformed into) a holistic approach to science policy.

Certainly Freeman contributed to the early approach. First, he had been advocating system analysis since the early 1960s: "There is no reason why these methodologies [operational research, system analysis and technological forecasting], developed for military purposes but already used with success in such fields as communication and energy, could not be adapted to the needs of civilian industrial technology"[93]. Second, he wrote the first edition of the Frascati manual, co-produced the background document for the first OECD ministerial conference on science, and acted as expert on many OECD committees, reports from which appear in Table 2. Inversely, Freeman's National Innovation System framework drew inspiration from, among others, three decades of OECD work and the contributions of OECD experts.

Where Freeman was even more influential was relative to a second systemic tradition in science and technology studies: technological systems. In the 1970s and 1980s, a whole literature concerned itself with (inter-industry) technology flows[94], technological regimes and

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Summer, p. 524-540; R. L. Ackoff (1968), Operational Research and National Science Policy, in A. De Reuck, M. Goldsmith and J. Knight (eds.), *Decision Making in National Science Policy*, Boston: Little, Brown and Co., p. 84-91.

93 OECD (1963), Science, Economic Growth and Government Policy, C. Freeman, R. Poignant and I. Svennilson, *op. cit.* p. 73; see also C. Freeman (1971), Technology Assessment and its Social Context, *Studium Generale*, 24, p. 1038-1050.

94 C. de Bresson and J. Townsend (1978), Notes on the Inter-Industry Flow of Technology in Post-War Britain, *Research Policy*, 7, p. 48-60; N. Rosenberg (1979), Technological Interdependence in the American Economy, *Technology and Culture*, January, p. 25-50; F. M. Scherer (1982), Inter-Industry Technology Flows in the United States, *Research Policy*, 11, p. 227-245; K. Pavitt (1984), Sectoral Patterns of Technical Change: Towards a Taxonomy and a Theory, *Research Policy*, 13, p. 343-373; M. Robson, J. Townsend and K. Pavitt (1988), Sectoral Patterns of Production and Use of Innovations in the UK, 1945-1983, *Research Policy*, 17, p. 1-14;

natural trajectories[95], technological guideposts[96], technological paradigms[97], and techno-economic networks[98]. This literature looked at technologies from a system-of-interrelated-components perspective[99]. Freeman added his voice to the literature with two concepts. First, he talked of "technology systems" as families of innovations clustering in a system with wide effects on industries and services[100]. Then, he coined the term "techno-economic paradigm" as a cluster of technological systems with pervasive effects that change the mode of production and management of an economy[101].

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95 R. S. Nelson and S. D. Winter (1977), In Search of a Useful Theory of Innovation, *op. cit*.

96 D. Sahal (1981), *Patterns of Technological Innovation*, Reading, Mass.: Addison-Wesley Publishing Company; D. Sahal (1985), Technological Guideposts and Innovation Avenues, *Research Policy*, 14, p. 61-82.

97 G. Dosi (1982), Technological Paradigms and Technological Trajectories, *Research Policy*, 11 (1982), p. 142-167.

98 M. Callon et al. (1992), The Management and Evaluation of Technological Programs and the Dynamics of Techno-Economic Networks: the Case of the AFME, *Research Policy*, 21, p. 215-236; G. Bell and M. Callon (1994), Techno-Economic Networks and Science and Technology Policy, *STI Review*, 14, p. 67-126.

99 The literature borrowed from economist J. Schumpeter's study of long waves, W. Leontief's input-output analyses, and historians. In fact, system was one of the most commonly discussed concepts among historians of technology who adopted a contextual approach. See, for example: T. P. Hughes (1983), *Networks of Power: Electrification in Western Society, 1880-1930*, Baltimore: Johns Hopkins University Press. For an early analysis of technological paradigms by a historian, see: E. W. Constant (1973), A Model for Technological Change Applied to the Turbojet Revolution, *Technology and Culture*, 14 (4), p. 553-572.

100 C. Freeman, J. Clark, and L. Soete (1982), New Technology Systems: an Alternative Approach to the Clustering of Innovations and the Growth of Industries, in *Unemployment and Technical Innovation*, Connecticut: Greenwood Press, p. 64-81.

101 C. Freeman (1987), Information Technology and Change in Techno-Economic Paradigm, in C. Freeman and L. Soete (eds.), *Technical Change and Full Employment*, Oxford: Basil Blackwell, p. 49-69; C. Freeman and C. Perez (1988), Structural Crises of Adjustment, Business Cycles and Investment Behaviour, in G. Dosi et al. (eds.), *Technical Change and Economic Theory*, London: Frances Pinter, p. 38-66. See

With these terms, Freeman developed a much-cited typology of innovation composed of four categories: incremental innovation, radical innovation, new technological system, techno-economic paradigm[102]. To Freeman, only the latter was equivalent to a revolution. And among the many generic technologies actually in existence, only electronics was of this type. This was precisely the rationale that the OECD needed to "sell" its new discourse on the information economy to policy-makers and the public[103]. Freeman's analyses on electronics as revolution contributed to the then-popular discourses on the information economy, or information society, at the OECD[104].

What, then, did the framework on National Innovation System add to the early system approach? Certainly, the issues studied and the types of relationships are more diverse and complex in the framework than those portrayed in the early approach. Globalization of research activities, networks of collaborators, clusters and the role of users are only some of the new terms added to the system approach in the 1990s. More fundamentally, however, the differences between the two periods are twofold. First, in its early years, the systemic view dealt above all with policy issues. The government was believed at that time to have a prime responsibility in the performance of the system. The role of government was its capacity to make the system work. But the policies had to be adapted and coordinated. That was the main message of OECD reports. With the National Innovation System, it would instead be the role of government as facilitator that

also: F. Kodama (1990), Can Changes in the Techno-Economic Paradigm Be Identified Through Empirical and Quantitative Study?, *STI Review*, 7, p. 101-129; F. Kodama (1991), Changing Global Perspectives: Japan, the USA and the New Industrial Order, *Science and Public Policy*, 19 (6), p. 385-392.

102 On OECD use of the typology, see, among others: C. Freeman (1987), The Challenge of New Technologies, in OECD, *Interdependence and Co-operation in Tomorrow's World*, Paris, p. 123-156; OECD (1988), *New Technologies in the 1990s: A Socio-Economic Strategy*, Chapter 1, Paris.

103 See Chapter 9 below.

104 See Chapter 9 below.

would be emphasized. The message was directed towards the actors, or sectors, and focused on the need for greater "collaboration". Second, whereas the early system approach was centered on the research system and its links to other components or sub-systems, the National Innovation System framework was wholly centered on the firm as its main component, around which other sectors gravitate. The two approaches, however, put the emphasis on technological innovation and its economic dimension, and urge all sectors to contribute to this goal – each in their respective roles.

What the framework on National Innovation System certainly brought to a system approach that had existed for thirty years was a name or label[105]. Such labels are important for academics as well as governments to highlight issues and bring them onto the intellectual or political agenda. Mode 1/Mode 2 and the Triple Helix are other examples of academic labels used to increase an issue's visibility – and the researcher's own visibility[106]. High-Technology, Knowledge-Based Economy, Information Economy or Society, and New Economy are examples of labels used by governments and the OECD

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105 This is what happened in the 1960s, when people started talking about the linear model of innovation, giving a name to a theory on technological change that had emerged in the 1940s. This phenomenon of labelling explains the difference in point of view between B. Godin and D. Edgerton on the history of the linear model of innovation. See D. Edgerton (2004), The Linear Model did not Exist, in K. Grandin, N. Worms, and S. Widmalm (eds.), *The Science-Industry Nexus: History, Policy, Implications*, Sagamore Beach: Science History Publications, p. 31-57; B. Godin (2006), The Linear Model of Innovation: The Historical Construction of an Analytical Framework, *op. cit*.

106 For critical analyses, see: B. Godin (1998), Writing Performative History: The New "New Atlantis", *Social Studies of Science*, 28 (3), p. 465-483; T. Shinn (2002), The Triple Helix and New Production of Knowledge: Prepackaged Thinking in Science and Technology, *Social Studies of Science*, 32 (4), p. 599-614. B.-A. Lundvall recently imitated the strategy of the authors on the Triple Helix to re-launch the concept of National Innovation System in a special issue of *Research Policy*. See: B.-A. Lundvall, B. Johnson, E. S. Andersen and B. Dalum (2003), National Systems of Production, Innovation and Competence Building, *Research Policy*, 31, p. 213-231.

to promote the case of science, technology and innovation and their inclusion in the policy agenda of governments[107]. The National Innovation System is one such recent label invented as a conceptual framework for policy that serves many purposes.

There is an irony in this story. The system approach suggested better theorizing of institutions, rules and culture and their integration into technological analyses, stating that innovation is not an autonomous activity but is embedded within the larger society. From a science-policy point of view, however, the approach saw the institutions, rules and culture as not only contributing to innovation, but as (almost) totally defined (or analyzed) in terms of, and as devoted to, innovation as the commercialization of technological invention. This is one more consequence of the economic approach that has driven science, technology and innovation policy for nearly sixty years[108].

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107 For critical analyses, see: B. Godin (2004), The Obsession for Competitiveness and its Impact on Statistics: The Construction of High-Technology Indicators, *Research Policy*, 33 (8), p. 1217-1229; B. Godin (2004), The New Economy: What the Concept Owes to the OECD, *Research Policy*, 33, p. 679-690; B. Godin (2006), The Knowledge-Based Economy: Conceptual Framework or Buzzword?, *op. cit*; B. Godin (2007), The Information Economy: the History of a Concept through its Measurement, or How to Make Politically Relevant Indicators, 1949-2005, *op. cit*.

108 See: B. Godin (2006), *Statistics and STI Policy: How to Get Relevant Indicators*, Communication presented at the OECD Blue Sky II Conference "What Indicators for Science, Technology and Innovation Policies in the 21st Century?", Ottawa, Canada, 25-27 September 2006 [http://www.oecd.org/document/60/0,2340,en_2649_34409_37083516_1_1_1_1,00.html#Wednesday] (page consulted on October 25, 2006).

CHAPTER EIGHT

THE KNOWLEDGE-BASED ECONOMY: CONCEPTUAL FRAMEWORK OR BUZZWORD?

According to many authors, think tanks, governments and international organizations, we now live in a knowledge-based economy. Knowledge is reputed to be the basis for many if not all decisions, and an asset to individuals and firms. Certainly, the role of knowledge in the economy is not new, but knowledge is said to have taken on increased importance in recent years, both quantitatively and qualitatively, partly because of the development of information and communication technologies.

Where does the concept of the knowledge-base economy or society come from? In 1932, the American sociologist W. F. Ogburn, who had worked for decades on technology and its impact on society, published a short paper titled *The Volume of Know*ledge[109]. To Ogburn, "the volume of knowledge has grown so great that it is beyond the human capacity of any one man to assimilate it all"[110]. Ogburn measured knowledge as being what was recorded by German scholar L. Darmstaeder in a bibliography of inventions and discoveries from 1300 to 1900 and published in 1908[111]. Ogburn computed an exponential growth curve and asked "how the human race will ever acquire all the present and future accumulation of knowledge"[112]. He answered that it would do so in two ways. The

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109 W. F. Ogburn (1932), The Volume of Knowledge, *Journal of Adult Education*, 4, p. 26-29.

110 *Ibid*., p. 26.

111 The data were produced for a chapter included in the report *Recent Social Trends*, published in 1933. See W. F. Ogburn and S. C. Gilfillan (1933), The Influence of Invention and Discovery, in *Recent Social Trends in the United States*, US Committee on Social Trends, Washington.

112 *Ibid*., p. 28.

first was through specialization, “a process being followed today”[113], and the second was through education. The latter was his recommendation. However, since “there is a limit to the length of the period of formal education for which society can afford to pay”[114], Ogburn recommended, without much discussion, adult education.

This was one of the first papers concerned directly with the role of knowledge in society and the implications for policy from a macro perspective. Although more a popularization than an academic paper, Ogburn’s article was nevertheless the first one written on the knowledge-based society. It was a discourse, or narrative, on the growth of knowledge, a measure of this growth and recommendations for policy. However, it is Fritz Machlup who is recognized as the real father of the topic and its measurement.

In 1962 Machlup, an Austrian-born economist, published a study that measured the production and distribution of (all kinds of) knowledge in the United States[115]. The author estimated that in 1958, the knowledge economy accounted for $136.4 million or 29% of GNP. Machlup was the first to measure knowledge as a broad concept, while other measurements were concerned with the production of scientific knowledge, either through counting of scientific papers or R&D expenditures, and not with its distribution.

Machlup’s calculations gave rise to a whole literature on the knowledge economy, its policies and its measurement. The first wave, starting in the 1970s, was concerned with the so-called information economy. In fact, both information and knowledge as terms were used interchangeably in the literature. Using Machlup’s insights and the System of National Accounts as source for data, M. U. Porat calculated that the information economy amounted to 46%

113 *Ibid*.

114 *Ibid*., p. 29.

115 F. Machlup (1962), *The Production and Distribution of Knowledge in the United States*, Princeton: Princeton University Press.

of GNP and 53% of labour income in the United States in 1967[116]. Porat's study launched a series of similar analyses, conducted in several countries and at the OECD. This is the subject of the next chapter. The second wave of studies on the knowledge economy started in the 1990s and still continues today. The OECD, and economist D. Foray as consultant to the organization, re-launched the concept of a knowledge economy, with characteristics broadly similar to those Machlup identified.

This chapter looks at the reemergence of the concept in the 1990s at the OECD. The first part discusses Machlup's measurement of the concept and the discourse he conducted on the concept. The second part discusses recent efforts at the OECD to define the concept and improve on its measurement.

MACHLUP'S CONSTRUCTION

Fritz Machlup (1902-1983), studied economics under Ludwig von Mises and Friedrich Hayek at the University of Vienna in the 1920s, and emigrated to the United States in 1933[117]. His two main areas of work were industrial organization and monetary economics, but he also had a life-long interest in the methodology of economics and in the ideal-typical role of assumptions in economic theory.

Machlup's work on the knowledge economy, a work of a methodological nature, grew out of five lectures he gave in 1959 and 1960. The rationale Machlup offered for studying the economics of knowledge was the centrality of knowledge in society, and the absence of theorizing on this subject in the economic literature. To Machlup, "knowledge has always played a part in economic analysis,

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116 M. U. Porat (1977), *The Information Economy*, Nine volumes, Office of Telecommunication, US Department of Commerce, Washington.

117 He taught at the University of Buffalo (1935-1947), then Johns Hopkins (1947-1960), then Princeton (1960-1971). After retiring from teaching in 1971, he joined New York University until his death.

or at least certain kinds of knowledge have (…). But to most economists and for most problems of economics the state of knowledge and its distribution in society are among the data assumed as given"[118]. To Machlup, "now, the growth of technical knowledge, and the growth of productivity that may result from it, are certainly important factors in the analysis of economic growth and other economic problems"[119]. However, Machlup argued, there are other types of knowledge in addition to scientific knowledge. There is also knowledge of an "unproductive" type to which society allocates ample resources: schools, books, radio and television. Also, organizations rely more and more on "brain work" of various sorts: "besides the researchers, designers, and planners, quite naturally, the executives, the secretaries, and all the transmitters of knowledge (...) come into focus"[120]. To Machlup, these kinds of knowledge deserved study.

Machlup suggested a definition of knowledge that had two characteristics. First, Machlup's definition included all kinds of knowledge, scientific and ordinary knowledge: "we may designate as knowledge anything that is known by somebody"[121]. Second, knowledge was defined as consisting of both its production and distribution: "producing knowledge will mean, in this book, not only discovering, inventing, designing and planning, but also disseminating and communicating"[122]. The intellectual sources of these definitions have been documented in Godin (2008): philosophy (epistemology), economics (of information), mathematics

[118] F. Machlup (1962), The Production and Distribution of Knowledge in the United States, *op. cit*. p. 3-4.

[119] *Ibid*., p. 5.

[120] *Ibid*., p. 7.

[121] *Ibid*., p. 7.

[122] *Ibid*.

(cybernetics), and accounting[123]. In this chapter, I concentrate on Machlup's measurement of knowledge.

Measuring Knowledge

When Machlup published *The Production and Distribution of Knowledge*, the economic analysis of science, technology and innovation was just beginning[124]. A "breakthrough" of the time was R. M. Solow's paper on using the production function to estimate the role of science and technology in economic growth and productivity[125]. As we saw in Chapter 3, a mathematical exercise such as the production function was, according to Machlup, "only an abstract construction". For measuring knowledge, Machlup chose another method than econometrics and the production function, namely national accounting. National accounting goes back to the 18th century and what was then called political arithmetic[126]. National

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123 B. Godin (2008), The Knowledge Economy: Fritz Machlup's Construction of a Synthetic Concept, in H, Etzkowitz and R. Viale (eds.), *Proceedings of the 5th Triple Helix Conference*, Edward Elgar, forthcoming.

124 D. A. Hounshell (2000), The Medium is the Message, or How Context Matters: The RAND Corporation Builds an Economics of Innovation, 1946-1962, in A. C. Hughes and H. P. Hughes (eds.), Systems, Experts, and Computers, *op. cit.*, p. 255-310.

125 R. M. Solow (1957), Technical Change and the Aggregate Production Function, *Review of Economics and Statistics*, 39, August, p. 312-320.

126 P. Deane (1955), The Implications of Early National Income Estimates for the Measurement of Long-Term Economic Growth in the United Kingdom, *Economic Development and Cultural Change*, 4 (1), Part I, p. 3-38; P. Buck (1977), Seventeenth-Century Political Arithmetic: Civil Strife and Vital Statistics, *ISIS*, 68 (241), p. 67-84; P. Buck (1982), People Who Counted: Political Arithmetic in the 18th Century, *ISIS*, 73 (266), p. 28-45; J. E. Cookson (1983), Political Arithmetic and War in Britain, 1793-1815, *War and Society*, 1, p. 37-60; A. M. Endres (1985), The Functions of Numerical Data in the Writings of Graunt, Petty, and Davenant, *History of Political Economy*, 17 (2), p. 245-264; J. Mykkanen (1994), To Methodize and Regulate Them: William Petty's Governmental Science of Statistics, *History of the Human Sciences*, 7 (3), p. 65-88; J.

accounting really developed after World War II with the establishment of a standardized System of National Accounts, which allowed a national bureau of statistics to collect data on the production of economic goods and services in a country in a systematic way[127]. Unfortunately for Machlup, knowledge was not – and is still not – a category in the National System of Accounts.

There are, argued Machlup, "insurmountable obstacles in a statistical analysis of the knowledge industry"[128]. Usually, in economic theory, "production implies that valuable input is allocated to the bringing forth of a valuable output", but with knowledge there is no physical output, and knowledge is most of the time not sold on the market[129]. The need for statistically-operational concepts forced Machlup to concentrate on costs, or national income accounting. To estimate costs[130] and sales of knowledge products and services, Machlup collected numbers from diverse sources, both private and public. However, measuring costs meant that no data were available on the internal (non-marketed) production and use of knowledge, for example inside a firm: "all the people whose work consists of conferring, negotiating, planning, directing, reading, note-taking,

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Hoppit (1996), Political Arithmetic in 18th Century England, *Economic History Review*, 49 (3), p. 516-540.

127 P. Studenski (1958), *The Income of Nations: Theory, Measurement, and Analysis, Past and Present*, New York: New York University Press; N. Ruggles and R. Ruggles (1970), *The Design of Economic Accounts*, National Bureau of Economic Research, New York: Columbia University Press; J. W. Kendrick (1970), The Historical Development of National-Income Accounts, *History of Political Economy*, 2 (1), p. 284-315; A. Sauvy (1970), Histoire de la comptabilité nationale, *Économie et Statistique*, 14, p. 19-32; C. S. Carson (1975), The History of the United States National Income and Product Accounts: the Development of an Analytical Tool, *Review of Income and Wealth*, 21 (2), p. 153-181; F. Fourquet (1980), *Les comptes de la puissance*, Paris: Encres; A. Vanoli (2002), *Une histoire de la comptabilité nationale*, Paris: La Découverte.

128 F. Machlup (1962), The Production and Distribution of Knowledge in the United States, *op. cit.*, p. 44.

129 *Ibid.*, p. 36.

130 Machlup preferred the concept of investments in the case of education and R&D.

writing, drawing, blueprinting, calculating, dictating, telephoning, card-punching, typing, multigraphing, recording, checking, and many others, are engaged in the production of knowledge”[131]. Machlup thus looked at complementary data to capture the internal market for knowledge. He conducted work on occupational classes of the census, differentiating classes of white-collar workers who were knowledge-producing workers from those that were not, and computing the national income of these occupations[132]. Machlup then arrived at his famous estimate: the knowledge economy was worth $136.4 million, or 29% of GNP in 1958, had grown at a rate of 8.8% per year over the period 1947-58, and occupied people representing 26.9% of the national income:

	$ (millions)	**%**
Education	60.194	44.1
R&D	10.990	8.1
Media of communication	38.369	28.1
Information machines	8.922	6.5
Information services	17.961	13.2

In conducting his accounting exercise, Machlup benefited from the experience of previous exercises conducted on education[133], on human capital[134] and, above all, on research. The US National

131 F. Machlup (1962), The Production and Distribution of Knowledge in the United States, *op. cit*., p. 41.

132 *Ibid*., p. 383 and 386.

133 J. D. Wiles (1956), The Nation’s Intellectual Investment, *Bulletin of the Oxford University Institute of Statistics*, 18 (3), p. 279-290.

134 J. R. Walsh (1935), Capital Concept Applied to Man, *Quarterly Journal of Economics*, 49 (2), p. 255-285; J. Mincer (1958), Investment in Human

Science Foundation, as the producer of official statistics on science in the United States, had started collecting data on R&D expenditures in the early 1950s[135]. Regular surveys were conducted on four economic sectors: government, universities, firms and non-profit organizations. Then, in 1956, the Foundation published its "first systematic effort to obtain a systematic across-the-board picture"[136]. It consisted of the sum of the results of the sectoral surveys for estimating national funds for R&D. The National Science Foundation calculated that the national budget for R&D amounted to $5.4 billion in 1953.

From the start, the data on R&D from the National Science Foundation were framed within the System of National Accounts' framework as model. Surveys were conducted according by economic sector, the classifications used corresponded to available classifications, the matrix of R&D money flows imitated the input-output tables accompanying the System of National Accounts, and a ratio R&D/GNP was constructed. To the National Science Foundation, such an alignment with the System of National Accounts was its way to relate R&D to economic output statistically, describing "the manner in which R&D expenditures enter the gross national product in order to assist in establishing a basis for valid

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Capital and Personal Income Distribution, *Journal of Political Economy*, 66 (4), p. 281-302; T. W. Schultz (1959), Investment in Man: An Economist's View, *Social Service Review*, 33 (2), p. 109-117; T. W. Schultz (1960), Capital Formation by Education, *Journal of Political Economy*, 68 (6), p. 571-583; T. W. Schultz (1961), Investment in Human Capital, *American Economic Review*, 51 (1), p. 1-17; T. W. Schultz (1961), Education and Economic Growth, in N. B. Henry (ed.), *Social Forces Influencing American Education*, Chicago: University of Chicago Press, p. 46-88; T. W. Schultz (1962), Reflections on Investment in Man, *Journal of Political Economy*, 70 (5), p. 1-8; G. S. Becker (1962), Investment in Human Capital: A Theoretical Analysis, *Journal of Political Economy*, 70 (5), p. 9-4; W. L. Hansen (1963), Total and Private Rates of Return to Investment in Schooling, *Journal of Political Economy*, 71, p. 128-140.

[135] B. Godin (2005), Measurement and Statistics on Science and Technology: 1920 to the Present, London: Routledge.

[136] National Science Foundation (1956), Expenditures for R&D in the United States: 1953, *Reviews of Data on R&D*, 1, NSF 56-28, Washington.

measures of the relationships of such expenditures to aggregate economic output"[137].

Machlup made wide use of the National Science Foundation's data for his own accounting. As we saw earlier, and as R. N. Nelson once stated, "the National Science Foundation has been very important in focusing the attention of economists on R&D (organized inventive activity), and the statistical series the NSF has collected and published have given social scientists something to work with"[138]. The organization's numbers were one of many sources Machlup added together in calculating his estimate of the size of the knowledge economy. However, for most of his calculations, Machlup did not use the System of National Accounts as Porat would for his work on the information economy. Instead he looked liberally at the literature for available numbers, like the National Science Foundation data, and conducted many different calculations (summations, mathematical projections, estimations and computations of opportunity costs). Neither was Machlup addicted to accounting. Although he chose costs for his estimate of the knowledge economy, he discussed and suggested many other statistics. For media of communication, he looked at the number of books and periodicals, their circulation and content; for information, he collected numbers on types of technology, and use of technologies in households; on education, he recommended using numbers on attendance, years of schooling, achievement tests, number of class hours, amount of homework, and subject-matter requirements; for R&D, he proposed a list of measures on input and output (see Appendix 3), and relationships or ratios between the two[139].

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137 National Science Foundation (1961), R&D and the GNP, *Reviews of Data on R&D*, 26, NSF 61-9, p. 1.

138 R. R. Nelson (1962), Introduction, in National Bureau of Economic Research, *The Rate and Direction of Inventive Activity*, Princeton: Princeton University Press, p. 4.

139 For an in-depth discussion of Machlup on this topic, see: F. Machlup (1960), The Supply of Inventors and Inventions, *Weltwirtschaftliches Archiv*, 85, p. 210-254.

Machlup was realistic about his own accounting, qualifying some of his own estimates as being speculative[140], that is, ideas of magnitude and trends based on conjecture rather than exact figures[141], and he qualified some of his comparisons as requiring interpretation "with several grains of salt"[142]. To Machlup, it was the message rather than the statistical adequacy that was important. The very last sentence of the book reads as follows: "concern about their accuracy [statistical tables] should not crowd out the message it conveys"[143].

The Message

Apart from his theoretical borrowings from philosophy, mathematics, economics and national accounting, we can identify policy issues and even professional interests in Machlup's analysis at several levels First, Machlup was concerned with the challenges facing the education and research system of which he was part. Second, he was concerned, as analyst, with the new information technology "revolution".

For each of the components"operationalizing" his definition of knowledge, Machlup identified policy issues, and this partly explains the inclusion of the components in the measurement. The policy issues Machlup identified were mainly economic. To begin with education, the central question discussed was productivity. Machlup suggested compressing the curriculum to accelerate the production of well-trained brainpower and therefore economic growth. "We need an educational system that will significantly raise the intellectual capacity of our people. There is at present a great scarcity of brainpower in our labor force (…). Unless our labor force changes its composition so as to include a much higher share of well-trained

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140 F. Machlup (1962), The Production and Distribution of Knowledge in the United States, *op. cit*., p. 62.

141 *Ibid.,* p. 103.

142 *Ibid*., p. 374.

143 *Ibid*., p. 400.

brainpower, the economic growth of the nation will be stunted and even more serious problems of employability will arise"[144]. Machlup also suggested considering (and measuring) education as an investment rather than as a cost, and as an investment not only with regard to the individual (for future earnings) but also to society (for culture), in line with studies on social rates of return on research[145].

As to the second component – R&D – Machlup confessed that "this subject was his first interest in the knowledge production industry. The temptation to expand the area of study to cover the entire industry came later, and proved irresistible"[146]. To Machlup, the policy issues involving R&D were twofold. One was the decline of inventions. He wondered whether this was due to the patent system itself, or to other factors. In the absence of empirical evidence, he suggested that "faith alone, not evidence, supports" the patent system. To Machlup, it seems "not very likely that the patent system makes much difference regarding R&D expenditures of large firms"[147]. A second policy issue concerning R&D was the productivity of research on the economy and society, particularly basic research, as there was then a preference for applied research in America, claimed Machlup. Echoing V. Bush, according to whom "applied research invariably drives out pure" research[148], Machlup argued that industry picks up potential scientists before they have completed their studies, and dries up the supply of research personnel (shortages). Furthermore, he argued that if investments in basic research remain too low (8% of

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144 F. Machlup (1962), The Production and Distribution of Knowledge in the United States, *op. cit.*, p. 135.

145 T. W. Shultz (1953), *The Economic Organization of Agriculture*, New York: McGraw-Hill, p. 114-122; Z. Griliches (1958), Research Costs and Social Returns: Hybrid Corn and Related Innovation, *Journal of Political Economy*, 46, p. 419-431.

146 *Ibid*., p. 48.

147 F. Machlup (1962), The Production and Distribution of Knowledge in the United States, *op. cit.*, p. 170.

148 V. Bush (1945) [1995], *Science: The Endless Frontier*, North Stratford (N.H.): Ayer Company Publishers, p. xxvi.

total expenditures on R&D), applied research would suffer in the long run, since it depends entirely on basic research.

These were the main policy issues Machlup discussed. Concerning the last two components of his definition – communication and information – Machlup was very brief. In fact, his policy concern here was mainly with information technologies and the technological revolution. To Machlup, there was the danger of increasing unemployment among unskilled manual labour[149]. In the long run, "the demand for more information may partially offset the labor-replacing effect of the computer-machine"[150].

Machlup wrote on knowledge at a time when science, or scientific knowledge, was increasingly believed to be of central importance to society – and scientists benefited greatly from public investments in research. Economists, according to whom "if society devotes considerable amounts of its resources to any particular activity, economists will want to look into this allocation and get an idea of the magnitude of the activity, its major breakdown, and its relation to other activities"[151], started measuring the new phenomenon, and were increasingly solicited by governments to demonstrate empirically the contribution of science to society – a means of cost control on research expenditures not yet being in sight. Machlup was part of this "movement", with his own intellectual contribution.

THE KNOWLEDGE-BASED ECONOMY AT THE OECD

Machlup's concept of a knowledge economy and its relationship to statistics was a concept originally supported by new trends in the economy. Its revival in the 1990s, however, has little to do with numbers and everything to do with politics. In fact, several authors

[149] *Ibid*., p. 397.

[150] *Ibid*., p. 321.

[151] F. Machlup (1962), The Production and Distribution of Knowledge in the United States, *op. cit*., p. 7.

argue that nothing really new has happened, at least with regard to the centrality of knowledge in the modern economy. I suggest that the concept of a knowledge-based economy at the OECD is simply a concept that serves to direct the attention of policy-makers to science and technology issues and to their role in the economy and, to this end, a concept that allows one to collect a large set of statistics under one roof. This kind of concept I will call an umbrella concept.

The concept of the knowledge-based economy at the OECD is a response to criticisms of the concept of the National Innovation System. The OECD used several strategies to revive the concept, one of them being enrolling the concept's promoters as consultants. The second most important strategy was using statistics, which helped crystallize the concept by giving it empirical content.

As we have seen in the previous chapter, the OECD project on the National Innovation System flirted with the concept of a knowledge economy, having even temporarily redefined the initial objectives of the project around knowledge access and distribution, whereas the original aims concerned institutional factors explaining the efficiency of a National Innovation System. The project also flirted with indicators on knowledge distribution, but rapidly concluded that it was too difficult to measure. In the end, the concept of the knowledge-based economy instead served a rhetorical role in papers on the National Innovation System: in section titles and introductory texts.

The first step toward the generalized used of the concept of a knowledge-based economy at the OECD came in 1995, with a document written by the Canadian delegation for the ministerial meeting of the Committee on Science and Technology Policy. The paper, including the knowledge-based economy concept in its title, discussed two themes: new growth theory and innovation performance[152]. On the first theme, the Secretariat suggested[153]:

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[152] OECD (1995), The Implications of the Knowledge-Based Economy for Future Science and Technology Policies, OCDE/GD(95)136.

> Economics has so far been unable to provide much understanding of the forces that drive long-term growth. At the heart of the old theory (neoclassical) is the production function, which says the output of the economy depends on the amount of production factors employed. It focuses on the traditional factors of labor, capital, materials and energy (…). The new growth theory, as developed by such economists as Romer, Grossman, Helpman and Lipsey, adds the knowledge base as another factor of production".

On the second theme – innovation – a dynamic national innovation system was again suggested as the key to effectiveness. But understanding a national innovation system required "better measures of innovation performance and output indicators"[154]. "Most current indicators of science and technology activities, such as R&D expenditures, patents, publications, citations, and the number of graduates, are not adequate to describe the dynamic system of knowledge development and acquisition. New measurements are needed to capture the state of the distribution of knowledge between key institutions and interactions between the institutions forming the national innovation system, and the extent of innovation and diffusion"[155]. This message was carried over into the 1995 ministerial declaration and recommendations: "there is need for Member countries to collaborate to develop a new generation of indicators which can measure innovative performance and other related output of a knowledge-based economy"[156]. From then on, two conceptual frameworks competed at the OECD for the attention of policy-

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[153] *Ibid.*, p. 3.

[154] *Ibid.*, p. 5.

[155] *Ibid.*, p. 6.

[156] OECD (1996), Conference on New Science and Technology Indicators for a Knowledge-Based Economy: Background Document, DSTI/STP/NESTI/GSS/TIP (96) 2, p. 2,

makers: the National Innovation System together with the analysis of its components and their interrelationships, and the Knowledge-Based Economy with its emphasis on the production, distribution and use of knowledge, and on its measurement.

Soon, various committees, working groups and people at the OECD appropriated the concept of a knowledge-based economy: conferences were held that included the concept[157], papers were published in the policy series (*Science, Technology and Industry Outlook*) that attempted to promote it[158], and a whole program of work on new indicators was developed[159], from which statistical scoreboards were produced[160].

Defining the Knowledge-Based Economy

In the mid-1990s, the knowledge-based economy was a fuzzy concept. At the OECD conference on employment and growth in the knowledge-based economy, Foray and Lundvall joined forces,

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157 OECD (1996), *Employment and Growth in the Knowledge-Based Economy*, Paris; OECD (1997), *Industrial Competitiveness in the Knowledge-Based Economy: The New Role of Governments*, Paris.

158 OECD (1996), Science, Technology and Industry Outlook, chapter 5, Paris; OECD (2000), Science, Technology and Industry Outlook, chapter 1, Paris; OECD (2002), Science, Technology and Industry Outlook, chapter 1, Paris.

159 A workshop and a conference on a new generation of indicators for the knowledge-based economy were organized in 1996 and 1998 (Blue Sky Project). See OECD (1996), *Conference on New Indicators for the Knowledge-Based Economy: Summary Record*, DSTI/STP/NESTI/GSS/TIP (96) 5; OECD (1997), *Progress Report on the "New Science and Technology Indicators for the Knowledge-Based Economy" Activity*, DSTI/EAS/STP/NESTI (97) 6; OECD (1998), *Seminar on New Indicators for the Knowledge-Based Economy: Development Issues*, CCNM/DSTI/EAS (98) 63; OECD (1998), *New S&T Indicators for a Knowledge-Based Economy: Present Results and Future Work*, DSTI/STP/NESTI/GSS/TIP (98) 1.

160 OECD (1999), STI Scoreboard: Benchmarking Knowledge-Based Economies, Paris; OECD (2001), Science, Technology and Industry Scoreboard: Towards a Knowledge-Based Economy, Paris.

arguing that the "economy is more strongly and more directly rooted in the production, distribution and use of knowledge than ever before"[161]. According to other authors, however, the concept was rather a rhetorical term, a metaphor "often used in a superficial and uncritical way"[162]. Briefly stated, it can be said that the term knowledge-based economy referred to at least two (supposed) characteristics of the new economy. Firstly, knowledge would be more quantitatively and qualitatively important than before. Secondly, applications of information and communication technologies would be the drivers of the new economy.

For a "systematic" definition of knowledge-based economies, we have to turn to the OECD *Science, Technology and Industry Outlook* series. In 1996, the OECD defined knowledge-based economies as: "economies which are directly based on the production, distribution and use of knowledge and information"[163]. A more or less identical definition has carried over into every subsequent OECD document dealing with the knowledge-based economy.

In the course of its efforts to define the knowledge-based economy, the OECD invented two related concepts that gave it more substance. The first concerned "investment in knowledge", and the definition was entirely statistical: "expenditures directed towards activities with the aim of enhancing existing knowledge and/or acquiring new knowledge or diffusing knowledge"[164]. According to the OECD,

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[161] D. Foray and B.-A. Lundvall (1996), The Knowledge-Based Economy: From the Economics of Knowledge to the Learning Economy, in OECD, Employment and Growth in the Knowledge-Based Economy, op. cit. p. 11-32.

[162] K. Smith (2002), What is the Knowledge Economy? Knowledge Intensity and Distributed Knowledge Bases, UNU/INTECH Discussion Paper, ISSN 1564-8370, p. 5.

[163] OECD (1996), *The Knowledge-Based Economy*, in OECD, Science, Technology, and Industry Outlook, Paris: OECD, p. 3.

[164] OECD (2001), Science, Technology, and Industry Scoreboard: Towards a Knowledge-Based Economy, *op. cit*. p. 14; M. Kahn (2001), Investment in Knowledge, *STI Review*, 27, p. 19-47.

investment in knowledge is the sum of expenditures on R&D, higher education and software. The second newly-coined concept was in fact a variation on the (controversial) indicator of high-technology intensity: knowledge-based industries. Knowledge-based industries were defined as those that had the following three characteristics: 1) a high level of investment in innovation, 2) intensive use of acquired technology, and 3) a highly-educated workforce[165].

But the main conceptual work on the subject at the OECD had to do with collecting a whole set of indicators under the concept of the knowledge-based economy. Recalling Foray and Lundvall's comment that evidence documenting trends in the knowledge-based economy was in fact anecdotal[166], the OECD suggested five categories of indicators to measure the concept: inputs, stocks and flows, outputs, networks and learning[167]. The first measurement exercise, to which we now turn, appeared in 1999, in the form of a scoreboard of indicators.

Measuring the Knowledge-Based Economy

In the mid-1990s, the Directorate for Science, Technology and Industry restructured its publication.[168] Until then, four reviews and/or outlooks had been prepared. The Secretariat suggested merging the "Industrial" and "Science and Technology Policy" reviews into one (*Science, Technology and Industry Outlook*), to be

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

166 D. Foray and B.-A. Lundvall (1996), The Knowledge-Based Economy: From the Economics of Knowledge to the Learning Economy, *op. cit*. p. 16.

167 OECD (1996), *The Knowledge-Based Economy*, in OECD, Science, Technology, and Industry Outlook, *op. cit*. p. 20.

168 OECD (1994), *Developing Science, Technology and Industry Review/Outlooks: A Proposal*, DSTI/IND/STP/ICCP (94) 4; OECD (1995), *Réunion ad hoc conjointe sur l'intégration des rapports relatifs aux perspectives*, DSTI/IND/STP (95) 1.

published every two years. In the alternating year, a scoreboard of indicators would be published.

The idea of the scoreboard followed the construction of the STAN database (Structural Analysis) and its affiliates in the early 1990s. One of the first reports to come out of the new database was a scoreboard of sixteen indicators covering R&D, investment, international trade, employment and structural change[169]. Thereafter, starting in 1995, an *Industry and Technology Scoreboard of Indicators* was published every two years. It included a series of economic and science and technology indicators, graphically illustrated, ranking countries on different dimensions, and with a very brief analytical text (two to five paragraphs per indicator).

From the scoreboards, the Directorate for Science, Technology and Industry also produced compendiums specifically designed for ministerial meetings: one in 1995[170], and another in 1999[171]. These documents were "synthetic and attractive" statistical and analytical documents that "tell a story readily understandable by generalists and the press"[172]. It included a set of indicators, each presented on one page, with graphs and bullet points highlighting the main trends.

The 1999 issue of the compendium dealt with the knowledge-based economy. It collected 32 indicators[173], of which nine were specifically identified as measuring the knowledge-based economy (see Appendix 5). The indicators showed, among other things, that: 1) knowledge-based industries have been outpacing GDP growth (up

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169 OECD (1993), *Manufacturing Performance: A Scoreboard of Indicators for OECD Countries*, DSTI/EAS/IND/WP9 (93) 2.

170 OECD (1995), *Science and Technology Indicators*, Meeting of the Committee for Scientific and Technological Policy at Ministerial Level, Paris.

171 OECD (1999), *The Knowledge-Based Economy: A Set of Facts and Figures*, Paris.

172 OECD (1998), *Possible Meeting of the CSTP at Ministerial Level: Statistical Compendium*, DSTI/EAS/STP/NESTI (98) 8, p. 3.

173 Including, for the first time in an OECD statistical publication, bibliometric indicators.

to 50% that of GDP growth), 2) OECD countries spend more and more resources on the production of knowledge (8% of GDP, a share as important as that on physical investments), 3) over 60% of the population aged 25-64 has completed upper secondary schooling, 4) OECD economies invested 7% of GDP in information and communication technologies, 5) R&D was expanding (US$500 billion in 1997), 6) the business sector was the main funder and performer of R&D (over 60%). The statistics were updated in 2000[174], and the number of indicators increased in 2001 (see Appendix 6)[175].

The work behind the measurement of the knowledge-based economy was conducted in part by the group of National Experts on Science and Technology Indicators (NESTI), via a project called Blue Sky, launched in 1996[176]. Six priority areas were identified for the development of a new generation of indicators:

- Mobility of human resources,
- Patents,
- Innovation capabilities of firms,
- Internationalization of industrial R&D,
- Government support for innovation,
- Information technology.

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[174] OECD (2000), Progress Towards a Knowledge-Based Economy, in OECD, STI Outlook, *op. cit*.

[175] OECD (2001), Science, Technology and Industry Scoreboard: Towards a Knowledge-Based Economy, *op. cit*.

[176] OECD (1996), Conference on New Science and Technology Indicators for a Knowledge-Based Economy: Summary Record of the Conference Held on 19-21 June 1996, *op. cit*.; OECD (1996), Conference on New S&T Indicators for a Knowledge-Based Economy: Background Document, *op. cit*.

The aim was to develop two types of statistical products[177]. The first were data and indicators, published on a regular basis, *i.e.*: yearly. The second were data sets for use in specific studies, like those on the knowledge-based economy. Two conferences were held, one in 1996 and another in 1998, where the six above areas were targeted and a program of work was developed for each, the various projects each being led by a specific country or group of countries. The criteria for the proposed topics were the following: they must 1) be relevant from a policy point of view, 2) be feasible in terms of methodology, 3) be not too resource-consuming, 4) refer to well-identified questions, and 5) be topics in which the OECD has a role to play and a comparative advantage. However, it was clearly mentioned that, "budget restrictions (and the burden for respondents) set strict limits on the possibility of developing new surveys. Against this background, the endeavor for building new data and indicators will consist mainly in extracting more and new information from the existing stock of data"[178]. This meant measuring new dimensions of science, technology and innovation using links between existing data rather than by producing new data, linking of existing data being far less expensive than developing brand-new surveys[179].

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177 OECD (1996), Conference on New Science and Technology Indicators for a Knowledge-Based Economy: Background Document, *op. cit.*, p. 2.

178 OECD (1996), *New Indicators for the Knowledge-Based Economy: Proposals for Future Work*, DSTI/STP/NESTI/GSS/TIP (96) 6, p. 4.

179 See OECD (1996), Conference on New Science and Technology Indicators for a Knowledge-Based Economy: Summary Record of the Conference Held on 19-21 June 1996, *op. cit.*; OECD (1996), New Indicators for the Knowledge-Based Economy: Proposals for Future Work, *op. cit.*

AN UMBRELLA-CONCEPT

Did the new indicators measure up to their promise[180]? The question can be answered by comparing the output to the recommendations of the promoters of the knowledge-based economy concept, among them the OECD itself, or by analyzing the definition and dimensions of the concept and measuring these dimensions. On the first comparison, it seems clear that everyone was dissatisfied with the existing indicators and early in the process suggested new measurements:

K. Smith[181]

- Inter-industry transactions embodying flows of technological knowledge,
- Patterns of use of formal scientific knowledge,
- Patterns of technological collaboration between firms, universities and research institutions,
- Measures of personnel mobility and related interactions.

D. Foray[182]

- Basic attributes of the knowledge base,
- Systems and mechanisms for transferring knowledge,
- Effectiveness of the knowledge base.

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180 For an overview of the results of the expert group (NESTI) program, see the special issue of *STI Review*, 27, 2002.

181 K. Smith (1995), Interactions in Knowledge Systems: Foundations, Policy Implications and Empirical Methods, *op. cit*.

182 D. Foray (2000), Characterizing the Knowledge Base: Available and Missing Indicators, in OECD, *Knowledge Management in the Learning Society*, Paris, p. 239-257.

OECD[183]

- Knowledge stocks and flows,
- Knowledge rates of return,
- Knowledge networks,
- Knowledge and learning.

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183 OECD (1996), The Knowledge-Based Economy, in OECD, Science, Technology, and Industry Outlook, *op. cit*.

On the other hand, from an analysis of the OECD scoreboards of indicators, one must conclude that the knowledge-based economy is above all a label. Most if not all of the indicators collected are indicators that the OECD had already been measuring for years or even decades, or are variations on old indicators that had suddenly become subsumed under the concept of the knowledge-based economy[184]. The documents simply aligned an existing series of indicators and fact-sheets under a new umbrella – the knowledge-based economy. In 1999, only nine of the thirty-two indicators were specifically located and analyzed under the concept – although the document as a whole was called *The Knowledge-Based Economy*. By 2001, there were twenty-five. In fact, a simple reorganization of categories (turning indicators from the 1999 category "science and technology policies", as well as some from the "output and impact" category, into the "creation and diffusion of knowledge" category) was responsible for the increase. All 59 indicators from the scoreboard, however, were now analyzed in the introductory text as measuring the knowledge-based economy.

If we now look at the OECD definition of knowledge-based economies ("economies which are directly based on the production, distribution and use of knowledge and information"), we would expect to find indicators on the production as well as the distribution and diffusion of knowledge. And indeed, several indicators dealt with the production side of knowledge, as has always been the case with science and technology indicators (R&D, human resources, patents). But the few that concern distribution and diffusion either concentrated on information and communication technologies, or were still measured using input and activity indicators rather than outputs and impacts. It is clear that the indicators draw on available

184 This is not peculiar to the OECD. Contrary to his claims, D. Foray did not totally succeed in distinguishing the traditional economics of R&D and innovation from the knowledge-based economy, at least with regard to the policy issues. See: D. Foray (2000), L'économie de la connaissance, *op. cit*.

data sets, and that the knowledge-based economy is above all a rhetorical concept.

In fact, a critical analysis of the concept reveals the following three rhetorical moves. Firstly, the concept is justified with the same arguments as those used for frameworks on the National Innovation System, the information society or the New Economy: knowledge and information and communication technologies are said to be important factors that bring about important changes in the economy. One finds here a network of concepts that feed at the same source and which reinforce each other. Secondly, the content of the concept is composed of a synthesis or collection of recent ideas in the field of science and technology studies. Like the National Innovation System literature that brought together the latest ideas on tacit learning, learning-by-doing, user-producer interactions, diffusion of technologies, clusters and networks, the concept of the knowledge-based economy collected fashionable ideas from new growth theories, the National Innovation System and the information society. Thirdly, the two previous moves combine to make the concept an umbrella concept: the knowledge-based economy is a term that now covers statistics in all areas of science and technology, broadly defined – R&D, information and communication technologies, education, etc. Therefore, it is very fertile "theoretically" and empirically, and can be used for any issues in science and technology – and anywhere: titles of whole reports; chapters or introductory sections; lists of indicators; and … policies.

How can we explain this situation? How do we explain organizing and packaging the previous material into a conceptual framework with buzzwords and slogans as labels? Do we really need such fuzzy concepts as the knowledge-based economy? The pervasiveness and popularity of such concepts at the OECD is due to two institutional factors. First, frameworks are linked to the political process of the organization. A large part of the work of the OECD is for presentation to ministerial conferences. The Secretariat has to feed ministers regularly for their meetings, which meetings in turn ask for more studies. Using narratives and popular labels, the Secretariat succeeds in influencing the political agenda, at least on paper (G-7 *communiqués*, national white papers and policy-makers' discourses). The second institutional aspect of the production of frameworks at OECD is the publication process. The organization publishes reports by the hundred every year, many of a periodic nature. Again, labels are very fertile intellectually for their broadness or fuzziness, and because they are fashionable.

Numbers, figures and graphs are also used liberally in frameworks to facilitate reading. However, at several places in its documents, the OECD recognized that its indicators were "not adequate to describe the dynamic system of knowledge development and acquisition"[185]. But they probably appeared sufficiently "objective", simply because they were quantitative, to draw the attention of policy-makers, politicians and the general public to matters of science, technology and innovation.

It remains that the concept of the knowledge-based economy is actually a rhetorical concept. Certainly, important methodological difficulties await anyone interested in measuring intangibles like knowledge. But the objective of a policy organization is not, above all, accuracy, but influence. As Foray and Lundvall once suggested: "One function of the notion of the knowledge-based economy is to attract the attention of statisticians and other experts in the field of social and economic indicators"[186].

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185 OECD (1995), The Implications of the Knowledge-Based Economy for Future Science and Technology Policies, *op. cit.* p. 6.

186 D. Foray and B.-A. Lundvall (1996), The Knowledge-Based Economy: From the Economics of Knowledge to the Learning Economy, in OECD, Employment and Growth in the Knowledge-Based Economy, *op. cit.* p. 18.

CONCLUSION

Machlup's study on the knowledge economy accomplished three tasks. It defined knowledge, measured it and identified policy issues. The message was that knowledge was an important component of the economy, but that it does not completely respond to an economic logic. With *The Production and Distribution of Knowledge*, Machlup brought the concept of knowledge into science policies and science studies. His conception of knowledge was synthesized from three intellectual trends of the time: "disintellectualizing" and "subjectivizing" knowledge (ordinary knowledge), looking at knowledge as a communication process (production and distribution), and measuring its contribution to the economy (in terms of accounting).

In the early 1980s, Machlup began updating his study on the knowledge economy with a projected ten-volume series titled *Knowledge: its Creation, Distribution, and Economic Significance*[1]. He died after finishing the third volume. By then, he was only one of many people measuring the knowledge or information economy. With this new project, Machlup kept to his original method as developed in 1962: national accounting. This was a deliberate choice. In fact, there were two types of accounting measurement in the economic literature of the time. One was growth accounting. It used econometrics, and was the cherished method among quantitative economists. With the aid of equations and statistical correlations, economists tried to measure the role of knowledge in economic growth, following in Solow's footsteps. Machlup did not believe in this method. The second method was national accounting. This method was not very attractive to economists – although developed by one of them (S. Kuznets). It relied on descriptive statistics rather than formalization. Its bad reputation and the reluctance of economists to use national accounting have a long tradition, going

1 F. Machlup (1980-84), *Knowledge: its Creation, Distribution, and Economic Significance*, Princeton: Princeton University Press.

back to the arguments of 18th century classical economists against political arithmetic[2]. It was a similar reluctance that economist R. R. Nelson expressed while reviewing Machlup's book in *Science* in 1963. Nelson expressed his disappointment that Machlup had not studied the role and function of knowledge: "Machlup is concerned principally with identifying and quantifying the inputs and outputs of the knowledge-producing parts of the economy and only secondarily with analyzing the function of knowledge and information in the economic system"[3].

Today, the measurement of knowledge is often of a third kind. Certainly, knowledge is still, most of the time, defined as Machlup suggested (creation and use) – although the term has also become a buzzword for any writing and discourse on science, technology and education. But in the official literature, knowledge is actually measured using indicators. Such measurements are to be found in publications from the OECD and the European Union, for example. Here, knowledge is measured using a series or list of indicators gathered under the umbrella of "knowledge"[4]. There is no summation (or composite value), as in accounting, but a collection of available statistics on several dimensions of knowledge, that is, science and technology, among them that on information technologies.

The methodology of indicators for measuring knowledge, information or simply science, comes partly from Machlup. We have seen how Machlup complemented his accounting exercise with discussions on various sorts of statistics, among them statistics on R&D organized into an input-output framework. In 1965, the British economist C. Freeman, as consultant to the OECD, would suggest

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2 K. Johannisson (1990), Society in Numbers: the Debate over Quantification in 18th Century Political Economy, in T. Frangsmyr et al. (eds.), *The Quantifying Spirit in the Eighteenth Century*, Berkeley: University of California Press, p. 343-361.

3 R. R. Nelson (1963), Role of Knowledge in Economic Growth, *Science*, 140 (3566), May 3, p. 473-474.

4 B. Godin (2006), The Knowledge-Based Economy: Conceptual Framework or Buzzword?, *op. cit*.

such a collection of indicators to the organization[5]. In the 1970s, the National Science Foundation initiated such a series, titled *Science Indicators*, which collected multiple statistics for measuring science and technology. To statistics on input, among them money devoted to R&D, the organization added statistics on output like papers, citations, patents, high technology products, etc. The rationale behind the collection of indicators was precisely that identified by Machlup as a policy issue: the "productiveness", or efficiency of the research system[6].

The knowledge-based economy is an umbrella concept: it allows one to gather existing ideas and concepts on science, technology and innovation, and any related indicators, into a conceptual framework, i.e.: all under one roof. This is a fertile strategy for rapidly producing new papers and discourses, and alerting policy-makers to new trends. But what impact has the concept had in recent history? There are two areas of possible influence to be explored.

The first is policy. The concept has probably helped to sustain, or at the very least give increased visibility to, science, technology and innovation policies. In a context of budget constraints, and after a

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5 C. Freeman and A. Young (1965), *The Research and Development Effort in Western Europe, North America and the Soviet Union: An Experimental International Comparison of Research Expenditures and Manpower in 1962*, Paris: OECD.

6 National Science Board (1973), *Science Indicators 1972*, Washington: National Science Foundation, p. iii.

decade of haphazard trends in R&D investments, buzzwords such as the knowledge-based economy helped re-launch discourses on science, technology and innovation. Several recent new science and technology policies now include the concept[1].

The second area of possible impact is statistics. To date, however, the concept of the knowledge-based economy has had a very limited impact on statistics. Traditional statistics and indicators, based on input and activity data sets, still dominate the measurement of science, technology and innovation, and above all the concept of the knowledge-based economy. Certainly there have been some efforts in new fields (i.e.: mobility of personnel) – although none really fruitful yet – but there has been far less effort on the central and new characteristics of the supposed knowledge-based economy, like tacit knowledge. The major innovation remains simply the collection of several indicators from different sources under a new label.

[1] See, for example: European Commission (2000), *Innovation in a Knowledge-Driven Economy*, COM (2000) 567; Commisariat du Plan (2002), *La France dans l'économie du savoir: pour une dynamique collective*, groupe de travail Vignier, Paris; Government of Canada (2002), *Canada's Innovation Strategy, I. Knowledge Matters: Skills and Learning for Canadians; II. Achieving Excellence: Investing in People, Knowledge and Opportunity*, Ottawa: Industry Canada.

CHAPTER NINE

THE INFORMATION ECONOMY: THE HISTORY OF A FRAMEWORK THROUGH ITS MEASUREMENT

For over fifty years, information and communication technologies have been everywhere in the literature, explaining changes in society and giving rise to many terms and buzzwords like the information economy[1]. Echoing early works, the OECD, in an influential study conducted in the 1960s, concluded that “the computer can be considered as the key to the second industrial revolution, just as the steam engine was the center of the first industrial revolution”. To the OECD, “the strategic significance of the computer is partly due to the fact that information is the key to management”[2]. More recently, the organization has used new concepts and frameworks to explain changes in the economy: the new economy, the knowledge-based economy and the information society. All of these changes are explained, partly or wholly, by information technology. How did we get there? How did information and its technologies acquire such a central role in public discourses?

This chapter documents the recent history of the concept of information and its framework through the lens of statistics. Many concepts depend on statistics for their definition. Such is the case for

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1 J. R. Beniger (1986), The Control Revolution: Technological and Economic Origins of the Information Society, Cambridge (Mass.): Harvard University Press.

2 OECD (1969), Gaps in Technology: Electronic Computers, Paris, p. 26-27.

productivity[3]. We cannot discuss productivity without statistics and ratios, or at least a minimal idea of quantities. Information is different. It is not a concept of a quantitative nature. However, it is amenable to (imperfect) quantification, like many other concepts. In such a case, statistics often proves influential in focusing or crystallizing the attention of people on specific dimensions of the reality or phenomenon, and not on others.

In this chapter, I analyze official statistics and the role they play in official narratives on the information economy. The chapter looks at the measurement of information at the OECD from 1949 to 2005. In 1949, W. Schramm edited a much-quoted book of papers by C. E. Shannon and W. Weaver on communication theory[4], but that year also corresponds to the entry of the OECD into the field. As an early promoter of national science policy and as a think tank to its Member countries, the OECD is an ideal test case for understanding the way governments think about information. National delegates bring their ideas to the organization which, in turn, produces working papers and policy recommendations that feed national policy-makers.

The thesis of this chapter is that, over the past fifty years, the concept of information developed in three stages (Table 16). The first was characterized by information as knowledge. In the 1950s and after, scientists and governments became preoccupied with information growth and "explosion". There was, so they argued, an explosion of literature, as measured by librarians and by historian D. J. D. Price. The computer was seen as the solution, but too-rapid development could complicate its use because of system incompatibility, thus the need for management of information and for appropriate technological systems to process it. Information-as-knowledge

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3 B. Godin (2006), The Value of Science: Changing Conceptions of Scientific Productivity, 1869-circa 1970, Communication presented to the international conference "The Future of Science, Technology and Innovation Policy: Linking Research and Practice", SPRU, Brighton, Great Britain, September 11-13.

4 C. E. Shannon and W. Weaver (1949), Mathematical Theory of Communication, Urbana: University of Illinois Press.

carried a “restricted” definition of information: information was limited to scientific and technological information – although transfer to non-scientists, namely industry, was often the main objective of early policies. The statistics developed reflected this choice: information was measured as documentation.

This conception of information was followed by a second one: information as commodity or economic activity. Such a conception was developed by American economists F. Machlup and M. U. Porat, and became very popular in the late 1970s and early 1980s. What preoccupied policy-makers was structural change in the economy, namely the transition from a manufacturing economy to a service or information economy, and “information gaps” between countries. Information came to be defined very broadly. It included just about anything that was intangible. The statistics developed to measure information relied on the national accounts: aggregating expenditures for certain industrial activities to produce an information field or category.

Table 16. Evolving OECD Conceptions of Information

Information as knowledge
Emblematic authors: Bernal and Price
Issue: information explosion
Restricted definition: scientific and technological information
Statistics: documentation
Information as economic activity (or commodity)
Emblematic authors: Machlup and Porat
Issue: structural change
Broad definition: information goods and services (industries)
Statistics: accounting
Information as technology
Emblematic authors: Freeman and Miles
Issue: technological revolution
Restricted definition: (information and communication) technologies
Statistics: applications and uses

More recently, a third conception of information emerged: information as technology. Many analysts came to view information technologies, because of their widespread effects on the economy, as bringing forth a new techno-economic paradigm or technological revolution. The key issue was no longer identifying the sector producing the technologies, but rather mapping the applications of information technologies and their uses. The concept of information was thereafter restricted, at least in official circles, to what came to be called “information and communication technologies”, and measurements emphasized the diffusion and use of these technologies. C. Freeman and I. Miles, from SPRU, were influential in this reorientation of the concept of information. From the 1990s onward, the OECD turned entirely to such an approach to information.

This chapter argues that the interest in the information economy, contrary to what most authors who have studied the phenomenon have stated, predates the literature that uses the concept. Information was the concern of science policy (scientific and technical documentation) before it became a matter of economic policy (industries responsible for information goods and services) and then technology policy (promotion of information and communication technologies). The preoccupation with the growth and management of scientific publications was the very first step toward the construction of the concept of the information economy. This chapter also argues that the history of the concept is intimately linked to its measurement. At all three stages, the OECD and its member countries developed and initiated projects on a methodological manual to crystallize the meaning of the concept of information and standardize its measurement. The efforts failed until very recently, namely until information came to be identified with technology. A large part of this chapter analyzes the history of these projects, and looks at the factors – conceptual, methodological and political – behind the experiences.

THE ECONOMICS OF INFORMATION

The OECD's concern with information goes back to 1949 when the OEEC) – the predecessor of the OECD – set up a working party on scientific and technical information (Working Party no. 3). According to A. King, head of the working party (and first head of the Directorate for Scientific Affairs at OECD), studying scientific and technical information was the means to get science policy considerations into the organization, an organization not very oriented toward science at the time[5]. Science policies did not yet exist, and there was reluctance to look at a "cultural" good (science) from an economic point of view. Over its few years of existence, the

5 A. King (1992), The Productivity Movement in Post-War Europe, mimeo, p. 5-6.

working party was concerned mainly with productivity, but it also dealt with the exchange of scientific and technical information between countries, particularly from the USSR to Western Europe and the United States, and set up a network of national centers for scientific and technical information. After two years, a Committee on Scientific and Technical Matters was finally set up that continued this work, and others. However, it was left to the European Productivity Agency, a body of the OEEC created in 1953, to conduct the first study on scientific and technical information. In 1955, under the coordination of the British Central Office of Information, the Agency conducted an international survey on the use made of scientific and technical information by more than 2,000 small and medium firms in five industries[6]. Although the literature was the main method identified for keeping abreast of information, the study found that contact with suppliers was the primary source for solutions to industrial problems.

Then in 1961 the OECD was created, with a mandate focused on policies. Whereas its predecessor organization had operational responsibilities, the new organization was oriented toward helping member countries establish policies in many fields, among them science, technology and innovation. A Directorate for Scientific Affairs was set up, supported by committees composed of national delegates. It was in this Directorate that information policies came to be discussed, first of all at the Committee for Scientific Research.

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6 EPA (1958), Technical Information and the Smaller Firm: Facts and Figures on Practices in European and American Industry, Paris; EPA (1959), Technical Information and Small and Medium Sized Firms: Methods Available in Europe and the United States, Numbers and Facts, Paris. The survey was followed by another one in 1960 concerned with suppliers of information: EPA (1960), Technical Services to the Smaller Firm by Basic Suppliers: Case Studies of European and American Industry, Paris.

The Ad Hoc Group on Scientific and Technical Information (1962)

In 1962, the OECD Committee for Scientific Research produced the first reflections of the organization on scientific and technical information policy[7]. Echoing work conducted elsewhere in the Directorate for Scientific Affairs on research[8] and on education[9], the document looked at information from an economic point of view: information as an economic asset. To the Committee, economic growth depended on scientific research and "the effective and rapid transmission of research results". The exchange of scientific and technical information concerned scientists themselves, but also transfers to the general public, which "is still not sufficiently science-conscious", and to industry. Scientists, the public and industry were thus identified as the three targets of an information policy, particularly industry: "The constant growth of scientific knowledge demands a closer liaison between science and industry than ever before. Information is the pipeline through which discoveries and facts reach the technologist and engineer, as well as managers and skilled workers"[10].

To the committee, the problem of scientific and technical information was the vast volume and dispersion of scientific and technical output, hence the increasing need for fast and reliable abstracting and indexing services, and networks of communication centers. However, "the task of coping with the increasing volume and complexity of material is too great to be handled efficiently by individual countries. Therefore, the OECD needs to encourage and stimulate coordination

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7 OECD (1962), The Function of OECD in the Field of Scientific and Technical Information, SR(62)25.

8 OECD (1962), Economics of Research and Development, SR(62)15.

9 OEEC (1960), Investment in Education and Economic Growth, Paris; OECD (1962), Policy Conference on Economic Growth and Investment in Education, Paris.

10 *Ibid.*, p. 3.

among Member countries"[11]. To this end, the Committee recommended the creation of an *ad hoc* group on scientific and technical information.

The main task of the group, over the first years of its existence, was conducting reviews of information centers, facilities and exchanges in industrial sectors like ceramics and glass, shipbuilding, fuel and heat processes, textiles, pharmaceuticals, electronics and electrical engineering[12]. Then, in 1965, a more policy-oriented approach was suggested. "Most of the attention devoted by governments, or by national or international organizations to the problems of scientific and technical information has been detailed and piecemeal"[13], commented the Committee for Scientific Research. The OECD itself had worked mainly on information for industry, with its sectoral reviews of facilities. Until then, "a scientific and technical information policy [was understood as] directed towards bridging the gap between science and industry"[14]. Now, the OECD was suggesting a "breath of approach": the organization should concentrate on the study of national information systems, and its links to science and economic policies[15]. Information policy was defined as including "any aspect of government intervention in the management of national scientific and technical information matters"[16].

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11 *Ibid.*, p. 5.

12 OECD (1964), Sectoral Reviews of Scientific and Technical Information Facilities: Policy Note, SR(64)38.

13 OECD (1965), Ad Hoc Group for Scientific and Technical Information Policy, SR (65) 51, p. 2.

14 OECD (1962), The Function of OECD in the Field of Scientific and Technical Information, op. cit., p. 2.

15 OECD (1965), Sectoral Review of Scientific and Technical Information, SR(65)15.

16 OECD (1966), Résumé of the Principal Action Resulting from the London Meeting, Held on 21st and 22nd March, 1966, DAS/CSI/66.74. See also: OECD (1966), Scientific and Technical Information and the Policies of Governments: Revised Synopsis, DAS/CSI/66.298, p. 4.

The Ad Hoc Group on Information Policy (1965)

At the suggestion of the American delegate, the Committee for Scientific Research created an *ad hoc* group on scientific and technical information policy. To the OECD, "scientific and technical information plays an integral part not only in the conduct of research and development but also in their application, as a factor in the innovation process. The significance of this is, of course, widely realized and many countries are already paying special attention to improving the flow of information However, the magnitude of the costs involved raises important problems for government"[17].

To the OECD, the problem with scientific and technical information was twofold. First, there was what the organization called the information explosion (other terms used were information deluge, information confusion, and information chaos) (Table 17). To the OECD, "the number of scientists and the amount they publish are increasing dramatically. More than 50,000 scientific journals are published regularly, containing more than a million scientific articles (...). The situation is complicated further by the presence of an unknown but increasing (and increasingly important) number of unpublished reports (...). Hence the problem: to tame and organize this growing mass of words and paper into a form that facilitates the transfer of the information"[18].

Table 17. OECD Vocabulary

Computer Revolution	Information Deluge	Information Economy
Information Age	Information Explosion	Information Society
Information Gaps	Information Chaos	Network Society
Awareness Gap	Information Confusion	Digital Economy
	Information Pollution	

17 OECD (1965), Ad Hoc Group for Scientific and Technical Information Policy, op. cit., p. 2.

18 OECD (1966), Scientific and Technical Information and the Policies of Governments: Revised Synopsis, op. cit., p. 2.

The second part of the problem with information was technologies. Although “the computer provides the only possible means of bringing order out of the information chaos”[19], the proliferation of information systems suggested the danger of an uncoordinated development: “A variety of local and national services have sprung up in particular fields to solve particular tactical problems (...)[20]. However, “the uneven development of the new systems in different countries is leading to a potential information gap”[21]. Therefore, “the development of a coherent system and a strategy is needed, and only governments have the breadth of responsibility and resources to attempt this”[22]. The OECD thus called for the development of national information policies where, “in each Member country, there should be one [and only one] office charged with the overall responsibility” of coordinating information development nationally[23]. For its part, the OECD should provide members with an “international mechanism to promote co-ordination and agreement in establishing comprehensive and compatible information systems”.

Briefly stated, the rhetoric on scientific and technical information at the OECD was threefold: 1) there is an information explosion; 2) new technologies can help bring order; 3) but there is need for a common approach (system compatibility and standards) and a single body in

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19 OECD (1967), Scientific and Technical Information Systems and Policies, DAS/SPR/67.109, p. 7.

20 OECD (1966), Scientific and Technical Information and the Policies of Governments: Revised Synopsis, op. cit., p. 2.

21 OECD (1967), Scientific and Technical Information Systems and Policies, op. cit., p. 2.

22 OECD (1966), Scientific and Technical Information and the Policies of Governments: Revised Synopsis, op. cit., p. 2.

23 *Ibid.*, p. 5. This recommendation would be reiterated at the third ministerial meeting on science in 1968.

member countries for national policy. “Failure to take such a co-ordinating action, besides the certainty of wasteful duplication of resources, will mean increased costs, reduced efficiency, delayed application and, above all, information gaps”[24].

The first step toward an OECD program of work was collecting information on international organizations active in the field, [25] and the different national systems of scientific and technical information, with indications on the flow of funds and sums of money[26]. Reviews of national information policies were also initiated[27]. The next step was developing statistics for policy-makers.

The Economics of Information Panel (1965)

During its very first meeting in 1965, the *ad hoc* group decided to set up a panel of experts on the economics of information[28]. The group argued that data in the field were at present notoriously deficient, among them those on the inventory of national information facilities, their cost and their effectiveness. Already in 1963, the national delegates to the Committee for Scientific Research asked for a study on money devoted to scientific and technical information[29], to be conducted in close liaison with the research and development (R&D) survey, as conventionalized in the OECD methodological manual

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24 OECD (1967), Scientific and Technical Information Systems and Policies, op. cit., p. 12.

25 OECD (1965), Information Activities of Some Major International Organizations, SR(65)52.

26 OECD (1966), Organigrammes des systèmes nationaux d’information, DAS/CSI/66.81.

27 Canada (1970), Ireland (1972), Switzerland (1973), Spain (1973), Germany (1975).

28 OECD (1966), The Economics of Information, DAS/CSI/66.173.

29 OECD (1963), Minutes of the 7th Session, SR/M (63) 2. Once finalized, the survey would be transferred to the statistical division of the Directorate for Scientific Affairs, and its results would provide a chapter in the biennial report on R&D.

known as the Frascati manual. Now, such economic studies were judged essential “for the efficient allocation of the national information budget”. “The task given to [the Economics of Information] panel is to provide, for these people (especially in government) who have to take decisions in the field of information, the economic elements which should form an important part of the bases for these decisions”[30]. A plan of action was drafted in 1966[31], centered around two main components: 1) identifying the processes by which information is transferred from research to users and measuring cost and effectiveness, and 2) developing standards on data to be collected. To the OECD, the unit of information for measurement was defined as “a scientific article, an abstract or a report”, and the studies’ suggested coverage include all sectors of the economy: government, higher education, industry and non profit.

The Secretariat recommended that governments give high priority to the task of measuring scientific and technical information and offered proposals for a specific survey “to supply governments with a solid statistical foundation on which to build their national policy”[32]. Until then, “several countries had expressed reluctance to make available figures of national expenditure on information, because of the lack of accepted definitions”[33]. As a consequence, a model survey was sketched out with the aim of complementing “the data obtained by means of the R&D survey. The purpose was to show the relationship between research costs and information costs and served as a basis

30 OECD (1967), Scientific and Technical Information Policy Group: Summary Record of the 7th Meeting Held in Paris on 26th and 37th June, 1967, RC (67) 15, p. 15.

31 OECD (1966), Plan of Action, DAS/CSI/66.209.

32 OECD (1968), Survey of Scientific and Technical Information Activities, DAS/SPR/68.35, p. 2.

33 OECD (1967), Scientific and Technical Information Policy Group: Summary Record of the 7th Meeting Held in Paris on 26th and 27th June, 1967, RC (67) 15, p. 5.

for a study of cost/effectiveness ratios of information facilities". Data to be collected were[34]:

- Total resources allocated to scientific and technical information.
- Allocation of resources by economic sector (business, government, non-profit and higher education).
- Distribution of resources by type of activity: publication and distribution, information and documentation services, symposia and audio-visual media, R&D in information.
- Services: function, resources, equipment and staff.
- Manpower employed by major professional category.

To conduct this work, two studies were contracted. One was to H. Paschen from the Heidelberg Studiengruppe fur Systemsforschung to measure the resources devoted to scientific and technical information (manpower and money), based on the model for R&D (Frascati manual), and another was to J. Wolfe from Edinburgh University on cost/effectiveness ratios of information services.

The task proved difficult. After two years of work, the OECD concluded that the compilation of data on manpower and money devoted to scientific and technical information had been harder than originally imagined: there was little experience for guidance, the field was vast, the transfer of information followed diverse routes, services were extremely diversified and therefore difficult to locate and classify, few countries (except the United States) possessed agencies which could provide information. Several national delegates criticized the first draft of a questionnaire (produced by the German Studiengruppe) because it seemed to them too detailed, answers difficult to find, and it was "not certain how far these would have a

[34] OECD (1968), Survey on Scientific and Technical Information Activities, op. cit., p.5.

direct bearing on government decisions"[35]. The Information Policy Group also "expressed its anxiety that progress seemed to be slow in the two studies, and that the Studiengruppe questionnaire seemed complex to the point that it might be difficult to apply in practice"[36].

The panel on the economics of information thus suggested a limited list of basic data for collection (see Appendix 7)[37]. The Information Policy Group decided to continue with the cost/efficiency ratio study of Wolfe[38], but gave priority to a methodological manual and recommended that some countries test the methodology[39]. The manual was finalized in 1969[40]. It proposed a definition of scientific and technical information as R&D output and their applications, and defined scientific and technical information activities as "those involved in the transfer of scientific and technical information to the users". They include "all management, administrative, and operational efforts directed to the planning, support, control, performance, and improvement of the functions or tasks which deal with the processing, handling and communication of scientific and technical information". Having defined scientific and technical information and its activities, the manual identified four specific classes of scientific and technical information activities: 1) recording, 2) editing, revising, translating, etc. 3) distribution (including conferences), 4) collection, storage and processing, and

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[35] OECD (1968), Scientific and Technical Information Policy Group: Summary Record of the 9th Meeting Held in Paris on 17th and 18th July, 1968, RC(68)15, p. 16.

[36] OECD (1968), Scientific and Technical Information Policy Group: Summary Record of the 9th Meeting, RC (68) 15, p. 6.

[37] OECD (1969), Information Statistics and Policy: The Next Steps, DAS/STINFO/69.10.

[38] Finalized in 1971. See: J. Wolfe (1971), The Economics of Technical Information Systems: A Study in Cost-Effectiveness, DAS/STINFO/71.17.

[39] OECD (1969), Economics of Information Progress Report and Plan for Future Action, DAS/STINFO/69.25.

[40] OECD (1969), Proposed Standard Practice for Surveys of Scientific and Technical Information Activities, DAS/STINFO/69.9.

5) acquisition. The manual recommended surveying institutions involved in activity 4 (Table 18). Finally, the manual proposed classifications for money and manpower involved in these activities (breakdown by economic sector[41], discipline, aim or function, institution size, information system used and type of user), methodological guidelines and model questionnaires.

The manual was tested in several countries, and vehemently criticized at a meeting held in Oslo in 1971[42]. The manual was qualified as too complicated and too clumsy and not providing governments with basic statistical data to formulate a scientific and technical information policy[43]. In fact, many countries preferred to go with their own version of a questionnaire. The Scientific and Technical Information Policy Group concluded on the "lack of realism of the methodology proposed. An overall approach similar to that of the R&D surveys is practically unattainable", but the methodology serves only as a starting point[44].

Table 18. Transfer Institutions to be Surveyed According to the OECD Draft Manual on Scientific and Technical Information

Library
- General
- Special
- Technical

Document Center

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41 With regard to the industrial sector, it was suggested excluding radio and television because "little scientific and technical information is transferred". Despite the recommendation, this industry would be included in the measurements of the 1970s.

42 OECD (1972), Notes on the Meeting of Countries Collecting Statistics on Resources Devoted to STI, DAS/STINFO/72.22.

43 OECD (1973), Collection of Statistical Data on STI, DAS/SPR/73.94; OECD (1973), Economics of Information: Summary Record of an ad hoc meeting held in Paris on 5th and 6th November, 1973, DAS/STINFO/73.18.

44 OECD (1972), Notes on the Meeting of Countries Collecting Statistics on Resources Devoted to STI, op. cit., p. 6.

Archives
Abstract Service
Technical Information Center
Information Evaluation Center
Data Center
Referral Center
Clearinghouse

By 1973, the panel on the economics of information itself concluded that the draft manual was “only an example: it should be modified for use, in the light of national needs”. It also added that data on manpower and money alone are insufficient. Other indicators should be identified and defined[45]. “Before fixing on a methodology, it is necessary to identify the essential data and to define the indicators that are needed”[46]. A steering group was thus created in 1974 to “identify the minimum data needed by countries to manage their information policies”[47] and a first meeting was held in October of that year[48]. A list of elementary statistics, some of them already collected in member countries, was drawn up covering financial resources, manpower, information produced and used, computers and communications, and users (see Appendix 8).

In the end, the two instruments – the methodological manual and the list of indicators –never were used to measure scientific and technical information at the OECD[49]. Two factors explained the organization’s

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45 OECD (1973), Economics of Information: Summary Record of an ad hoc meeting held in Paris on 5th and 6th November, 1973, op. cit.

46 *Ibid*., p. 3.

47 OECD (1974), Statistics, Time Series and Indicators for Scientific and Technical Information, DAS/STINFO/74.16.

48 OECD (1974), Steering Group on Indicators for STI: Summary Record of the first meeting of the Group Held on 24th and 25th October, 1974, DAS/STINFO/74.28.

49 A second manual was also envisaged on costs/effectiveness, but never developed. See: OECD (1975), STINFO: Summary Record of the 24th Meeting, DSTI/STINFO/75.19, p. 6; STINFO: Summary Record of the 25th Meeting, DSTI/STINFO/75.33, p. 7.

failure in measuring scientific and technical information. The first and most important was the absence of a conceptual framework to guide statisticians. Whereas other measurement exercises conducted in the Directorate were based on a framework that helped orient the collection of statistics, namely the highly-popular accounting framework[50], statistics on information at the OECD were entirely driven by a rhetoric on the information explosion. The rhetoric relied on findings like those of D. D. S. Price on the exponential growth of the literature on the topic[51], and the emerging literature on the growth of scientific publications[52], of which the British left-wing scientist J. D. Bernal was an active advocate of the management[53]. To Bernal, the system of scientific publications "was an enormous and chaotic

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50 The framework was already used at OECD in studies on R&D, where the surveys were aligned with the System of National Accounts by way of the Frascati manual, and studies on education, which relied on the then-new theory on human capital.

51 D. D. S. Price (1951), Quantitative Measures of the Development of Science, Archives internationales d'histoire des sciences, 5, p. 85-93; D. D. S. Price, (1956), The Exponential Curve of Science, Discovery, 17, p. 240-243; D. D. S. Price (1961), Science since Babylon, New Haven: Yale University Press; D. D. S. Price (1963), Little Science, Big Science, New York: Columbia University Press. In 1971, the OECD commissioned a study on forecasting growth in scientific and technical information (see G. Anderla (1973), Information in 1985: A Forecasting Study of Information Needs and Resources, Paris: OECD) which served as a basis for a workshop held in 1973, in which Price participated (see OECD (1974), Information in 1985: Notes on a Workshop Held in Paris, 101-12 December 1973, DAS/STINFO/74.2).

52 The first important conferences on the subject were: Royal Society (1948), The Royal Society Scientific Information Conference: Reports and Papers Submitted, London: Royal Society; National Academy of Sciences (1959), Proceedings of the International Conference on Scientific Information, Two volumes, Washington: National Academy of Sciences.

53 J. D. Bernal (1939) [1973], The Social Function of Science, Cambridge (Mass.): MIT Press, p. 292-308; J. D. Bernal (1948), Provisional Scheme for Central Distribution of Scientific Publications, in Royal Society, The Royal Society Information Conference, op. cit., p. 253-258.

structure”[54], and a centralized institute was much needed. To Price, science was “near a crisis” because of the proliferation and superabundance of literature[55], a monster as he called it[56]. “Some radically new technique must be evolved if publication is to continue as a useful contribution”[57]. The Information Policy Group listened, and flirted with the idea of a European clearinghouse as a single point of entry through which documents passed, discussed a network of referral centers and contracted studies on specialized information systems (physics, chemistry, medicine and social sciences). However, framed as it was, the issue was entirely concerned with science and scientists, not technology and innovation[58]. It was not enough to construct relevant and meaningful statistics for policies. Measuring the stock of information and its growth was only peripherally related to the needs of policy-makers…and those of an economic organization (the OECD).

The second factor at the origin of the failure was the fuzziness of the concept of information itself. To mathematicians and physicists[59],

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54 *Ibid*., p. 117. This is the first occurrence in the literature of the term chaos in this context.

55 D. D. S. Price (1961), Science since Babylon, op. cit., p. 124.

56 *Ibid*., p. 104.

57 D.D.S. Price (1956), The Exponential Curve of Science, op. cit., p. 524.

58 However, it gave rise to a literature on information flows in R&D and, later, technology transfer. Pioneering studies were: Bureau of Applied Social Research (1958), The Flow of Information Among Scientists: Problems, Opportunities, and Research Questions, report prepared for the National Science Foundation, Columbia University; T. J. Allen (1966), Performance of Information Channels in the Transfer of Technology, Industrial Management Review, 8, p. 87-98; D. G. Marquis and T. J. Allen (1966), Communication Patterns in Applied Technology, American Psychologist, 21, p. 1052-1060; T. J. Allen (1969), The Differential Performance of Information Channels in the Transfer of Technology, in W. H. Gruber and D. G. Marquis (eds.), Factors in the Transfer of Technology, Cambridge (Mass.): MIT Press, p. 137-154.

59 N. Wiener (1948), Cybernetics: Or Control and Communication in the Animal and Machine, Cambridge (Mass.): MIT Press; C. E. Shannon (1948), The Mathematical Theory of Communication, Bell System Technical Journal, 27 (3-4), p. 379-423; C. E. Shannon and W. Weaver

biologists[60] and economists[61], to name just a few disciplines, information means different things, and is often a metaphor. In his pioneering work titled *The Production and Distribution of Knowledge in the United States* (1962), F. Machlup tried to make sense of the concept and distinguished knowledge from information with the verb form: "to *inform* is an activity by which knowledge is

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(1949), The Mathematical Theory of Communication, op. cit.; N. Wiener (1950), The Human Use of Human Beings: Cybernetics and Society, Boston: Houghton Mifflin.

60 H. Quastler (1953), Essays on the Use of Information Theory in Biology, Urbana: University of Illinois Press; J. D. Watson and F. Crick (1953), Genetical Implications of the Structure of Deoxyribonucleic Acid, Nature, 171, p. 964-967. For a contemporary debate on information and biology, see the paper from J. Maynard Smith and comments from K. Sterelny, P. Godfrey-Smith, and S. Sarkar in *Philosophy of Science*, 67 (2) 2000, p. 177-218.

61 On information as knowledge in economics, see: F. Hayek (1937), Economics and Knowledge, Economica, 4, p. 33-54; F. Hayek (1945), The Use of Knowledge in Society, American Economic Review, 35 (4), p. 519-530; F. Hayek (1978), Competition as a Discovery Procedure, in New Studies in Philosophy, Politics, Economics and the History of Ideas, London: Routledge, p. 179-190; G. J. Stigler (1961), The Economics of Information, Journal of Political Economy, LXIX (3), p. 213-225; J. E. Stiglitz (1974), Information and Economic Analysis, in M. Parkin and A. R. Nobay (eds.), Current Economic Problems, Cambridge: Cambridge University Press, p. 27-52; J. E. Stiglitz (1985), Information and Economic Analysis: A Perspective, Economic Journal, 95, p. 21-41; K. J. Arrow (1962), Economic Welfare and the Allocation of Resources for Invention, in NBER, The Rate and Direction of Inventive Activity, Princeton: Princeton University Press, p. 609-625; K. J. Arrow (1973), Information and Economic Behavior, Lecture Given at the 1972 Nobel Prize Celebration, Stockholm: Federation of Swedish Industries; K. J. Arrow (1974), Limited Knowledge and Economic Analysis, American Economic Review, 64, p. 1-10; K. J. Arrow (1979), The Economics of Information, in M. L. Dertouzos and J. Moses (eds.), The Computer Age: A Twenty-Year View, Cambridge (Mass.): MIT Press, p. 306-317; K. E. Boulding (1966), The Economics of Knowledge and the Knowledge of Economics, American Economic Review, 56 (1-2), p. 1-13; J. Marschak (1968), Economics of Inquiring, Communicating, Deciding, American Economic Review, 58 (2), p. 1-18; J. Marschak (1974), Economic Information, Decision and Prediction, Dordrecht: Reidel.

conveyed; to *know* may be the result of having been informed"[62]. One is a process, an activity, while the other is a state, a result. But, added Machlup, "information as that which is being communicated becomes identical with knowledge in the sense of that which is known". Machlup therefore recommended, whenever possible, the use of the word knowledge[63]. However, his suggestion did not resolve the issue. In the following decades, every measurement exercise that followed in Machlup's footsteps used the terms information and knowledge interchangeably.

At the OECD, early measurements of information had two characteristics. First, information was limited to scientific and technical information, and second, information was measured as documentation. This was a rather restrictive definition compared to Machlup's five classes of information or knowledge: practical, intellectual, entertainment, spiritual and unwanted[64]. Defined as knowledge, the measurement of information included, to Machlup: education, R&D, media of communication (documentation, including audio-visual media), and information machines and services. Machlup's measurement was based on a policy-oriented framework, namely an accounting framework, using the System of National Accounts classes and data to estimate money and manpower devoted to information activities. This was a far cry from OECD work on scientific and technical information and its specific surveys. From 1969 on, there had been frequent suggestions from national delegates to redirect the then-current work of the OECD statisticians[65]. The

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62 F. Machlup (1962), The Production and Distribution of Knowledge in the United States, Princeton: Princeton University Press, p. 15.

63 *Ibid.*, p. 8.

64 *Ibid.*, p. 21-22.

65 OECD (1969), Draft Proposals for a Change in the Orientation of the Programme of the Working Panel on the Economics of Information, DAS/STINFO/69.27; OECD (1969), Proposed Developments in the Programme of the Working Panel on Management/Economics of Information, DAS/STINFO/69.45; OECD (1971), New Activities in Management and Economics of Information, DAS/STINFO/71.27.

malaise was only partly understood and only partly explicit, and the critics had little success.

The OECD was not alone in experiencing limited success in measuring scientific and technical information. UNESCO was another organization that left the field after some preliminary work. In its efforts to extend the range of science, technology and innovation indicators in order to better cover developing countries' activities, UNESCO drafted a methodological guide for measuring scientific and technical information and documentation (STID). The guide was tested in seven countries, and published in a provisional version in 1984[66]. It was based on a study written for UNESCO in 1979 by D. Murphy from the Irish National Science Council[67]. The guide defined scientific and technical information and documentation as "the collection, processing, storage and analysis of quantitative data concerning information activities (…)". 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. Three types of respondents were identified for surveying: 1) producers, 2) collectors, processors and disseminators, and 3) users. The first stage of measurement was to collect information on the second type of institutions only, namely:

- specialized libraries and centers;
- national libraries and libraries of higher education, referral centers;
- editing, publishing, printing, consulting and advisory services and enterprises.

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66 UNESCO (1984), Guide to Statistics on Scientific and Technological Information and Documentation (STID), ST-84/WS/18, Paris.

67 D. Murphy (1979), Statistics on Scientific and Technical Information and Documentation, PGI-79/WS/5, Paris: UNESCO.

In the end, UNESCO never did collect data on information. In fact, few countries were interested in these activities. Measuring R&D remained the priority. 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[68].

Both the OECD and UNESCO were preceded in their efforts by another organization, the US National Science Foundation. The Foundation, a pioneering agency in this field that produced work that greatly influenced the OECD[69], abandoned a similar methodology after twenty years of data collection. From its very beginning in the 1950s, the National Science Foundation conducted regular surveys of R&D, among them surveys on government research. The results were published in a document titled *Federal Funds for Science*[70]. R&D data included "other scientific activities" (later called related scientific activities), as did most surveys conducted at the time in other countries. But these activities were not separated from R&D activities. Then in 1958, the National Science Foundation published *Funds for Scientific Activities in the Federal Government*[71]. The

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

69 The ad hoc group on scientific and technical information (1962) was chaired by B. W. Adkinson from the National Science Foundation. The ad hoc group on information policy (1965) was created at the suggestion of the US delegate. The Foundation approach (definition and list of scientific and technical information activities) was adopted as a model by both the German Studiengruppe and the steering group on indicators.

70 National Science Foundation (1953), Federal Funds for Science, Government Printing Office: Washington.

71 National Science Foundation (1958), Funds for Scientific Activities in the Federal Government, Fiscal Years 1953 and 1954, NSF-58-14, Washington.

publication was, among other things, a re-analysis of the 1953-54 data. Scientific activities were presented as being broader than R&D alone, and were defined as the "creation of new knowledge, new applications of knowledge to useful purposes, or the furtherance of the creation of new knowledge or new applications" (no page number). The activities were broken down into seven classes, the first three, R&D, planning and administration, and plant defining R&D, and the last four, data collection, dissemination of scientific information, training, and testing and standardization defining "other scientific activities". It was estimated that "other scientific activities" accounted for $199 million, or 7.8% of all scientific activities. Of these, data collection was responsible for nearly 70%, and information 6.5%, but the latter was said to be greatly underestimated, by a factor of at least three.

Subsequent editions of *Federal Funds for Science* (renamed in 1964 as *Federal Funds for R&D and Other Scientific Activities*) included data on scientific and technical information, and, for a shorter period, general-purpose data collection. Over time, detailed sub-classes were developed for each of these categories, reaching a zenith in 1978 when scientific and technical information alone had four subclasses which were in turn subdivided into eleven other subclasses (Table 19)[72].

The National Science Foundation stopped collecting data on "other scientific activities" with the 1978 edition of Federal *Funds*. Why did organization abandon the measurement of scientific and technical information activities? The first reason has to do with the magnitude of the activities. Over the period 1958-1978, the surveys reported that information and data collection represented only about 1% to 2% of

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

federal government scientific activities. A survey of such a low volume of activities was not considered worth the effort[73].

Table 19. Scientific and Technical Information According to NSF (1978)

Publication and distribution	
	Primary publication
	Patent examination
	Secondary and tertiary publication
Support of publication	
Documentation, reference and information services	
	Library and reference
	Networking for libraries
Specialized information centers	
	Networking for specialized information centers
	Translations
Symposia and audiovisual media	
	Symposia
	Audiovisual media
R&D in information sciences	

It was not worth the effort considering that, secondly, the National Science Foundation began publishing *Science Indicators (SI)* in 1973[74]. Everyone applauded the publication, including Congress and the press. Among the indicators that soon appeared in *SI* for measuring science, technology and innovation were what were considered to be good statistics on scientific information – at least as far as the United States was concerned: counting publications (bibliometric indicators). The National Science Foundation's Division of Science Information had commissioned three studies "to develop and initiate a system of statistical indicators of scientific and technical communication". One dealt with measuring scientific and

73 A survey on scientific and technical information in industry was also planned as early as 1964 but was never, to the best of my knowledge, conducted. In 1961, however, the NSF conducted the first survey on publication practices in industry. See: NSF (1961), Publication of Basic Research Findings in Industry, 1957-59, NSF 61-62, Washington.

74 National Science Board (1973), Science Indicators: 1972, Washington: National Science Foundation.

technical information activities in the traditional sense (expenditures, products and services offered by libraries), plus some indicators on publications (growth of literature, citations)[75]. The other two focused on bibliometrics exclusively[76]. This last option prevailed at the National Science Foundation.

Such was the fate of the early measurements of information in public organizations. In the following decades, the measurement of scientific and technical information activities (manpower and money) in their survey of government R&D was limited to very few countries. Measuring information as documentation became the province of bibliometricians, whereas official statisticians were totally absent as producers of data, but were (reluctant) users. The revival of the measurement of information at the OECD was due to a factor external to the organization: an accounting framework developed by the American M. U. Porat from Stanford University.

THE INFORMATION ECONOMY

In 1977, Porat, in collaboration with M. R. Rubin, published a nine-volume study titled *The Information Economy* as part of work done for the US Department of Commerce and its Office of Telecommunications[77]. Porat took the information economy for

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75 King Research Inc. (1976), Statistical Indicators of Scientific and Technical Communication: 1960-1980, three volumes, Washington: National Science Foundation. Some of the statistics from the report were included in National Science Foundation (1977), Science and Engineering Indicators: 1976, Washington, p. 59-63.

76 F. Narin (1976), Evaluative Bibliometrics: The Use of Publications and Citation Analysis in the Evaluation of Scientific Activity, Report prepared for the National Science Foundation, New Jersey: Computer Horizons Inc.; National Federation of Abstracting and Indexing Services (1975), Science Literature Indicators Study, Report prepared for the National Science Foundation, Philadelphia: National Federation of Abstracting and Indexing Services.

77 M. U. Porat and M. R. Rubin (1977), The Information Economy, Office of Telecommunications, US Department of Commerce, Washington.

granted, and did not really develop a rationale for studying it. His aim was simply to measure it. Porat took for granted the fact that the United States has evolved "from an economy that is based primarily in manufacturing and industry to one that is based primarily in knowledge, communication and information"[78]. To Porat, the rationale for studying the information economy had already been offered by F. Machlup[79], D. Bell[80], and P. Drucker[81], and Porat acknowledged his debt to these authors: "Most of the basic insights and concepts motivating this study were established in Fritz Machlup's groundbreaking book on the knowledge industries. [Machlup] provides an empirical backdrop to subsequent work by Daniel Bell, Peter Drucker and others"[82].

To Porat, "information is data that have been organized and communicated. The information activity includes all the resources [capital and labor] consumed in producing, processing and distributing information goods and services"[83]. Defined as such, information covered all kinds of information, not only scientific and technical information: "The end product of all information service markets is knowledge. An information market enables the consumer to know something that was not known beforehand: to exchange a symbolic experience; to learn or relearn something; to change perception of cognition; to reduce uncertainty; to expand one's range of options; to exercise rational choice; to evaluate decisions; to control a process; to communicate an idea, a fact, or an opinion"[84].

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[78] M. U. Porat (1977), The Information Economy, volume 1, Office of Telecommunications, US Department of Commerce, Washington, p. 1.

[79] On Fritz Machlup, see: B. Godin (2007), The Knowledge Economy: Fritz Machlup's Construction of a Synthetic Concept, forthcoming.

[80] D. Bell (1973), The Coming of Post-Industrial Society: A Venture in Social Forecasting, New York: Basic Books.

[81] P. Drucker (1968), The Age of Discontinuity: Guidelines to Our Changing Society, New York: Harper and Row.

[82] M. U. Porat (1977), The Information Economy, op. cit., p. 44.

[83] *Ibid.*, p. 2.

[84] *Ibid.*, p. 22.

To Porat, measuring information was a difficult task, because information is not a sector *per se* but an activity: “Information is not a homogeneous good or service such as milk or iron ore. It is a collection or a bundle of many heterogeneous goods and services that together comprise an activity”[85]. To measure the information economy, Porat used an accounting framework, as first suggested by Machlup, aggregating different industrial classes into an information field. However, according to Porat, there existed significant methodological differences between Machlup’s approach and the one set forth in his work. Porat used value-added instead of final demand as indicator of the volume of information, and separated information into two sectors: primary (production) and secondary (consumption)[86].

Porat calculated two estimates, one for each sector, and added them to get a total value of information in the economy. The primary information sector was defined as being composed of eight broad categories of industries corresponding to many specific industrial classes[87], and was constructed from the System of National Accounts data and its derived input-output tables. Porat estimated that the information sector grew from around 18% of national income in 1929 to 25.1% in 1967[88]. He also estimated the information workers involved in this activity. Using a typology consisting of five broad classes of workers and constructed from occupational classes used by the US Bureau of Labor Statistics, Porat estimated that the information sector increased from less than 10% of all of the workforce in 1860 to over 40% in 1970, representing 53% of all labour income[89]. With regard to the secondary information sector (which included information services produced by non-information

85 *Ibid.*, p. 2.

86 *Ibid.*, p. 44. This kind of separation of activities in statistics was anticipated by Fritz Machlup. See F. Machlup (1962), The Production and Distribution of Knowledge in the United States, op. cit., p. VI.

87 *Ibid.*, p. 27-28.

88 *Ibid.*, p. 65.

89 *Ibid.*, p. 119.

firms and public organizations and consumed internally), Porat used the Bureau of Labor Statistics classification of occupations, computing that it amounted to 21% of GNP in 1967[90]. Overall, for the two sectors combined, the information economy amounted to 46% of GNP and 53% of labour income in the United States. These were the numbers that astonished the OECD bureaucrats.

The Working Party on Information, Computer, and Communications Policy (1976)

The concept of an information economy and its accounting provided the OECD with a solution to the recurrent problem of defining information and imagining a field of action. In fact, from 1969 on, several review groups were set up to formulate recommendations and to reorient the work of the organization toward what was called an integrated approach to information, namely looking at more horizontal issues like management, economics, legal aspects and education[91]. Progress was slow, and information lacked recognition within the Committee for Scientific Affairs[92].

Then, in February 1975, the OECD held a conference on Computers and Telecommunications Policy. The idea of a conference had been first proposed in 1973 to look at the development of computer and

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90 *Ibid.*, p. 154.

91 OECD (1971), Information for a Changing Society, Paris, known as the Piganiol report; OECD (1971), Report of the Ad Hoc Group on Information, Computer and Communication, SP(71)19, known as the Whitehead report; OECD (1973), Report of the Coordination of the Information Policy Group, the Computer Utilization Group, and Related Activities on Information, Computer, and Communication, SPT(73)6; OECD (1973), Information Technology: Some Policy Issues for Governments, SPT(73)7; OECD (1976), Task Force on Information, Computer and Communication Policy Programme, SPT(76)7; OECD (1976), First report of the Ad Hoc Group on Information, Computer, Communication Policy, SPT(76)25.

92 OECD (1972), STINFO: Summary Record of the 18th Meeting, DASA/STINFO/72.37; OECD (1975), A New Approach, DSTI/CUG/75.25, p. 15.

telecommunication technologies and their role (or promise) as a "key industry". The objectives of the conference were to understand the economic and social implications of new technologies, identify policies, and promote international cooperation[93]. The conference took notice of a structural transition from an industrial society to a post-industrial society with a strong service economy that is basically information-oriented. Such was the message from E. B. Parker from Stanford University in a communication to the conference that included a contribution from Porat[94]. To the OECD, such structural change in the economy required new tools for rational management, namely for the allocation of resources. But there was a lack of statistics and indicators to this end[95].

In order to participate in the new economy, the Secretariat thus suggested a new approach to work. It recommended a horizontal approach or framework to information[96]. Here, it meant defining more clearly the information sector and its contribution to GDP, trade and employment by way of accounting and input-output matrices, as Parker and Porat suggested. In 1976, the OECD Committee for Science and Technology Policy (or CSTP, formerly the Directorate for Scientific Affairs) thus created a Working Party on Information, Computer, and Communications Policy (ICCP)[97]. The Working Party integrated work conducted in different groups, among them the

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93 OECD (1973), Conference on Computers/Telecommunications Policies: Alternatives for Policy Makers, DAS/SPR/73.105.

94 E. B. Parker (1975), Social Implications of Computer/Telecommunications Systems, DSTI/CUG/75.1.

95 OECD (1975), Conference on Computers and Telecommunications Policy, SPT(75)3.

96 OECD (1975), Information, Computer, Telecommunications: A New Approach to Future Work, DSTI/STINFO/75.22.

97 OECD (1976), Draft Mandate of the ICCP Group, SPT(76)40; OECD (1977), Final Mandate of the Working Party on Information, Computer and Communications Policy, DSTI/ICCP/77.58.

Information Policy Group[98]. According to the then-director of the Directorate for Science, Technology and Industry, D. Beckler, "One of the objectives of this new body would be to define new interrelationships between the various components of this field", i.e.: develop an integrated approach[99]. The group started as a Working Party, and became a Committee in 1982[100].

The first thing the Working Party did was develop a project on the "information economy" (*sic*) titled *Macro-Economic Analysis of Information Activities and the Role of Electronic, Telecommunications and Related Technologies*, first sketched out in 1973. The aim of the project was to analyze and quantify information activities, assess their growth and innovation potential, and investigate their socio-economic consequences[101]. According to the Working Party, "the rapid development and diffusion of advances in electronics (micro-electronics, micro-processors, the computer-on-a-chip) and telecommunications (broadband cable, satellites, laser) and related physical technologies such as optical and video systems, are becoming of critical importance for the industrialized countries. Indeed, it is argued that these technologies are an emerging national

98 As well as the Computer Utilization Group, created in 1969, and a Panel on Information Technology and Urban Management. A Panel on Data Bank continued on its own for few more years.

99 OECD (1977), Draft Summary Record of the First Session, DSTI/ICCP/77.17, p. 2.

100 In 1978, the Secretariat General's budget proposal suggested elevating the status of the group to a Division in the Directorate for Science, Technology and Industry. See OECD (1978), Draft Summary Record of the Fourth Session, DSTI/ICCP/78.30, p. 3. Then, in 1980, the French delegate, supported by several countries, proposed that a committee be set up (on the "informatization of society"). See OECD (1980), High Level Conference on Information, Computer and Communication Policies for the 1980s, DSTI/ICCP/80.38, p. 34.). In 1981, the CSTP proposed elevating the Working Party to a Committee. The Working Party became a Committee on its own (no longer attached to the Committee on Science and Technology Policy) in 1982.

101 OECD (1977), Macro-Economic Analysis of Information Activities and the Role of Electronic, Telecommunications and Related Technologies, DSTI/ICCP/77.5.

resource and thus the basis for further economic and social development"[102]. Above all, "advanced information technologies promise to introduce productivity increases for most information goods and services and contribute to overall productivity of an economy"[103]. It was no longer the information explosion that guided the efforts of the OECD, but rather technologies and the "technological revolution".

The project proposed to identify and measure the consequences of the information sector on economic growth (productivity and value-added), changes in employment (transition from an industrial to an information society, automation, division of labour) and determine whether there was "concentration of these technologies and relevant industries within a few countries only"[104]. The general objective was to find empirical evidence for the emerging "information economy", and to suggest policies. To the OECD, technological policies would have to be "distinct from the past where the simple desire to promote prestige projects and/or the "technological gap" argument was often justification enough to provide resources"[105]. Four major sub-projects were proposed: estimate the size and growth of the information sector, study the innovation potential of the technologies, develop indicators of economic, industrial and social impacts, and offer policy guidance and strategies.

According to the Working Party, the design and methodology of the studies should rely on a macro-economic analysis of information activities. To this end, the project needed clear definitions and, above all, an empirical approach that started at the micro-level – the company – not a theoretical approach like input-output matrices, since these were qualified as too global with a too-high degree of aggregation. "This requires considerably more than the exploitation

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[102] *Ibid.*, p. 3.
[103] *Ibid.*, p. 4.
[104] *Ibid.*, p. 7.
[105] *Ibid.*, p. 8.

of existing measurement and analysis techniques"[106]. An expert group was thus suggested to support this work.

The group of experts was established by the Committee for Science, Technology and Industry in 1977[107], and the first meeting was held in March that same year[108]. An action plan followed[109]. To the expert group, what one observes is a "transition from industrial economies towards a post-industrial society, where the relative importance of industrial production (in the classical sense) and the size of the labor force employed in this sector is diminishing while the processing of large volumes of information for the management of our increasingly complex society is quantitatively and qualitatively gaining momentum"[110]. These transformations suggested a need for a new terminology and a definition of the information sector. The information sector, however, cuts across all sectors of the economy and is difficult to measure. Following Porat, "the Group recommends work to extract the information sector from the conventional labor force statistics and national accounts", plus micro-economic studies of specific industrial sectors[111]. The action plan was approved at the second meeting of the group of experts in June 1977[112]. At that meeting, Porat was invited to summarize his work and present a

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106 *Ibid.*, p. 12.

107 OECD (1977), Mandate of the Group of Experts on Economic Analysis of Information Activities and the Role of Electronic, Telecommunications and Related Technologies, DSTI/ICCP/77.37.

108 OECD (1977), Working Party on ICCP: Draft Summary Report, DSTI/ICCP/77.17.

109 OECD (1977), Preliminary Project Outline, Terms of Reference and Action Plan, DSTI/ICCP/77.33.

110 *Ibid.*, p. 1.

111 *Ibid.*, p.2 .

112 OECD (1977), Draft Summary Record of the Second Session, DSTI/ICCP/77.39.

practical guide, or cookbook as he called it, for building the information sector's accounts[113]. For its part, the Secretariat proposed guidelines for measuring the sector, based on Porat's work[114]. A questionnaire was then sent to countries on the availability of the statistics required to construct a "Porat type" analysis.

The next meeting (December 1977) studied the guidelines proposed[115], particularly in light of the report by a consultant, S. Wall (University of Cambridge, UK), who looked at national data available for conducting a "Porat type" analysis[116]. Wall's conclusions were that "few countries have a convenient and detailed single source of data as yielded by the United States input-output worktape. Even Porat had to carry out a considerable amount of search. (…) In the case of studies seeking to replicate Porat's work, the conclusion must be drawn that national researchers need to engage in a considerable amount of search activity"[117]. Still, some immediate work was possible using existing nomenclature: information occupations might reasonably be extracted, and measurement from the national accounts of the sector's value-added was feasible, for the marketed goods and services at least. Wall then presented a program of work separating responsibilities among different countries for a final report to be finished in less than a year (October 1978). Members of the group agreed.

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113 M. U. Porat (1977), Building a Primary and Secondary Information Sector: A National Income Accounts Manual, DSTI/ICCP/77.26. See also: M. U. Porat (1978), Policy Uses of a Macroeconomic Model of the Information Sector and of Microeconomic Production Functions, DSTI/ICCP/78.18.

114 OECD (1977), Definitions and Data to Build Information Sector Accounts, DSTI/ICCP/77.40. The final guidelines can be found in OECD (1978), Work Programme for Deriving Comparative Information Sector Statistics, DSTI/ICCP78.4.

115 OECD (1978), Draft Summary Record of the Third Session, DSTI/ICCP/78.3

116 S. Wall (1977), A Preliminary Analysis of Country Replies to Questionnaire, DSTI/ICCP/77.52.

117 OECD (1978), Draft Summary Record of the Third Session, DSTI/ICCP/78.3, p. 5.

The results were presented at the *High Level Conference on ICCP for the 1980s*[118], and published in two volumes in what was known as the Red ICCP reports series in 1981[119]. A major question, reported the document, "was to know whether these changes [information economy] occurred only in the United States or whether they constituted a more general trend"[120]. According to the OECD, "there [was] increasing concern in Europe about the so-called "information gap" between Europe and the United States"[121]. Nine countries for which data were available were studied[122]. Using Porat's typologies, method and classifications, the OECD estimated that the primary sector of information amounted to 20.3% of total value-added, and that over a third of professions were concerned with information. Furthermore, 30% of trade in manufacturing goods was concerned with information commodities. To the OECD, the data confirmed that a structural change was happening in OECD economies: a progressive shift toward an information economy, at least on the supply side (production of goods and services). On the demand side, however, "consumption of information goods and services is still playing a fairly minor role in the budget of the average household"[123].

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118 ICCP: Information, Computers, and Communication Policy.

119 OECD (1981), Information Activities, Electronic and Telecommunications Technologies: Impact on Employment, Growth and Trade, Paris.

120 *Ibid.*, p. 3.

121 OECD (1978), Draft Summary Record of the Fourth Session, DSTI/ICCP/78.30, p. 3.

122 Germany, Austria, Canada, United States, Finland, France, Japan, United Kingdom and Sweden.

123 OECD (1981), Information Activities, Electronic and Telecommunications Technologies, op. cit., p. 12.

The Group of Experts on ICC Statistics (1982)

The exercise on the information economy proved difficult[124]. According to the OECD, "the methodological problem stems from the fact that information, computers and communication (ICC) activities have to be considered as an object of study *per se* whereas general statistics pay them no special attention"[125]. "The current system of national accounts emphasizes older, mature or even declining economic activities and provides only little information on emerging new industries and new employment. The decision on what constitutes a major "industry" was made in the 1930s. This explains why agriculture and extracting industries are major industries. By contrast, digital computers which did not exist when the classification schemes were set up, appear as part of the non-electrical machinery group. Microprocessors do not have a code at all (…), software is not mentioned either"[126]. For these reasons, "it proved almost impossible to collect data on the growth of what was called the "information sector. It was only possible to extract from official sources a limited number of data on employment, output growth and trade in information technology goods and services to plot rough trends (…). These trends were much questioned and indeed were too weak for policy analyses and policy formulations"[127].

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124 See Chapter 2 of OECD (1981), Information Activities, Electronics and Telecommunications, Volume 2, Paris.

125 OECD (1982), Proposal for the development of a statistical system in the field of information, computer and communications, DSTI/ICCP/82.25, p. 1.

126 OECD (1984), Proposed Scope of Project on ICC-Statistics, ICCP (84) 6, p. 3.

127 *Ibid*., p. 4. An expert group on transborder data flows experienced similar problems. See: OECD (1979), Note on Approaches to the Quantification of Transborder Flows of Non-Personal Data, DSTI/ICCP/79.10; OECD (1979), Transborder Flows of Non-Personal Data: Questionnaire, DSTI/ICCP/79.18; OECD (1979), Replies to Questionnaire on Flows of Non-Personal Data, DSTI/ICCP/79.49.

The difficulties were discussed at length on several occasions at the OECD[128]. In 1982, the OECD Secretariat thus proposed to the Working Party on ICCP a statistical program and the creation of an *ad hoc* group of experts on statistics[129]. To the Secretariat, "the post-World War II period was characterized by sustained innovation, particularly in the field of electronics. In order to better encompass and monitor the structural changes, improved statistical concepts and data bases are needed, as well as a quantitative framework to better analyze and evaluate the importance of emerging changes related to the use of the new technology". The Secretariat proposed the development of a conceptual framework for collecting statistical data and a methodology for assessing the impact of information, computer and communications technologies on the economy. The framework was built around three levels through which information technology enters the economy: production of components, systems, and use. The methodology consisted of developing a series of indicators based on internationally-agreed classifications[130], and used an input/output model to measure the diffusion of technologies.

At its 11th Session (April 1982), the national delegates endorsed an exploratory activity on statistics based on the Secretariat's proposal. The Working Party called for a meeting of experts and users of statistics to study the required methodology. The first meeting, convened to develop "a coherent and reliable statistical database in the ICC field", was held in September 1982. The suggested data collection would cover information goods, services and impacts

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[128] At the 1980 conference where the report on the information economy was first presented, and again in October 1981 at a special session of the Working Party on Information Technology, Productivity and Employment which produced OECD (1982), Information Technology, Productivity and Employment, DSTI/ICCP/82.11. Published in 1981, in the Red ICCP series, as report no. 5.

[129] OECD (1982), Information Technology Statistics: Draft Study Design, DSTI/ICCP/82.13.

[130] R&D, supply of skilled labour, trade flow, ICC intensity (products, services, employment) by industrial sector, investment, household expenditures, stocks of products, new companies.

(diffusion). Two tasks were identified[131]. The first was developing a framework for statistics; the second, collecting data for immediate use for policy-makers and other Working Parties, in line with the 1981 study on measuring the information economy.

The Secretariat thus prepared a detailed proposal and submitted it to the *ad hoc* group[132]. The document reiterated that methodology should enable measuring the trends in the field of information and the impacts on economic variables such as growth, employment, consumption, investment and trade. It proposed 1) a statistical information system that would allow tracking of the ICC field based on a few simple indicators constructed from existing statistics for immediate use; 2) setting up a think tank within the OECD to develop "a methodological guide playing a similar role for this field to that of the Frascati Manual for research and development". Then the document proposed a definition of the ICC field as consisting of five parts (electronic components, electronic equipment, communication systems, network and computer system management services, and information services) and suggested a preliminary series of indicators[133]. The aim of the statistics and indicators would be to analyze production and utilization by way of input-output tables to "show how the ICC field products (goods and services) are used by other industries to make final products".

The next meeting of the group (June 1983) started defining the program of work, based on an updated plan submitted by the

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131 OECD (1982), Ah Hoc Meeting of Experts on Statistics on ICC: Draft Summary Record, DSTI/ICCP/82.41.

132 OECD (1982), Proposal for the Development of a Statistical System in the Field of Information, Computer and Communications, DSTI/ICCP/82.25.

133 Production (market volume/GDP, import rate, export rate, degree of foreign penetration, degree of concentration), utilization (users' expenditures in relation to industry and field), environment.

Secretariat[134]. The document suggested a new definition of ICC as composed of two sectors, plus context, or environment: information (ICC-1), in the sense of documentation; its production and distribution (ICC-2): hardware, software, networks and systems; environment (ICC-3). Indicators were suggested as follows:

ICC-1

Volume and value
Trade (imports and exports)
Costs of production
Stocks

ICC-2

Production and market

- Value
- Market
- Labour
- Investments
- Stocks

Use

- Expenditures by type of user
- National expenditures
- Labour

ICC-3

Environment

- R&D
- Patents
- Technological Balance of payment
- Public Expenditures on R&D

This division of the information field into sectors was adopted by the experts. The Secretariat's program of work was also adopted, centered around three points: 1) updating previously-collected statistics like those of the report on measuring the information

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[134] OECD (1983), Plan de travail pour l'élaboration de statistiques relatives à l'information, à l'informatique et aux communications, DSTI/ICCP/83.13.

economy, 2) working on a selected series of indicators for immediate use (6 months), and 3) initiating long-term work on ICC-1 and a manual (18-24 months).

A few months later, after the October 1983 meeting, the scope of the program was redefined. “A choice must be made”, stated the Secretariat, “between a total revision of the existing system and the more limited approach of collecting indicators relevant to the ICC field (…). While the total approach remains a long-term objective, it has been decided to concentrate on a modular approach”[135]. Clearly stated, the OECD was abandoning the idea of a manual, and suggested preparing guidelines for a classification of the ICC field and developing indicators on the basis of existing statistics or ad-hoc surveys.

In 1984, the Committee on ICCP (formerly the Working Party) initiated the implementation of the program of development on indicators. A few months later, the Secretariat insisted again on collecting immediate statistics: “In the recent past, the ICCP Secretariat has made a number of proposals (…). At the three meetings held, it was argued that the scope and dimensions presented in these proposals were too ambitious, in particular given the amount of human and financial resources available in the ICCP Secretariat”[136]. To the Secretariat, “preparing a Frascati-type manual might prove too time and resource consuming and might result in too rigid a system”[137]. Therefore, a “pragmatic” approach was proposed that “does not require the creation of entirely new classifications, but rather suggests building on the foundations of existing statistics”[138].

135 OECD (1984), Proposed Scope of Project on ICC-Statistics, ICCP (84) 6, p. 4.

136 OECD (1985), Draft Scope and Structure for ICC Statistics, DSTI/ICCP/85.57, p.3.

137 *Ibid.*, p. 4.

138 *Ibid.*, p. 5.

The program of work suggested making little effort on ICC-1 but rather concentrating on ICC-2[139].

To a certain extent, the program produced results. As preliminary work, an inventory of available and planned national statistics on information, computers and communication was conducted[140], and an analysis of current classifications and databases was performed[141]. Statistics on the information economy were updated[142], and a pilot survey on the production and trade of goods and services was conducted[143], evaluated[144], and followed by two more data

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139 Recommendations were made to concentrate on only five classes of goods (electronic components, data processing equipment, office equipment, industrial electronics, telecommunications) and the corresponding services (including software), on limiting the measurement of environment to its technological component, and prioritizing statistics on trade (because they allow tracking of products, and because trade was identified as the main issue in debates on information technology as well as for the Committee).

140 Available in OECD (1985), Australian Proposal for a Work Programme for the Development of a Manual of ICC Statistics, DSTI/ICCP/85.49, p. 33s.

141 OECD (1985), An Inventory of ICC-Related Data Available at OECD, DSTI/ICCP/85.50. The analysis revealed that current classifications (on industries and trade) were not sufficiently detailed and did not cover the whole field of ICC activities.

142 OECD (1984), Update of Information Sector Statistics, ICCP (84) 19. Published as OECD (1986), Trends in the Information Economy, Paris. Four new countries participated: Australia, Denmark, Norway and New Zealand.

143 OECD (1986), Draft Questionnaire on ICC-Based Goods and Services, DSTI/ICCP/86.4.

144 OECD (1988), Questionnaire on ICC-Based Goods and Services: An Evaluation of the Results, DSTI/IP/88.7.

collections[145]. Data on trade were also extracted from the OECD Foreign Trade database[146].

However, it was the manual that interested the expert group most. Impatient, some members of the group pointed out in 1988 that "it was necessary to give it priority over data collection" which is usually out-of-date and deficient[147]. The idea of a manual was originally suggested by the Australian delegate to the ICCP High Level Ministerial Meeting in 1980[148], and integrated into the early program on ICC statistics in 1982, then abandoned. In 1985, at the same meeting where the program of work based on the Secretariat's paper was adopted, Australia submitted a discussion paper summarizing the current position reached within the group of experts on ICC statistics and outlined a list of tasks to be undertaken, culminating in a workshop in September 1987 to review and finalize a draft version of the manual[149]. The Australian document started as follows: "Lack of ICC data is something of a paradox, given the rapidly increasing importance of the storage and retrieval of information to support so many aspects of the workings of sophisticated industrialized countries". Therefore, "the development of a manual for ICC statistics is seen as the most critical component

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145 OECD (1989), Results of the Mini-Survey on ICC Goods, DSTI/IP/89.5; OECD (1989), Revised Questionnaire, DSTI/IP/89.6. All in all, three data collection exercises were conducted (the database covered 1982-1989; data for the years 1986 and 1989 include services).

146 OECD (1985), Trade in ICC-Related Products and Systems as Reported in the OECD Trade File, DSTI/ICCP85.52. See also: OECD (1989), Report of the ICC Trade Database, DSTI/IP/89.7; OECD (1990), The Treatment of International Trade in Services in National Statistical Surveys, DSTI/IP/90.7.

147 OECD (1988), Group of National Experts on Statistics for ICC: Summary Record, ICCP (88) 19, p. 4.

148 OECD (1980), Statistics for ICCP: An Australian Action Paper, DSTI/ICCP/80.26; and intervention of J. D. Bell in OECD (1980), High Level Conference on Information, Computer and Communications Policies for the 1980s, Annex, DSTI/ICCP/80.38, p. 61-62.

149 OECD (1985), Australian Proposal for a Work Programme for the Development of a Manual of ICC Statistics, DSTI/ICCP/85.49.

of further work within the OECD in this field of statistics"[150]. The aim of the manual was to provide a conceptual framework, practical guidelines, and a basis for international statistical comparisons, "as with the Frascati manual for research and development"[151].

To this end, the Australian document discussed options for framing the measurement: a set of policy issues as identified previously by the Secretariat (see Appendix 9)[152] and organized around three broad categories (supply, application, and winners and losers), or an economic-oriented framework on trade, production and investment[153]. The proposal then analyzed the options available for defining the field of ICC and its boundaries: using Porat's primary and secondary sectors, or the OECD definition of ICC-1 and ICC-2. Finally, the document recommended organizing the statistics to be collected[154] into categories (supply, demand, population, labour, infrastructure, others). The document emphasized that "it is clear that modifications of a number of major international classifications will be a critical determinant of ICC data availability"[155]. It would have to relate the statistics to the System of National Accounts and other structural data in order "to understand the impact of ICC activities on the structure and performance of the economy as a whole"[156]. The manual would also make recommendations on methodologies: guidelines for special surveys designed specifically to collect ICC data, and procedures for deriving indicators from available statistics.

As discussed above, the Secretariat rejected the idea of a manual in 1985. Then, in 1988, the Secretariat re-examined the Australian

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150 *Ibid.*, p. 6.

151 *Ibid.*, p. 6.

152 OECD (1983), Policy Issues to Define the Scope of the Project, ICCP (83) 9; OECD (1984), ICC Statistics Project, ICCP (84) 20.

153 As in OECD (1985), 1986 Work Program Proposal, ICCP (85) 4.

154 Those suggested in OECD (1984), Update of Information Sector Statistics, op. cit.

155 OECD (1985), Australian Proposal for a Work Programme for the Development of a Manual of ICC Statistics, op. cit., p. 15.

156 *Ibid*., p. 18.

proposal and suggested creating a small group of national experts to produce what it called an "interim" manual. "While the aim [of a manual] remains valid, it has become clear that the proposal needs to be reinterpreted in the light of a number of factors"[157]. These factors were, firstly, the continued resource constraints that favour more modest alternatives like using existing sources of data, adding questions to existing surveys, and a minimal set of guidelines. The second factor was progress made in the last few years in the revision of international classifications. The Secretariat suggested "the development of a basic manual of concepts and practical guidelines for the collection of ICC data primarily through the addition of new questions to existing surveys, but also the reworking of existing data sources"[158]. To the Secretariat, the manual should carry "a strong economic performance and structural adjustment perspective, reflecting the primary concern of policy makers"[159]. This meant that the framework should evolve around the pattern of ICC innovation and diffusion (growth and structural change) and its economic impacts[160]. From an indicators point of view, three broad policy goals were suggested: innovation and production (what goods and services are produced, their importance in terms of output, employment, trade, industries, market structure, investments), diffusion (demand, patterns of use within industries, investments), and environment (climate, infrastructure, impact on productivity, employment, competitiveness and trade).

These were only the first recommendations of the Secretariat. The paper continued as follows: "it is probable that the problem [of defining the boundaries of what constitutes ICC goods and services] has been overemphasized. In general, policy issues tend to be fairly narrowly focused on a limited range of ICC goods and services in

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157 OECD (1988), Revised Proposal for the Development of a Manual for ICC Statistics, DSTI/IP/88.9, p. 2.

158 *Ibid.*, p. 2.

159 *Ibid.*, p. 5.

160 *Ibid.*, p. 3.

relation to the economics of just one or a few sectors: the growing use of computers in financial business services, for example, or the nexus between new telecommunications technologies and regulation in the industry. For such analyses, a precise global definition of the ICC sector as a whole is unnecessary. There are few policy issues that need to address the entire sector. It is only in calculating the contribution of ICC as a whole to global GDP or employment that the question of a global boundary becomes important"[161]. Because "the focus of policy is almost exclusively on those ICC goods and services based on new computer or telecommunications technologies", the interim manual should focus on 1) defining the ICC-2 sector alone, not ICC-1, and deal with the goods and services of major interest, 2) link these definitions to corresponding international classifications, 3) provide guidelines for existing surveys or for conducting ad-hoc surveys.

In sum, the manual was to be developed in three stages: define the scope and structure of the field, establish detailed definitions and concepts, and develop methodologies. The meeting of experts on ICC statistics in June 1988 decided to go ahead with drafting "an interim manual on the model of the Frascati manual"[162], "aimed to be a comprehensive framework which would help the compilation of internationally comparable statistics"[163]. The committee recommended that a consultant be engaged to draft the outline of the manual in line with the revised proposal from the Secretariat for an interim manual. This was qualified as an "acceptable balance between the desirability of a clear conceptual framework accompanied by the appropriate definitions and recommendations for

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161 *Ibid.*, p. 5.

162 OECD (1988), Group of National Experts on Statistics for ICC: Summary Record, ICCP (88) 19, p. 1.

163 OECD (1990), Draft Summary Record of the Fourth Session, DSTI/ICCP/M (90) 2, p. 11.

standard practices and the need to make rapid progress on a balanced programme of data-collection and methodological work"[164].

The plan and timetable for the manual were discussed and approved. As a first step, a discussion paper was prepared by R. Staglin and R. Filip-Kohn from the German Institute for Economic Research (DIW) and presented to the group of expert in May 1989[165]. The paper had the structure of a manual, with sections dealing with aim and scope, basic definitions and conventions, statistics, collection and interpretation, and survey procedure, and it identified major issues for discussion and choices to be made. The Secretariat also produced a paper of the same type based on both its previous note for an interim manual and the German paper[166]. In it, we find expressed clearly the understanding of the Secretariat with regard to the manual. The interim nature of the manual meant that it was an *initial* standard practice methodology for reworking *existing* data for *immediate* use. The manual was defined as "an intermediate stage toward the longer term goal of a full manual"[167]. To the Secretariat, a full manual would have to go beyond the scope of the System of National Accounts, deal with socio-economic indicators, and cover other indicators like the economic climate or environment (regulatory and tax environment, investment climate standards, skill level of the workforce, foreign ownership, degree of competition, etc.) and social aspects[168]. It would have to deal with both private sources of data and specific surveys. Briefly stated, it would have a broader coverage of variables, measurement units and sources. Actually, the interim

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164 OECD (1988), Group of National Experts on Statistics for ICC: Summary Record, op. cit., p. 5.

165 OECD (1989), Detailed Discussion Paper on a Proposed Interim ICC2 Manual, DSTI/IP/89.11.

166 OECD (1989), A Framework for an Interim ICC Manual, DSTI/IP/89.10.

167 *Ibid.*, p. 4.

168 "Though social questions are of undoubted importance, given the limited aims of the present proposal the focus will be on economic issues alone". OECD (1988), Revised Proposal for the Development of a Manual for ICC Statistics, op. cit., p. 3.

manual was to 1) use a list-based approach to defining the field (list of products from the Central Product Classification used for trade statistics) with correspondence to other classifications of industrial activities and occupations, 2) be restricted to marketed production (ICC-2), 3) add questions to existing surveys and 4) be framed within the System of National Accounts.

Both drafts were discussed by the group of experts in detail in May 1989. The meeting gave tasks to five volunteering countries for drafting different parts of the manual[169]. The countries reported back for the next meeting of experts (April 1990)[170]. This was the last meeting of the group. Although a revised schedule for the production of the manual was adopted – Spring 1991 at the latest – the manual would never be completed. The Secretariat informed the group that "the ICC statistical programme was not universally supported in the Directorate for Science, Technology and Industry nor, apparently, among Member governments and that the continuation of the programme would be re-examined in the context of a) its perceived relevance and potential usefulness to the programme of work of the ICCP committee and b) the review of the whole statistical programme of the Directorate for Science, Technology and Industry to be carried out in the context of the Technology-Economy Program"[171]. To the then-head of the ICCP Division, "the speed of the innovation push of the sector meant that it was difficult for official statistics to keep up [and] that the group was in a difficult competitive situation with respect to trade associations and private consultants (…). Maybe 10 years hence the field might have stabilized but for the moment it was extremely difficult to create and maintain up-to-date official statistics in the ICC area (…). The sector is a lot different from that of R&D statistics, which is more

169 OECD (1989), Meeting of Volunteer Experts on an Interim ICC Statistics Manual, DSTI/IP/89.8.

170 OECD (1990), Ad Hoc Group of Experts on Statistics for ICC: Summary Record, ICCP (90) 15.

171 *Ibid*., p. 2.

aggregated (Frascati manual)"[172]. The director concluded that "it was arguable whether the ICC statistics manual was really useful" due to rapid change in the field[173]. Later during the meeting, he mentioned that data required for analytical purposes were indicators like value-added networks, information technology-usage indicators, telecommunication costs to users, and trade in ICC services and telecommunications equipment, but several of these indicators were criticized by the group.

The statistical database on ICC trade in goods was frozen in 1990[174], statistical work was incorporated into other programs of work within the Directorate, namely the Group of Experts on Science and Technology Indicators (NESTI) and the Industry Committee[175], and the interim manual was shifted to low-priority. The ICC statistics program was "no longer considered relevant from the point of view of its timeliness and focus"[176].

In the history of the OECD, this was the second failure of a statistical program on information, and of a manual – the first was on information as knowledge. The failure is surprising since, according to the OECD itself, "many countries [were] looking to the OECD for further work in this field"[177], since the work of the Working Party on ICCP and ICC statistics in general had received increased attention from other OECD Committees (Trade, Industry, Multinational

172 *Ibid.*, p. 2.

173 *Ibid*.

174 The database was criticized for the sparseness of the data and the classifications used (not adapted to the developments in the field). OECD (1992), Activities of the OECD Sectoral Groups and Working Parties Relating to Services Statistics, DSTI/STII/IND/WP9 (92) 10.

175 OECD (1990), A Draft Medium Term Plan for the Work of the STIID, DSTI/IP (90) 22.

176 OECD (1991), Summary Record of the Meeting of Experts on the Consequence of the TEP Indicators Conference, DSTI/STII/IND/STP (91) 2.

177 OECD (1981), Draft Summary Record of the 9th Session, DSTI/ICCP/81.6, p. 3.

Enterprises)[178], and since the Secretariat worked to strengthen the ICCP Division and broaden the scope of the Statistics groups to serve other divisions of the Directorate, namely Industry as well as Science and Technology Policy[179]. The causes of this failure were threefold. The first is methodological. The task of constructing an information sector account was too complex for the time: the field was evolving rapidly and no standardized classification was available. The scope of the project was too large and countries had no adequate statistics. The second factor responsible for the failure relates to the method of work, or to the expert group itself. The OECD explicitly refused to set up a standing working party[180], preferring an informal expert group. Progress was slow and dynamism lacking, and the ICCP Committee never hesitated to comment on this[181]. There was also reluctance in the group to work with other units of Directorate. While a single division for statistical work was created in 1987 within the Directorate, the Committee itself did "not favor the creation of [a] joint Working Party" (ICCP, Science and Technology, Industry)[182]. Third, as discussed in the next section, other perspectives on measurement became available that proved more attractive.

THE INFORMATION SOCIETY

After Porat, the work on information at the OECD was conducted according to a concept of information as a commodity or industrial activity: information is a good or service, produced by many

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[178] OECD (1980), Draft Summary Record of the 7th Session, DSTI/ICCP/80.12, p. 3.

[179] OECD (1984), Draft Summary Record of the Fifth Session, ICCP/M (84) 2, p. 17.

[180] OECD (1983), Summary Record of the Second Session, ICCP/M(83)1, p. 10.

[181] OECD (1986), Meeting of Experts on Statistics for ICC: Summary Record, DSTI/ICCP/86.15, p. 3.

[182] OECD (1986), Draft Summary Record of the Eighth Session, ICCP/M (86) 1, p. 10.

industries, consumed by other industries, and measured with accounting statistics (economic activities of sectors). Information was no longer restricted to science and technology, but concerned all sectors of the economy. At the OECD, such an orientation was in the air as early as 1970. The third ministerial meeting on science in 1968 invited the OECD to reinforce its action on information policies, and proposed setting up an *ad hoc* policy group to advise on future actions. The group, headed by P. Piganiol, produced its report in 1970[183]. Echoing the Brooks report on science and technology[184], the group suggested integrating information policy into R&D policy, and extending the focus from information for scientists to transfers to government and non-specialists[185]. As a consequence, the Information Policy Group passed from working under the Committee for Scientific Research to the Committee for Science Policy in 1970. In the following years, several reviews of OECD activities in the field were conducted that urged closer coordination between the different expert groups, and a new mandate was proposed to the Information Policy Group in 1974[186].

A second shift in the use of the concept of information occurred in the 1990s. As we have seen, the first shift was from information as knowledge to information as commodity or industrial activity. Now, it was information technology *per se* that came to interest policy-

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183 OECD (1970), Information for a Changing Society: Some Policy Considerations, DAS/STINFO/70.30. Published as OECD (1971), Science, Growth, and Society: A New Perspective, Paris.

184 OECD (1972), Science, Growth, and Society: A New Perspective, Paris.

185 This argument was first offered in 1967 by the US delegate and submitted to the third ministerial meeting: “Information for scientific research may be far too narrow (...). The Information Policy Group might do well to broaden its scope to examine all those resources that serve the economic development and welfare of the countries. See OECD (1967), Scientific and Technical Information Group: Summary Record of the 7th Meeting Held in Paris on 26th and 27th June, 1967, RC (67) 15, p. 10.

186 OECD (1974), The Information Policy Group: History, Programme and Mandate, DAS/STINFO/74.7.

makers and statisticians and to define what constitutes information[187]. With regard to technology specifically, the reorientation goes back to Porat once again. In concluding his report, Porat focused on technology: "we are just on the edge of becoming an information economy. The information technologies – computers and telecommunications – are the main engines of this transformation"[188]. "No portion of the US economy is untouched by information technology"[189]. To Porat, "information policy attends to the issues raised by the combined effects of information technologies (computers and telecommunications) on market and non-market events"[190]. Porat then suggested a policy framework and identified policy issues based on flows of information technology into society: production, application and impact[191].

Information technology was also the main focus of the OECD's rhetoric on the information economy, as expressed in the work on ICC statistics. Yet the measurement did not revolve around technologies and specific surveys but, as with Porat, on information sectors and accounting. In the 1990s, however, information as technology came to define the core of the ICCP program of work. The new conception did not entirely replace the previous ones. All three conceptions of information overlapped. As we have seen, information as knowledge continued to be discussed within the conception of information as commodity (ICC-1). Equally, information as commodity continued to be measured in the new conception discussed in this section (information as technology). However, information as technology mainly added a new dimension to the measurements, with dedicated measurement instrument.

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[187] Indeed, the Committee for Scientific Affairs had changed its name in 1972 to the Committee for Scientific *and Technological* Policy.

[188] M. U. Porat (1977), The Information Economy, op. cit., p. 204.

[189] *Ibid.*, p. 207.

[190] *Ibid*.

[191] See also: M. U. Porat (1978), Communication Policy in an Information Society, in G. O. Robinsen (ed.), Communications for Tomorrow, New York: Praeger, p. 3-60.

At the OECD, the interest in information technology and the economy goes back to the late 1960s. In 1966, the OECD initiated a study on what was then called "technological gaps". The organization looked at the disparities in economic performance between the United States and Europe, and the role of technologies in these disparities. The results were published in 1968 and 1970[192]. Among the technologies studied were electronic components and electronic computers[193]. To the OECD, the computer constituted a "key" industry: "because of its widespread use in commerce, industry and government (…), the computer is coming to play the role of a nervous system, and can be considered a key factor in the economic and social structure of a country; it is also of obvious strategic significance to countries with major defense capabilities"[194]. The OECD measured a "clear-cut lead of the United States" on every indicator studied: source of major inventions, technological balance of payments (or licensing agreements), market share and international trade.

One conclusion of the study on gaps, with regard to statistics, was the poor quality of the data, or their absence: "Perhaps the main finding of the present survey of the computer industry is the existence of a major statistical gap"[195]. Following *Gaps in Technology* and a request from the third ministerial meeting on science in 1968, a Group on Computer Utilization was set up in 1969 and a survey on computer use was conducted[196]. To the Group, "member countries have a vital interest in accelerating the use of computers in all segments of society and the economy"[197]. In the following years, the Group on

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[192] OECD (1970), Gaps in Technology: Comparisons Between Member Countries in Education, Research & Development, Technological Innovation, International Economic Exchanges, Paris.

[193] OECD (1968), Gaps in Technology: Electronic Components, Paris; OECD (1969), Gaps in Technology: Electronic Computers, Paris.

[194] OECD (1969), Gaps in Technology: Electronic Computers, op. cit., p. 8.

[195] *Ibid.*, p. 157.

[196] OECD (1969), Questionnaire on Computer Utilisation, DAS/SPR/69.5.

[197] OECD (1969), Outline of the Study, DAS/SPR/69.1, p. 3.

Computer Utilization studied many aspects of information technology. It was this group that first suggested the idea of a conference on Computers and Telecommunications Policy (1975), which launched the project on the information economy. The new understanding of information as technology also came from this group. This shift was not without its opponents at the OECD, first among them the Information Policy Group. To that group, which was more concerned with documentation and its computerized systems, a concentration on the technological aspects of the information economy meant "unbalance and incompleteness" and "failure to give due attention to the intellectual aspects of information and the needs of its users"[198]. Eventually, the Computer Utilization Group won out over the Information Policy Group, and when the two groups merged into a working party on ICCP in 1976, the agenda of the Computer Utilization Group supplanted that of the Information Policy Group.

The contribution to economic growth and productivity of technology, particularly information technology, became a major concern in member countries and at the OECD in the 1980s: technical change and economic policy, technology and structural change, technology and competitiveness, technical change and economic growth, and technology and the economy were the subjects of many projects carried out by the OECD during this period[199]. This work was influenced and supported by C. Freeman, a consultant from the Science Policy Research Unit (SPRU), whose works developed the idea that "generic" technologies, because of their pervasive effects on the economy, ought to be the focus of policies. To Freeman, there have been five waves of innovation since the industrial revolution.

198 OECD (1975), IPG/CUG: Summary Record of the Joint Meeting, DSTI/STINFO/75.25.

199 For published reports, see: OECD (1980), Technical Change and Economic Policy: Science and Technology in a New Socio-economic Context, Paris; OECD (1988), New Technologies in the 1990s: A Socio-Economic Strategy, Paris; OECD (1992), Technology and the Economy: the Key Relationships, Paris.

Only the last one, information technologies, qualified as a change of "techno-economic paradigm" or a technologic revolution[200].

From its very beginning in 1982, the ICCP Committee has studied several information technologies and their effects on the economy, and published its analyses in the Red ICCP series (see Appendix 10). The data used were rarely standardized, relying on different sources (official, academic and private). In 1988, the Committee then launched a project on the economic implications of information technologies[201]. The project aimed to look at the socioeconomic impacts of information technology, construct a policy framework, and develop appropriate data and indicators. The declared focus of the project was not the production of technology that "in itself contributes little to economic growth", but the broader contribution to economic development through the use of technologies[202]. This was the origin of a preoccupation for the so-called information society, rather than the information economy, at the OECD – although widespread use of the term information society came later, and the term information economy continued to be used[203]. To study the

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200 C. Freeman, J. Clark and L. Soete (1982), Unemployment and Technical Innovation, Connecticut: Greenwood Press; C. Freeman (1987), Information Technology and Change in Techno-Economic Paradigm, in C. Freeman and L. Soete (eds.), Technical Change and Full Employment, Oxford: Blackwell, p. 49-69; C. Freeman (1987), The Challenge of New Technologies, in OECD, Interdependence and Co-operation in Tomorrow's World, Paris, p. 123-156; C. Freeman and C. Perez (1988), Structural Crises of Adjustment, Business Cycles and Investment Behavior, in G. Dosi et al. (eds.), Technical Change and Economic Theory, London: Pinter, p. 38-66.

201 OECD (1988), Socio-economic Implications of Information and Communication Technology and Applications: Opportunities for Change, ICCP (88) 4.

202 OECD (1988), Economic Implications of Information Technologies: Draft Summary Record of the First Session, DSTI/ICCP/EIIT/88.4.

203 To the OECD, the term information economy refers to the implications of information technologies on the economy, on firms' performance, (productivity, profitability and employment), while the information society refers to the social consequences of technologies (modes of behavior, relationships in and between communities). See: OECD (2003),

phenomenon, an expert group was created on Economic Implications of Information Technologies (EIIT).

The Working Party on Economic Implications of Information Technologies (1988)

In approving the project on the Economic Implications of Information Technologies, the ICCP Committee agreed on the importance of determining indicators, mainly on the use of information technology[204]. The first task of the group on Economic Implications of Information Technologies was therefore to develop indicators on information technology usage "as the foundation for the investigations on impacts"[205]. I. Miles from SPRU was invited as a consultant to present his Information Technology Accounting Framework (ITAF)[206]. Miles urged a change in both object and methodology: from measuring technology sectors to measuring the use of information technologies. "Most approaches to the information economy have been content to develop highly aggregated estimates of the size of an information sector", with little attention to the use of

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A Framework Document for Information Society Measurements and Analysis, DSTI/ICCP/IIS (2003) 9, p. 7. "Tomorrow's economy will be, to a great extent an information economy and society will be increasingly an information society. That is information will contribute in great part to the value added of most goods and services and information intensive activities will increasingly be carried out by households and citizens". See: OECD (1998), The ICCP Ad Hoc Statistical Panel: A Proposal for a Programme of Work, DSTI/ICCP/AH/RD (98) 5, p. 2.

204 OECD (1989), Draft Summary Record of the Thirteenth Session, ICCP/M (88) 1, p. 8.

205 OECD (1989), Economic Implications of Information Technologies: Draft Summary Record of the Second Session, DSTI/ICCP/EIIT/89.1.

206 I. Miles (1989), The Statistical Analysis of the Information Economy: Why an Accounting Framework is Needed, OECD, DSTI/ICCP/89.2; I. Miles (1990), Mapping and Measuring the Information Economy, London: British Library; I. Miles (1991), Statistics and the Information Age, Futures, 23 (9), p. 915-934.

information technologies themselves, claimed Miles[207]. To Miles, the information economy does not simply refer to information sectors, nor to information-technology producing sectors, but to the diffusion of information technology. Information technology, particularly microelectronics, is a pervasive technology across the whole economy and across a wide range of applications. To account for the diffusion of information technology, Miles suggested using existing but unexploited data and, above all, input-output tables to track the interrelationships between production and applications or uses.

This "philosophy" was what the group on Economic Implications of Information Technologies adopted, but it did not adopt the methodological approach. Until full input-output information became possible, the Secretariat recommended, for example, that specific surveys on advanced manufacturing technologies be used to track the diffusion of information-technology-related goods[208]. At a meeting held in September 1988 in Stockholm, a questionnaire was prepared on the use of information technology and sent to member countries. Despite the absence of some data within member countries, a statistical analysis was conducted by I. Miles and D. Kimpel and

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[207] I. Miles (1989), The Statistical Analysis of the Information Economy, p. 2.

[208] OECD (1988), Group of National Experts on Statistics for ICC: Summary Record, ICCP (88) 19, p. 5. As conducted in the United States, Canada and Australia. For the United States, see National Science Foundation (1991), Science and Engineering Indicators 1991, Washington, p. 154-157; National Science Foundation (1996), Science and Engineering Indicators 1996, Washington, p. 6-24 to 6-27; National Science Foundation (1998), Science and Engineering Indicators 1998, Washington, Chapter 8; National Science Foundation (2000), Science and Engineering Indicators 2000, Washington, Chapter 9. For Canada: Statistics Canada (1989), Survey of Manufacturing Technology: The Leading Technologies, Science Statistics, 88-001, 13 (9), October; Y. Fortier and L. M. Ducharme (1993), Comparaison de l'utilisation des technologies de fabrication avancées au Canada et aux États-Unis, STI Review, 12, p. 87-107. For Australia: B. Pattinson (1992), Survey of Manufacturing Technology – Australia, DSTI/STII/STP/NESTI (92) 8, OECD.

published in the Red ICCP series[209]. This kind of work, with its "pragmatic" approach, was a model often brought to the attention of the expert group on ICC statistics for emulation, but in vain.

Then, in 1992, the expert group discussed a new project on developing new indicators and launching an "Information Economy Revisited" study. A special session on national information technology policies and structures was therefore held in October[210], while a project was identified to "map" the relationships between information technology and the economy, that is, to assess the impacts of information technology on the economy, and particularly on productivity[211]. To the group, such analysis "requires an enormous body of cross national information and databases. Unfortunately, the currently developed body of knowledge or data collection system is not sufficient to allow empirically convincing and scientifically valid conclusions about various aspects of information technology impacts on productivity"[212]. The group added, "the existing literature has had an opportunistic focus on case studies of small populations where data happens to be available or is easily gathered"[213]. To establish the foundations for the task, a workshop was hosted by the National Science Foundation in the fall of 1993 to review the state of the art in productivity measurement methods, investigate cross-national studies, analyze available data sets and examine the feasibility of new

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209 OECD (1990), Indications and Analysis of Current and Emerging IT Usage, DSTI/ICCP/EIIT/90.10. Published as report no. 31 in the ICCP Red series: OECD (1993), Usage Indicators: A New Foundation for Information Technology Policy, Paris.

210 OECD (1992), Proposal for a First Special Session on Information Technology Policy, DSTI/ICCP (92)11; OECD (1993), Report on the Special Session on Information Technology Policies: New Challenges for Competition and Co-Operation, DSTI/ICCP (92) 13.

211 OECD (1992), Micro- and Macroeconomic Impacts of National IT Policies, DSTI/ICCP/EIIT (92) 11; OECD (1993), Micro- and Macroeconomic Impacts of IT and National Information Technology Policies and Programmes, DSTI/ICCP/EIIT (93) 1.

212 *Ibid.*, p. 5.

213 *Ibid.*, p. 6.

international statistical series[214]. The project became part of the Technology, Productivity and Job Creation Project, the first joint project of the Directorate for Science, Technology and Industry (combining ICCP, the Science and Technology Policy division and the Industry division)[215] and a precursor to the Growth project of the late 1990s, where information technology appeared as central in explaining the performance of the New Economy[216].

As a follow-up to the session on information technology policies, a review group was set up to identify future directions of work on information, computer and communications policies – to identify issues and challenges of the group on Economic Implications of Information Technologies, elicit views on a future agenda, and renew and refocus the mandate of the group. The review reaffirmed the importance and relevance of the expert group on Economic Implications of Information Technologies, but expressed "concern about the lack of reliable statistical data in the area of usage statistics" and the "absence of appropriate methodologies and concepts quantifying intangible benefits"[217]. The report also recommended elevating the status of the group to that of a Working Party. The Group on Economic Implications of Information Technologies then became the Working Party on Information Technology Policy in 1993[218]. By mid-1995, the group had not yet met. According to some, there were increasing difficulties in interesting member countries in the concept of the information

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[214] OECD (1994), The Productivity Impacts of Information Technology Investment, DSTI/ICCP (94)1. Some of the papers from the conference were published in Economics of Innovation and New Technology, 3 (3-4), 1995.

[215] OECD (1994), STI Work on Technology, Productivity, and Employment, DSTI/IND/STP/ICCP (94) 2. Report published as OECD (1996), Technology, Productivity and Job Creation, Paris.

[216] See Chapter 4 above.

[217] OECD (1993), EIIT Review Report, DSTI/ICCP/EIIT (93) 2.

[218] OECD (1993), Working Party on Information Technology Policy: Draft Mandate, DSTI/ICCP (93) 6.

economy or society[219]. The OECD Council asked for cuts in the ICCP Committee budget: the 1993 program of work weakened ICCP by eliminating one post and reduced consultancy resources and the hosting of meetings by 30%. There was also a suggestion that the committee be terminated[220] and a proposed restructuring of the Directorate for Science, Technology and Industry: from 1994 onward, the ICCP committee would be served by a Science, Technology and Communications Policy Division.

In an ultimate bid for survival, the ICCP Committee drafted a proposal on the Information Society to be included in the final communiqué of the May 1995 ministerial meeting (G-7)[221]. The proposal dealt with the importance of information technology and the need for a policy framework. As a result, the ministers asked the OECD for a policy framework on the Information Society (Global Information Infrastructure/Global Information Society, or GII/GIS). "The world community needs to adapt [to the Global Information Infrastructure] in all the political, economic, social and cultural dimensions, thus establishing the basis for a new Global Information Society"[222]. But a common vision was lacking with regard to the Information Society concept[223]. Using available and recently completed work, the ICCP Secretariat produced, in a very short time, a policy framework in which the principle of market competition held

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219 There were already plenty of discourses and initiatives at other levels of governments. For influential documents, see the EU Commission's Bangemann report (European Commission (2004), Europe and the Global Information Society: Recommendations to the European Council, Brussels) and the US initiative for the Information Super Highway (Task Force on Information Infrastructure (1995), Global Information Infrastructure: Agenda for Co-Operation).

220 OECD (1994), Draft Summary Record of the 26th Session, ICCP/M (94) 2, p. 3.

221 OECD (1995), Draft Summary Record of the 27th Session, ICCP/M (95) 1, p. 5-6

222 OECD (1996), GII-GIS: Statement of Policy Recommendations Made by the ICCP Committee, DSTI/ICCP (96) 10, p. 2.

223 *Ibid.*, p. 3.

preeminence, and where government's role was that of a catalyst and facilitator for developing efficient markets, overcoming barriers and obstacles, promoting equal access to information, and protecting cultural and linguistic diversity in content products and services (software, multimedia, publishers, broadcasters, audio-visual and sound recording producers)[224]. The report was submitted to a meeting of ICCP at the ministerial level in May 1996, and endorsed by the G-7 in May 1997.

These efforts from the ICCP Committee had two consequences. The first was reactivating the newly-created Working Party on Information Technology Policy (formerly the Working Party on Economic Implications of Information Technologies). The renewed mandate of the Working Party focused on developing a policy framework for the information economy centered around the demand or user side of technologies (diffusion and impacts) rather than the supply side, and with a specific mention of developing "methods and tools for measurement". The Working Party was, for a second time in as many years, renamed the Working Party on Information Economy in 1995[225]. The first task of the Working Party was organizing a series of six workshops (1995-1999) on the economics of the information society, a regular feature of which were sessions on data and indicators[226].

A relatively new series titled *Information Technology Outlook* became a top priority of the Working Party. The series was first

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[224] OECD (1996), GII-GIS: Policy Requirements, DSTI/ICCP (96) 24; OECD (1996), GII-GIS: Policy Recommendations for Action, DSTI/ICCP (96) 25.

[225] OECD (1995), Mandate and Activities of the Working Party on Information Technology Policy, DSTI/ICCP (95) 28; OECD (1996), Mandate, Terms of Reference and Name of the Working Party, DSTI/ICCP/IE (96) 2; OECD (1996), Proposed New Mandate of the Working Party, DSTI/ICCP/IE (96) 3.

[226] OECD (1999), OECD Workshops on the Economics of the Information Society: A Synthesis of Policy Implications, DSTI/ICCP/IE (99) 1.

proposed in 1990[227]. It was created to cover both information technology and communication technology, and to collect data from any source (international organizations, directorates of the OECD, ICCP research projects, member countries and private consultants). The publication would not necessitate new data collection. The focus was rather on the analysis of existing data, and updated data on an *ad hoc* basis. The added value was to bring together data from diverse sources and present them in a common framework. The second objective was to "give a higher profile to the regular work of the ICCP" and "an enhanced sense of identity" to the Committee and the to work of its working parties. A *Communication Outlook* came first (from a Working Party on Telecommunications and Information Services Policies), as the consequence of a special session on telecommunications policy held in 1990. The first edition of *Information Technology Outlook* followed in 1992 (from the Working Party on Economic Implications of Information Technologies)[228]. The biennial series continues to this day – since 1997 with three sections (scoreboard of indicators, policies and issues) and more use of official statistics (than private sources)[229].

The series became the "showcase" for statistical work on the theme of the information economy. Editions carried results from work conducted on electronic commerce, software, skills and employment, and the so-called "digital divide" (the have and have-not of technologies). There had been suggestions to change the name of the series to Outlook for the Information Economy[230], but without success.

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[227] OECD (1990), Information Technology and Communications (ITC) Outlook: Proposal for a New ICCP Publication Project, DSTI (90) 9.

[228] OECD (1991), Information Technology Outlook, DSTI/ICCP (91) 1.

[229] OECD (1997), Recent Changes in the Information Technology Outlook and Implications for Future Editions, DSTI/ICCP/IE (97) 2.

[230] OECD (1996), Summary Record of the First Meeting of the Working Party, DSTI/ICCP/IE (96) 1, p. 4.

The Working Party on Indicators for the Information Society (1999)

The second consequence of the ministerial meeting was the creation of another Working Party. At the suggestion of the ICCP Committee, in May 1996 the ICCP at the ministerial level suggested that the Secretariat develop "a common framework for indicators and standard definitions" for the information society and set up a statistical panel to develop "new indicators which identify, assess and monitor the emergence" of the information society[231]. A statistical panel was set up in 1997[232], and the ICCP Committee asked the panel to start its work by surveying existing data on both the supply and demand for information and communication technology, or ICT (the new term for ICC, as emblematic of the third conception of information). The work would have to be conducted in close cooperation with Eurostat and its Working Group on Statistics for the Information Society.

The statistical panel was chaired by F. Gault from Statistics Canada, and met for the first time in June 1997. From the start, and as a lesson from past experiences, a "pragmatic and concrete approach was emphasized which would produce tangible results in the near-term"[233]. The group agreed to produce a survey of available data in member countries, as well as a preliminary ICT definition (industries) by June 1998. Work was also suggested on an ICT product-based or commodity-based definition and, once that was achieved, one definition on content (industries that create information). Eurostat suggested it would take the lead on the commodity-based definition, and France proposed to undertake the work on content. Finally, work

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231 OECD (1996), Global Information Infrastructure-Global Information Society: Statement of Policy Recommendations Made by the ICCP Committee, DSTI/ICCP (96) 10, p. 9; OECD (1996), GII-GIS: Policy Requirements, op. cit., p. 23.

232 OECD (1997), The ICCP Statistical Panel: Mandate, Mission, Goals and Work, DSTI/ICCP/AH 97) 1.

233 OECD (1997), Summary Record of the Ad Hoc Meeting on Indicators for the Information Society, DSTI/ICCP/AH/M (97) 1, p. 3.

was envisaged to measure the use of ICT (in households, government and business).

The statistical panel, renamed the Working Party on Indicators for the Information Society in 1998, "has been able to provide a high quality response in a relatively short time span"[234]. It produced a definition of the ICT sector in less than a year[235], from which a series of statistics were published[236], and developed a list of ICT products[237]. It also developed model questionnaires on the use of ICT technologies in business[238] and households[239], including electronic commerce[240].

One area where results did not pan out was in measuring what was called "content". From 1998 on, the working party succeeded in settling debates on definitions (conventions on boundaries), particularly for ICT products and e-commerce. Content was not that easy. As we have seen, from the very beginning of information statistics, there was hope of measuring information *per se* (knowledge or documentation). The idea came back on the agenda in the mid 1990s under the name "content", those industries which produce and disseminate informational products. Defined as such,

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[234] OECD (2004), Policy Relevant Indicators and Empirical Analysis for the Information Society: A Discussion of WPIIS Outputs and Ideas for Future Work, DSTI/ICCP/IIS (2004) 1, p. 9.

[235] OECD (1998), Summary Record of the Second Ad Hoc Meeting on Indicators for the Information Society, DSTI/ICCP/AH/M (98)/REV1, p. 9. Revised in 2002: DSTI/ICCP/IIS (2002) 2.

[236] OECD (2000), Measuring the Information Sector, Paris.

[237] OECD (2003), A Proposed Classification of ICT Goods, DSTI/ICCP/IIS (2003) 1/REV2.

[238] OECD (2001), Measuring ICT Usage and Electronic Commerce in Enterprises: Proposal for a Model Questionnaire, DSTI/ICCP/IIS (2001) 1/REV1.

[239] OECD (2001), Measurement of ICT Usage in Households/By Individuals: Proposal for a Model Questionnaire, DSTI/ICCP/IIS (2001) 2 and DSTI/ICCP/IIS (2002) 1/REV1.

[240] Work on electronic commerce was conducted jointly with the Working Party on Information Economy.

content was a sensitive political issue. While previous work of statisticians had concentrated on the knowledge and/or commodity side of information, content involved looking at, among others, culture and cultural industries.

The ministerial meeting of 1996 on the information society had called for economic efficiency and more equitable access to media and content resources. The Working Party on Indicators for the Information Society started work on content in 1999. France and Canada proposed a new definition of ICT that would include images, sound and text that are displayed, processed, stored and transmitted by ICT[241]. This category of goods and services was called "communication product". It was not concerned, in the end, with the industries that create such products, but with the medium of diffusion, or technology. The suggested list of industrial classes included publishing, printing and media, but also radio and television, motion pictures, libraries, museums and services like marketing and advertising, education and health. Many believed that the concept was too broad, and requested a review of the principles outlined in the paper[242], in line with the Canadian experience that limited content to industries engaged in disseminating and/or reproducing products by new electronic technologies[243]. Indeed, the meeting of the Working Party in November 1999 specified that the requirement was for electronic content, and the Secretariat produced a paper on defining and measuring (that small part of) the electronic content sector[244]. The French and Canadian delegates therefore produced a discussion paper that amended their first suggestion, proposing a

241 OECD (1999), Defining the Content Sector: A Discussion Paper, DSTI/ICCP/IIS (99) 1.

242 OECD (1999), Summary Record of the 3rd Ad Hoc Meeting of the Working Party on Indicators for the Information Society , DSTI/ICCP/IIS/M (99) 1, p. 3-4.

243 OECD (1999), NAICS, the ICT Sector and the Content Sector: the Canadian Experience and Proposed Approach, DSTI/ICCP/IIS/RD (99) 4.

244 OECD (2000), The Electronic Content Sector and Electronic Communication Products, DSTI/ICCP/IIS (2000) 1.

narrower definition that excluded marketing and advertising, libraries and museums, and education and health, the latter two because they targeted specific individuals or groups[245]. On the other hand, the United States delegate proposed keeping the set of industries larger, i.e.: education, health services and other industries where ICTs are having an impact on the way the product or service is delivered. In the end, delegates preferred to continue with France's and Canada's discussion paper as a framework. No agreement was reached, and the meeting ended with the suggestion to create an expert group and take a different approach that would include both traditional and electronic content[246].

What is not mentioned in the minutes of the Working Party (nor in the Guide discussed below) is the opposition of the United States to measuring informational (or cultural) content. As measured in a study by the Working Party on Information Economy on the content industry, the United States was the largest market for music and audio-visual sales and, above all, it dominated the European market[247]. From the very beginning of the Working Party's work on the ICT sector, the United States delegate refused to discuss and include content industries in the definition. The instructions to do so were given to him by the Department of Commerce, the Department of Trade and the State Department[248]. As a consequence, two industries were eliminated from the 1998 ICT sector definition (reproduction of recorded media, and radio and television services).

Despite the failure on content, the Working Party's methodological outputs contributed to several statistical analyses by the Directorate for Science, Technology and Industry, firstly in terms of regular and

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245 OECD (2001), The Content Sector: Outline and Features, DSTI/ICCP/IIS (2001) 5.

246 OECD (2000), Summary Record of the 4th Meeting of the Working Party on Indicators for the Information Society, DSTI/ICCP/IIS/M (2000) 1, p. 5-6.

247 OECD (1996), Content as a New Growth Industry, DSTI/ICCP/IE (96) 6.

248 Confidential interview, 12 July 2004.

updated indicators on the information economy[249] and the knowledge-based economy[250], and secondly as contributions to projects like the Growth project (New Economy) which, according to the OECD, "with its fresh analysis and bold new conclusions [, made] quite a splash within the Organization"[251]. Studies produced included:

- *A New Economy? The Changing Role of Innovation and Information Technology in Growth, 2000.*
- *Drivers of Growth: Information Technology, Innovation and Entrepreneurship, 2001.*
- *Seizing the Benefits of ICT in a Digital Economy, 2003.*
- *ICT and Economic Growth: Evidence from OECD Countries, Industries and Firms, 2003.*
- *The Economic Impact of ICT: Measurement, Evidence and Implications, 2004.*

How can we explain what enabled the Working Party on Indicators for the Information Society to succeed, whereas previous efforts had failed? Three factors can be identified. The first is history. The Working Party on Indicators for the Information Society worked at a time when industrial classifications, although still imperfect, had improved over the 1980s, and countries were able to deliver data more rapidly. The second reason is pragmatism, a lesson learned from the experiences of the 1980s. The Working Party developed a definition that could be implemented quickly and thus be of

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249 OECD (2002), Measuring the Information Economy, Paris. From 1995, a series of key Indicators plus metadata are published on http://www.oecd.org/document/23/0,2340,en_2649_34449_33987543_1_1_1_1,00.html.

250 See the OECD Science, Technology and Industry Scoreboard series for 2001 and after.

251 OECD (2000), Draft Summary Record of the 37th Session, DSTI/ICCP/M (2000) 1, p. 7.

immediate use to data users, and to this end it followed an industry definition[252]. The most difficult tasks (content) were dealt with only when other work was finalized. The third factor has to do with the method of work. Unlike other Working Parties, such as the one on the Information Economy, here it was the Working Party on Indicators for the Information Society that conducted the work. Nearly all of the substantive work was done by the delegates, and not by the OECD.

The most recent output of the Working Party is a methodological guide published in 2005. Until 2001, the Working Party "agreed that standards and definitions will need to be revisited frequently in such a fast moving area. Rather than developing a manual on statistics for the information society, the group decided to continue with its approach of building blocks" (individual outputs accompanied by explanatory and methodological guidelines)"[253]. Then, at the meeting in April 2001, the idea of a "manual collecting the definitional and methodological work carried out by the Working Party on Indicators for the Information Society" emerged: "the Working Party might want to consider whether to produce some synthesis of its definitional and methodological work, e.g. in the form of methodological guidelines for the measurement of statistics for the Information Society"[254]. By 2003, the Secretariat had produced an early draft of a guide that drew together the methodological decisions reached within the Working Party[255]. The guide was finalized for the 2005 World Summit on the Information Society held in Tunis[256].

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[252] OECD (1998), Summary Record of the Second Ad Hoc Meeting on Indicators for the Information Society, DSTI/ICCP/AH/M (98)/REV1, p. 2.

[253] OECD (2001), Summary Record of the Meeting of the Working Party on Indicators for the Information Society, DSTI/ICCP/IIS/M (2001) 1, p. 7.

[254] OECD (2001), WPIIS Work Programme and Terms of Reference, DSTI/ICCP/IIS (2001) 6, p. 2.

[255] OECD (2003), A Framework Document for Information Society Measurements and Analysis, DSTI/ICCP/IIS (2003) 9.

[256] OECD (2005), Guide to Measuring the Information Society, DSTI/ICCP/IIS (2005) 6/FINAL.

The guide is a strange document. It is not really a methodological manual, but part of a new lot of documents not mature enough for international standards (see Appendix 2). The guide does not provide instructions and conventions for measuring the information economy or society. Essentially, it documents the statistical work of the Working Party on Indicators for the Information Society and related work done within the OECD on ICT:

- Products (goods and services),
- Infrastructure (telecommunications networks, Internet),
- Supply (industries)
- Demand (ICT and e-commerce)
    - Business
    - Households and Individuals
- Content

"The Guide describes areas of work sufficiently advanced in their conceptual and definitional underpinnings, and for which sufficient experiences have been accumulated"[257], but it also discusses works in their early stages or works-in-progress. It includes discussions of debates that occurred during the development of that work and refers to OECD internal documents (not available for general distribution). The Guide is a "compilation (*sic*) of concepts, definitions, classifications and methods for the measurement of the information society"[258]. It is presented as a "living manual", "open to receiving new components, as well as being subject to revision"[259].

Why had the Directorate for Science, Technology and Industry produced such a Guide – the third methodological document in the same year that did not deserve the name manual? At the OECD, it

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[257] OECD (2005), Guide to Measuring the Information Society, op. cit., p. 10.

[258] *Ibid*.

[259] *Ibid.*, p. 6.

was hoped that the Working Party work "will become a standard reference"[260], and help newcomers to the field to "progress more quickly"[261]. "It is hoped that the Guide will facilitate improved harmonization of practices (…). This, in turn, will enable better international comparability of data, a key requirement for benchmarking, identification of relative strengths and weakness, and tracking progress"[262]. Fine. However, there is a more political explanation, considering the past history of information statistics and the difficulties of the ICCP Committee in interesting people in its statistical output. On several occasions, the Working Party on Indicators for the Information Society congratulated itself that its work, as used in OECD studies, raised "the visibility of official ICT statistics"[263] – as well as of the *Information Technology Outlook* series. This was also an important reason for the publication of an early Guide: increase the visibility of the Working Party on Indicators for the Information Society's work and of the ICCP Committee[264]. Incidentally, the head of the Working Party himself (F. Gault) became head of a more visible group in 2002, namely the Group of Experts on Science and Technology Indicators (NESTI). A related factor in publishing an early Guide was "controlling" the field, namely extending the OECD standards to non-OECD countries[265]. This factor, or task, was one to which the OECD devoted itself explicitly after the fall of the Berlin Wall. However, this was precisely what the OECD qualified as "empty internationalism" in the 1970s, when UNESCO tried to extend the measurement of

260 *Ibid*.

261 *Ibid.*, p. 12.

262 *Ibid*.

263 OECD (2001), Summary Record of the Meeting of the Working Party on Indicators for the Information Society, DSTI/ICCP/IIS/M (2001) 1, p. 8.

264 OECD (2001), WPIIS Work Programme and Terms of Reference, DSTI/ICCP/IIS (2001) 6, p. 2.

265 OECD (2004), Policy Relevant Indicators and Empirical Analysis for the Information Society: A Discussion of WPIIS Outputs and Ideas for Future Work, DSTI/ICCP/IIS (2004) 1, p. 9.

science, technology and innovation to Eastern countries, using new definitions developed specifically for this purpose[266].

CONCLUSION

Information has occupied a large part of the OECD's work on science, technology and innovation. Since 1949, the organization has created as many as fifteen bodies specifically concerned with information policy, information technology and its measurement (see Appendix 11). These bodies have produced hundreds of working papers and notes. Over this period, the concept of information has shifted from an understanding concerned with knowledge, mainly scientific and technical knowledge, to technology. Two *leitmotifs* guided the efforts of the organization. The first was accounting. To the OECD, "it seems normal today, in statistical matters, to use an accounting framework based on the national accounts" (free translation)[267]. This was the model suggested in the United States by Machlup and Porat, and imitated in many other countries like France[268], Great Britain (I. Miles), Germany and Australia. The second *leitmotif* was structural change. To the ICCP Committee, "the object of structural change has been on the policy agenda of OECD programmes for many years. In this context the transition of advanced economies from industrial societies to service and even information societies has gained particular momentum and attention. The Committee of ICCP has been attracted by such visions and [has]

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266 OECD (1977), Response by the Secretariat to the Questions of the Ad Hoc Group, DSTI/SPR/77.52, p. 16.

267 "Il paraît aujourd'hui normal, en matière de systèmes statistiques, de se placer d'emblée dans un cadre de cohérence comptable inspiré de la comptabilité nationale." OECD (1983), Plan de travail pour l'élaboration de statistiques relatives à l'information, à l'informatique et aux communications, DSTI/ICCP/83.13.

268 OECD (1982), The Statistical Information System on the Computer Sector: a French Proposal, DSTI/ICCP/82.22.

assessed the role of information technologies in this process of change"[269].

Over the whole period, a major objective, if not an ideal, of the OECD was measuring information and, to that end, developing a methodological manual. The cherished model for a manual was the Frascati manual, adopted in 1963 by member countries for surveying their R&D activities. Both for the Group on Information Policy and its project on a manual for Scientific and Technical Information Activities, and for the ICCP Committee and the manual for Information, Computers and Communication statistics, the proclaimed model to emulate was the Frascati manual. In the end, there has never been a Frascati-type manual produced for measuring information. The above two projects failed (as did a third on counting scientific papers, or bibliometrics: a manual was planned in the early 1990s[270], and drafted[271], but then transformed into a working paper because its structure and coverage did not bear any relationship to a manual)[272]. The only methodological guidelines on information available at the OECD appeared in 2005 in the form of a guide, not a manual.

How can we explain these failures? Apart from the conceptual, methodological and political factors as discussed in this chapter, the failure also has to do with the innovation capacities of the international organization. Although the OECD is a think tank for its member countries and produces papers by the thousand, the organization is rarely an innovator in the matter of theories and concepts. Generally, the organization needs exemplars or models.

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[269] OECD (1984), Update of Information Sector Statistics, op. cit., p. 3.

[270] OECD (1991), Record of the NESTI Meeting, DSTI/STII/STP/NESTI/M (91) 1; OECD (1997), Record of the NESTI Meeting, DSTI/EAS/STP/NESTI (97) 1.

[271] OECD (1995), Understanding Bibliometrics: Draft Manual on the Use of Bibliometrics as Science and Technology Indicators, DSTI/STP/NESTI/SUR (95) 4.

[272] Y. Okubo (1997), Bibliometric Indicators and Analysis of Research Systems: Methods and Examples, OECD/GD (97) 41.

This explains the success of the OECD Frascati manual. The manual rested entirely on the experience of the US National Science Foundation, itself the result of previous experiences since the 1920s[273]. This was also the case for the Oslo manual, a methodological manual for measuring innovation[274], which benefited from a definition launched in the 1960s in a survey conducted by the US Department of Commerce[275], and a common understanding of what innovation was, at least among economists. The history of the failed manuals on information shows that in the absence of long experience and models, the OECD can proceed only slowly.

The role of the OECD lies elsewhere. History shows that the OECD's contribution to statistics is threefold. First, the organization selects a conceptual framework, generally a fashionable and recent one. This was the case for the information economy. Second, it adapts (often improves) a methodology (existing), and standardizes and conventionalizes it. This was the work of the Working Party on Indicators for the Information Society. Finally, the organization internationalizes early and "innovative" analyses (official and academic) conducted at the national level, as it did in studies on the role of information technology in productivity and on the emergence of a new economy.

Despite the decades of work on the concept of information and its measurement, almost any kind of discourse can be, and is, conducted in an attempt to pin down the concept[276]. Even statistics, reputed for its power to crystallize and "objectivize" concepts, has failed to stabilize what information is or to produce a consensus operational

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[273] B. Godin (2005), Measurement and Statistics in Science and Technology: 1920 to the Present, London: Routledge.

[274] OECD (1991), OECD Proposed Guidelines for Collecting and Interpreting Innovation Data (Oslo Manual), DSTI/STII/IND/STP (91) 3. General distribution under catalog number OECD/GD (92) 26.

[275] US Department of Commerce (1967), Technological Innovation: Its Environment and Management, USGPO, Washington.

[276] F. Webster (2002), Theories of the Information Society, London: Routledge.

definition. Information remains a fuzzy concept, although many have jumped on the “bandwagon” of technology as a proxy for information in practice.

CONCLUSION

The measurement of science, technology and innovation is one hundred and fifty years old. Since the late 1860s, researchers have developed statistics, first on input, then on output[1]. Statistical bureaus followed after World War II[2]. As we have discussed in this book, the statistics served the many conceptual frameworks developed for policy purposes. What has proved more difficult is measuring the effects, or the impacts or outcomes, of science on society and on the economy. One would look in vain for a framework on the social impacts of science in the literature.

Everyone wants evidence and indicators on impacts. As the OECD stated recently: "senior policymakers want and need to base their decisions upon more than advocacy, and upon more than indicators of inputs that have no established causal links to outcomes of research and development funding"[3]. Recently, the OECD emphasized the "need for a better understanding of the links between public investments in basic research and their impacts on society"[4]. But there are, so it is said, important conceptual and methodological challenges.

There has never been a conceptual framework constructed on the social impacts of science, technology and innovation. Certainly, history is full of discussions on the impacts of science, technology and innovation on society. And we owe to sociologists of the early 20th century the first systematic reflections on this subject. We also owe to them the first statistics developed for linking science, technology and innovation with their social impacts.

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1 B. Godin (2007), From Eugenics to Scientometrics: Galton, Cattell and Men of Science, *Social Studies of Science*, 37 (5), p. 691-728; B. Godin (2006), On the Origins of Bibliometrics, *Scientometrics*, 68 (1), p. 109-133.

2 B. Godin (2005), *Measurement and Statistics on Science and Technology*, London: Routledge.

3 OECD (2006), *Summary of the Workshop on Science Policy: Developing our Understanding of Public Investment in Science*, DSTI/STP/MS(2006)6, p. 2.

4 *Ibid.*, p. 3.

If Karl Marx has been an early student of technology among the economists[5], William J. Ogburn was the sociologist. Ogburn was one of those early researchers with an interest in the social impacts of science, technology and innovation[6]. Others were S. Colum Gilfillan, Hornell Hart and F. Stuart Chapin in the United States. In Europe, one can name the scientist J. D. Bernal. All shared an interest in science, technology and innovation and their impacts on society, and all five were quantifiers. Many theories, concepts and measurements yet to come in science, technology and innovation studies were already there (like the evolutionary nature of science, technology and innovation, exponential growth, the S-shaped curve). But Ogburn held a privileged place because of the volume and regularity of his writings over thirty years.

Ogburn has been as important to introducing the subject of technology in sociology as Robert K. Merton has been for science. After Ogburn, however, sociologists turned to the internalist, or Mertonian, analysis of the scientific community. It was left to economists to develop the study of impacts. As to their contribution to the debates on technological unemployment in the 1930s, economists started measuring labor productivity (and, later, multifactor productivity) as the main statistics on the impacts of science, technology and innovation. Since then, economic growth, productivity and competitiveness have entirely defined officials' understanding and measurement of the impacts of science, technology and innovation on society. Such impacts are many, but economists have focused, by definition, on economic ones, particularly economic growth, productivity and competitiveness. Governments followed. This happened from the very beginning of science policy in the 1960s, and acquired increased importance with new growth theories and discourses on the new economy in the

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5 N. Rosenberg (1976), Marx as a Student of Technology, *Monthly Review*, June-August, p. 56-77.

6 B. Godin (2008), Measuring the Social Impacts of Research: What History Teaches Us, in S. Kuhlmann (ed.), *Science Impact: Rethinking the Impact of Basic Research on Society and the Economy*, Forthcoming.

1990s. This focus on economic growth, productivity and competitiveness as impact of science, technology and innovation we owe largely to the accounting framework used for measuring science. To "accounting", the economics is what is significant, what is rendered visible and what becomes imperative for action. The social is the residual and is relegated to the periphery[7].

In the history of the OECD, there has been one and only one document centered on the social aspects of science, technology and innovation[8]. It never led to a conceptual framework. The document was rather an *erreur de parcours*. The organization, as we have seen, entirely devoted its energies to documenting the economic aspects of science, technology and innovation, and used conceptual frameworks of an economically-oriented type to this end: accounting, economic growth, productivity and competitiveness. More recent frameworks are still of an economic kind: national innovation system, knowledge-based economy and information economy.

In fact, it is organizations (and the economic sector to which they belong) that are the main actors of narratives on science, technology and innovation, above all firms (think of the innovation surveys), and not the individuals or groups who compose them, nor the people from society who are supposed to benefit from science, technology and innovation. Whereas early studies of science, technology and innovation, particularly sociological studies, were concerned with people and the varied impacts of science, technology and innovation on people's lives, conceptual frameworks used in policy focus entirely on economic issues. Economic growth, productivity, competitiveness and profitability generally drive policies.

If conceptual frameworks can be compared, to a certain extent, to T. Kuhn's paradigms in the sense that they serve as focusing devices for

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7 A. G. Hopwood (1984), Accounting and the Pursuit of Efficiency, in A. G. Hopwood and C. Tomkins (eds.), *Issues in Public Sector Accounting*, Oxford: Philip Allan, p. 167-187.

8 OECD (1971), *Science, Growth, and Society: A New Perspective*, Paris: OECD.

how to think about issues, there has been no revolution, or paradigm shift over the last sixty years. Certainly, the narratives have changed, as the emergence of new conceptual frameworks attests. But there has been no paradigm shift, only more economic obsession – under different guises[9]. The (official) statistics developed over history to support the frameworks are witness to this trend. Most are concerned with the economic dimensions of science. Thus, they have contributed to a specific understanding of science[10]. They are also responsible for the introduction into science studies and policies of concepts like scientific productivity[11].

A complete genealogy of the frameworks developed over the history of science policy waits to be written. Such a genealogy would certainly identify two broad types of frameworks: those concerned with accounting, and those based on economic performance. Under these two types, all the frameworks studied in this book fall, as well as narratives and statistics on science, technology and innovation.

Some authors often contrast science policies between two periods. The first period (policy for science) would have been concerned with funding science for its own sake, the golden age of university funding according to many researchers, while the second period (science for policy), in which we now live, is one where research is supported mainly for political and socioeconomic goals[12]. Such a contrast is not

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[9] On how science policy is about *how much* rather that *what for*, see: D. Sarewitz (2007), Does Science Policy Matter? *Issues in Science and Technology*, Summer, p. 31-38.

[10] B. Godin (2005), *Measurement and Statistics on Science and Technology: 1920 to the Present*, London: Routledge.

[11] B. Godin (2006). *Statistics and STI Policy: How to Get Relevant Indicators*. Communication presented at the OECD Blue Sky II Conference "What Indicators for Science, Technology and Innovation Policies in the 21st Century?" Canada: Ottawa. 25-27 September.

[12] See, for example, the Piganiol report OECD (1963), *Science and the Policies of Government*, Paris, p. 18, and the Brooks report OECD (1972), *Science, Growth and Society*, Paris: OECD, p. 37. See also: A. Elzinga and A. Jamison (1995), Changing Policy Agenda in Science and

unlike a more recent one constructed by M. Gibbons et al. on the new production of knowledge, where Mode 2 (after 1945) is defined with characteristics totally opposed to Mode 1 (before 1945)[13]. In fact, history is quite different. There has never been a "policy for science" period, as many authors argue, only a "science for policy" one, urging all sectors of society to contribute to innovation. Science policy has always been concerned with applying science to public goals. And from its very beginning, science policy, whether implicit or explicit, was constructed through reflections on accounting, economic growth, productivity, and competitiveness.

Technology, in S. Jasanoff et al. (eds.), *Handbook of Science and Technology Studies*, Thousand Oaks (Calif.): Sage, p. 572-597.

13 See B. Godin (1998), Writing Performative History: The New "New Atlantis", *Social Studies of Science*, 28 (3), p. 465-483.

APPENDIX 1

LABELS USED FOR MODERN SOCIETAL TRANSFORMATIONS, 1950-1984

(Beniger, 1986)

Year	Transformation	Source
1950	Lonely Crowd	Riesman, 1950
	Posthistoric Man	Seidenberg ,1950
1953	Organizational Revolution	Boulding, 1953
1956	Organization Man	Whyte, 1956
1957	New Social Class	Djilas, 1957; Gouldner, 1979
1958	Meritocracy	Young, 1958
1959	Educational Revolution	Drucker, 1959
	Postcapitalist Society	Dahrendorf, 1959
1960	End of Ideology	Bell, 1960
	Postmaturity Economy	Rostow, 1960
1961	Industrial Society	Aron, 1961; 1966
1962	Computer Revolution	Berkeley, 1962; Tomeski, 1970; Hawkes, 1971
	Knowledge Economy	Machlup, 1962; 1980; Drucker, 1969
1963	New Working Class	Mallet, 1963; Gintis, 1970; Gallie, 1978
	Postbourgeois Society	Lichtheim, 1963
1964	Global Village	McLuhan, 1964
	Managerial Capitalism	Marris, 1964
	One-Dimensional Man	Marcuse, 1964
	Postcivilized Era	Boulding, 1964
	Service Class Society	Dahrendorf, 1964
	Technological Society	Ellul, 1964
1967	New Industrial State	Galbraith, 1967
	Scientific-Technological	Richta, 1967; Daglish, 1972; Prague Revolution Academy, 1973
1968	Dual Economy	Averitt, 1968
	Neocapitalism	Gorz, 1968

	Postmodern Society Technocracy Unprepared Society	Etzioni, 1968; Breed, 1971 Meynaud, 1968 Michael, 1968
1969	Age of Discontinuity Postcollectivist Society Postideological Society	Drucker, 1969 Beer, 1969 Feuer, 1969
1970	Computerized Society Personal Society Posteconomic Society Postliberal Age Prefigurative Culture Technetronic Era	Martin and Norman, 1970 Halmos, 1970 Kahn, 1970 Vickers, 1970 Mead, 1970 Brzezinski, 1970
1971	Age of Information Communications Postindustrial Society Self-Guiding Society Superindustrial Society	Helvey, 1971 Oettinger, 1971 Touraine, 1971; Bell, 1973 Breed ,1971 Toffler, 1971
1972	Limits to Growth Posttraditional society World without borders	Meadows, 1972; Cole, 1973 Eisenstadt, 1972 Brown, 1972
1973	New Service Society Stalled Society	Lewis ,1973 Crozier, 1973
1974	Consumer Vanguard Information revolution	Gartner and Riessman, 1974 Lamberton, 1974
1975	Communications Age Mediacracy Third Industrial Revolution	Phillips 1975 Phillips, 1975 Stine, 1975; Stonier, 1979
1976	Industrial-Technological Society Megacorp	Ionescu, 1976 Eichner, 1976
1977	Electronics Revolution Information Economy	Evans, 1977 Porat, 1977
1978	Anticipatory Democracy Network Nation Republic of Technology Telematic Society Wired Society	Bezold ,1978 Hiltz and Turoff, 1978 Boorstin, 1978 Nora and Minc, 1978; Martin, 1981 Martin, 1978
1979	Collapse of work	Jenkins and Sherman, 1979

	Computer age	Dertouzos and Moses, 1979
	Credential society	Collins, 1979
	Micro millennium	Evans, 1979
1980	Micro revolution	Large 1980, 1984; Laurie, 1981
	Microelectronics revolution	Forester, 1980
	Third wave	Toffler, 1980
1981	Information society	Martin and Butler, 1981
	Network market place	Dordick, 1981
1982	Communications revolution	Williams, 1982
	Information age	Dizard, 1982
1983	Computer state	Burnham, 1983
	Gene age	Sylvester and Klotz, 1983
1984	Second industrial divide	Piore and Sabel ,1984

APPENDIX 2

METHODOLOGICAL DOCUMENTS FROM THE DIRECTORATE FOR SCIENCE, TECHNOLOGY AND INDUSTRY (OECD)

(First edition)

Manuals
The Measurement of Scientific and Technical Activities: Proposed Standard Practice for Surveys of Research and Development (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).
Handbook
OECD Handbook on Economic Globalisation Indicators (2005).
Framework
A Framework for Biotechnology Statistics (2005).
Guide
Guide to Measuring the Information Society (2005).
Statistics on the Careers of Doctorate Holders: Methodological Guidelines (2007).
Others
Bibliometric Indicators and Analysis of Research Systems: Methods and Examples (1997).

APPENDIX 3

Appendix

The Flow of Ideas through the Stages of Research, Invention, and Development to Application

	INPUT			OUTPUT	
Stage	Intangible	Tangible	Measurable	Intangible	Measurable
I "Basic Research" [Intended output: "Formulas"]	1. Scientific Knowledge (old stock and output from I-A) 2. Scientific problems and hunches (old stock and output from I-B, II-B and III-B)	Scientists Technical aides Clerical aides Laboratories Materials, fuel, power	Men, man-hours Payrolls, current and deflated Outlays, current and deflated Outlay per man	A. New scientific knowledge: hypotheses and theories B. New scientific problems and hunches C. New pratical problems and ideas	Research papers and memoranda; formulas ___ ___
II "Inventive Work" (Including minor improvements but excluding further development of inventions) [Intended output: "Sketches"]	1. Scientific Knowledge (old stock and output from I-A) 2. Scientific problems and hunches (old stock and output from II-A and III-A) 3. Practical problems and ideas (old stock and output from I-C, II-C, III-C and IV-A)	Scientists Non-scientist inventors Engineers Technical aides Clerical aides Laboratories Materials, fuel, power	Men, man-hours Payrolls, current and deflated Outlays, current and deflated Outlay per man	A. Raw inventions: technological recipes a. Patented inventions b. Patentable inventions, not patended but published c. Patentable inventions, neither patented nor published d. Non-patentable inventions, published e. Non-patentable inventions, not published f. Minor improvements B. New scientific problems and hunches C. New pratical problems and ideas	a. Patent applications and patents b. Technological papers and memoranda c. ___ d. Papers and memoranda e. ___ f. ___ ___ ___
III "Development Work" [Intended output: "Blueprints and Specifications"]	1. Scientific Knowledge (old stock and output from I-A) 2. Technology (old stock and output from III-A) 3. Practical problems and ideas (old stock and output from I-C, II-C, III-C and IV-A) 4. Raw inventions and improvements (old stock and output from II-A)	Scientists Engineers Technical aides Clerical aides Laboratories Materials, fuel, power Pilot plants	Men, man-hours Payrolls, current and deflated Outlays, current and deflated Outlay per man Investment	A. Developed inventions: blueprints, specifications, samples B. New scientific problems and hunches C. New pratical problems and ideas	Blueprints and specifications ___ ___
IV "New-type Plant Construction" [Intended output: "New-type plant"]	1. Developed inventions (output from III-A) 2. Business acumen and market forecasts 3. Financial resources 4. Enterprise (venturing)	Entrepreneurs Managers Financiers and bankers Builders and contractors Engineers Building materials Machines and tools	$ investment in new-type plant	A. New pratical problems and ideas	New-type plant producing a. novel products b. better products c. cheaper products

Source: F. Machlup (1962), *The Production and Distribution of Knowledge in the United States*, Princeton: Princeton University Press, p. 180-181.

APPENDIX 4

INDICATORS OF KNOWLEDGE FLOWS IN NATIONAL INNOVATION SYSTEMS

(National Innovation Systems, OECD, 1997)

Type of knowledge flow	Main [source of] indicator
Industry alliances	
Inter-firm research cooperation	Firm surveys
Literature-based counting	
Industry/university interactions	
Cooperative industry/university R&D	university annual reports
Industry/University co-patents	patent record analysis
Industry/University co-publications	publications analysis
Industry use of university patents	citation analysis
Industry/University information-sharing	firm surveys
Industry/University institute interactions	
Cooperative industry/institute R&D	government reports
Industry/institute co-patents	patent record analysis
Industry/institute co-publications	publications analysis
Industry use of research institute patents	citation analysis
Industry/institute information-sharing	firm surveys
Technology diffusion	
Technology use by industry	firm surveys
Embodied technology diffusion	input-output analysis
Personnel mobility	
Movement of technical personnel among	labour market statistics
Industry, university and research	university/institute reports

APPENDIX 5

INDICATORS FROM THE KNOWLEDGE-BASED ECONOMY: A SET OF FACTS AND FIGURES

(OECD, 1999)

1. **Knowledge-based economy**
   a. Investments in capital and knowledge
   b. Human resources (education)
   c. GERD
   d. Fundamental research
   e. Business R&D
   f. R&D in manufacturing industries
   g. R&D in services
   h. Innovation
   i. Venture capital

2. **Information and communication technologies (ICT)**
   a. ICT spending as a percentage of GNP
   b. Use of computers
   c. Internet and e-commerce
   d. ICT sector
   e. Innovation in ICT

3. **S&T policies**
   a. Public R&D/GNP
   b. Socio-economic objectives of R&D
   c. Share of public R&D
   d. R&D financial flows between sectors
   e. Public support to R&D

f. Business R&D by size
g. Tax subsidies

4. **Globalization**

a. R&D abroad
b. Patent ownership
c. Technological alliances
d. Co-signatures and co-inventions

5. **Output and impact**

a. Scientific publications
b. Patents
c. Innovation
d. Productivity
e. Share of knowledge industries in added value
f. High technology trade
g. Technological balance of payments

APPENDIX 6

INDICATORS FROM TOWARDS A KNOWLEDGE-BASED ECONOMY

(OECD, 2001)

A. Creation and Diffusion of Knowledge

Investments in knowledge

Domestic R&D expenditure

R&D financing and performance

Business R&D

Business R&D by industry

R&D in selected ICT industries and ICT patents

Business R&D by size classes of firms

Collaborative efforts between business and the public sector

R&D performed by the higher education and government sectors

Public funding of biotechnology R&D and biotechnology patents

Environmental R&D in the government budget

Health-related R&D

Basic research

Defence R&D in government budgets

Tax treatment of R&D

Venture capital

Human resources

Human resources in science and technology

Researchers

International mobility of human capital

International mobility of students

Innovation expenditure and output

Patent applications to the European Patent Office (EPO)

Patent families

Scientific publications

B. Information Economy

Investment in information and communication technologies (ICT)

Information and communication technology (ICT) expenditures

Occupations and skills in the information economy

Infrastructure for the information economy

Internet infrastructure

Internet use and hours spent on-line

Access to and use of the Internet by households and individuals

Internet access by enterprise size and industry

Internet and electronic commerce transactions

Price of Internet access and use

Size and growth of the ICT sector

Contribution of the ICT sector to employment growth

Contribution of the ICT sector to international trade

Cross-border mergers, acquisitions and alliances in the ICT sector

C. Global Integration of Economic Activity

International trade

Exposure to international trade competition by industry

Foreign direct investment flows

Cross-border mergers and acquisitions

Activity of foreign affiliates in manufacturing

Activity of foreign affiliates in services

Internationalization of industrial R&D

International strategic alliances between firms

Cross-border ownership of inventions

International co-operation in science and technology

Technology balance of payments

D. Economic Structure and Productivity

Differences in income and productivity

Income and productivity levels

Recent changes in productivity growth

Labour productivity by industry

Technology and knowledge-intensive industries

Structure of OECD economies

International trade by technology intensity

International trade in high and medium-high-technology industries

Comparative advantage by technology intensity

APPENDIX 7

BASIC DATA FOR INFORMATION POLICY

(From DAS/STINFO/69.10)

Characteristics of existing information sources and services:

(a) Type and number of primary services, volume of information, field, mode of financing services, etc.

(b) Type and number of secondary services, fields covered, services offered, number and qualifications of staff, equipment, performance, method of financing, etc.

Market for information:

(a) The various types of users, their present and potential specific needs;

(b) The foreseeable development of these needs;

(c) The relative efficiency of the various information services in the light of these needs;

(d) The identification of present and future needs to be met;

(e) The influence of promotion operations on the development of needs.

Role of information and its links with other activities:

(a) The educational role of information and the training facilities which the new information services need for their operators and users;

(b) The reciprocal relations and interaction of information and research;

(c) The contribution of information to the scientific, economic and social activities of the nation and how far would the development of certain information activities help the nation to achieve the goals it has set itself in these fields?

General economy of information activities:

(a) Cost of the main information services and their cost/efficiency ratios;

(b) The development prospects of certain services, enabling them to become self supporting;

(c) The general cost of information and its distribution among the different sectors of the economy;

(d) State finances assigned to these activities and the financial constraints applied;

(e) The foreseeable growth in costs and its distribution among the different sectors of the economy.

Characteristics of new systems:

(a) What are their technical characteristics and performances;

(b) How will they be integrated with existing services;

(c) What work of research, promotion and training will they need;

(d) What will they cost to install and operate and what commercial possibilities do they offer?

APPENDIX 8

BASIC STATISTICS FOR STI INDICATORS

(From DAS/STINFO/74.28)

Volume of information produced and used

Primary publications

a. number of publications (books, periodicals, etc.) produced by language
b. number of pages printed (number of pages x number of copies) by scientific disciplines and/or by mission

Secondary services

a. number of services by information activity
b. number of services by scientific discipline and/or mission
c. number of citations published
d. number of abstracts produced
e. number of existing databases by scientific discipline and/or mission
f. number of SDI profiles
g. number of retrospective searches

Libraries

a. number of libraries with number of books and number of periodicals held
b. number of books and periodicals lent
c. number of visitors or enquiries
d. number of photocopies and of microfiches produced
e. number of translations

Congress

a. number of national and international congresses, symposia, etc. by scientific discipline and/or mission
b. number of participants

Computer and communication

Computers used for STI activities

a. number of computers used full-time
b. number of computers used part-time
c. number of terminals

Volume of communication traffic

Potential users of STI

a. scientists and engineers by scientific discipline
b. scientists and engineers by sector of employment
c. R&D scientists and engineers by scientific activity
d. technicians by sector of employment

APPENDIX 9

POLICY ISSUES FOR ICC STATISTICS

(From ICCP (83) 9)

1. How fast are the information-technology-based activities being diffused in member countries? Is economic welfare related to the speed of diffusion?
2. What are the factors influencing the rate of diffusion? Are there any implications for policy formulation?
3. What have been and will be the likely effects of information technology on levels of employment (both direct and indirect)?
4. What have been and will be the likely effects of information technology on structures of employment? Which occupational groups are being made redundant; which new groups are being created; and which groups are being only marginally affected by the new technologies (to be broken down by industrial sector, sex, age, geographical location, etc.)?
5. Is information technology "neutral" or "biased" toward the relative saving of labor or capital?
6. What are the impacts of information technology on work and the home environment?
7. Will information technology affect income distribution between wages and profits, and if so, what remedial measures could be adopted?
8. Is information technology likely to initiate a new long-term cycle of investment and growth?
9. What are the factors fostering long-term business confidence and will information technology systems affect these factors?
10. Are existing financial mechanisms adequate to support the use of the new technologies and industries?

11. What are the effects of information technology on domestic and international market structures (e.g.: via scale economies, barriers to entry, etc.)?
12. What are the likely impacts of information technology goods and services on patterns of international specialization and trade flow?
13. Is information technology a useful medium for promoting "conservation" (e.g.: energy, materials, avoidance of pollution, etc.)?
14. Will information technology systems promote or retard the development of personal autonomy (privacy, etc.)?

APPENDIX 10

ICCP RED SERIES

1. Transborder Data Flows and the Protection of Privacy, 1979
2. The Usage of International Data Networks in Europe, 1979
3. Policy Implications of Data Network Developments in the OECD Area, 1980
4. Handbook of Information, Computer and Communications Activities of Major International Organisations, 1980
5. Microelectronics Productivity and Employment, 1981
6. Information Activities, Electronics and Telecommunications Technologies,
   Volume 1: Impact on Employment, Growth and Trade, 1981:
   Volume 2: Expert's Report ("Background Papers" Series)
7. Microelectronics, Robotics and Jobs, 1982
8. An Exploration of Legal Issues in Information and Communication Technologies, 1983
9. Software: An Emerging Industry, 1985
10. Computer-Related Crime, Analysis of Legal Policy, 1986
11. Trends in Information Economy, 1986
12. Information Technology and Economic Prospects, 1987
13. Trends in Change in Telecommunications Policy, 1987
14. The Telecommunications Industry: The Challenges of Structural Change, 1988
15. Satellites and Fibre Optics - Competition Complementarity, 1988
16. New Telecommunications Services - Videotex Development Strategies, 1989
17. The Internationalization of Software and Computer Services, 1989

18. Telecommunication Network-Based Services: Policy Implications, 1989
19. Information Technology and New Growth Opportunities, 1989
20. Major R&D Programmes for Information Technology, 1989
21. Trade in Information, Computers and Communications Services, 1990
22. Performance Indicators for Public Telecommunications Operators, 1990
23. Universal Service and Rate Restructuring in Telecommunications, 1991
24. Telecommunications Equipment: Changing Materials and Trade Structures, 1991
25. Information Technology Standards: The Economic Dimension, 1991
26. Software Engineering: The Policy Challenge, 1991
27. Telecommunications Type Approval: Policies and Procedures for Material Access, 1992
28. Convergence Between Communications Technologies: Case Studies for North America and Western Europe, 1992
29. Telecommunications and Broadcasting: Convergence or Collision?, 1992
30. Information Networks and New Technologies: Opportunities and Policy Implications for the 1990s, 1992
31. Usage Indicators: A New Foundation for Information Technology Policies, 1993
32. Economy and Trade Issues in the Computerized Database Market, 1993
33. The Economics of Radio Frequency Allocation, 1993
34. International Telecommunications Tariffs: Charging Practices and Procedures, 1994

35. Telecommunications Infrastructure: The Benefits of Competition, 1995
36. International Telecommunications Pricing Practices and Principles: A Progress Review, 1995
37. Price Caps for Telecommunications: Policies and Experiences, 1995
38. Universal Service Obligations in a Competitive Telecommunications Environment, 1995
39. Mobile Cellular Communication: Pricing Strategies and Competition, 1996

APPENDIX 11

BODIES OF THE OEEC/OECD RESPONSIBLE FOR INFORMATION

OEEC	
Working Party on Scientific and Technical Information	1949
OECD (Directorate for Scientific Affairs, then Directorate for Science, Technology and Industry)	
Committee for Scientific Research	
Ad Hoc Group on Scientific and Technical Information	1962
Ad Hoc Group on Information Policy	1965
Panel on the Economics of Information	1965
Committee on Science Policy (then Committee for Science and Technology Policy)	
Group on Computer Utilization	1969
Working Party on Information, Computer, and Communications Policy	1977
Group of Experts on the Economic Analysis of Information Activities	1977
Division on Information, Computer, and Communications Policy	1978
Committee on Information, Computer, and Communications Policy	1982
Ad Hoc Group on Information and Communication Statistics	1982
Group of Experts on the Economic Implications of Information Technology	1988
Working Party on Information Technology Policy	1993
Wor king Party on the Information Economy	1995
Statistical Panel on GII/GIS	1996
Working Party on Indicators for the Information Society	1998