# SCIENCE AND TECHNOLOGY POLICY

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**Contents**

**Summary**

Science and technology policy covers all the public sector measures designed for the creation, funding, support, and mobilization of scientific and technological resources. It covers a very broad range of knowledge producing activities. Definitions of the research endeavor abound and they depend upon the practical social, political, and economic context where they come from. This article presents basic definitions, as well as outlining the main changes that have modified the demands made on science and technology in the recent decades. A new institutional and economic framework has been set up where knowledge becomes the most important resource: the ways science is done and the way policy is conceived have been profoundly modified by a more direct and aggressive participation of the private sector, new perceptions of the role of the environment, the more active participation of the public in decision-making, networking, and the globalization of the economy. This context, where public and private research activities are closely related, represents a fundamental change in policy making motivations and needs. A brief historical evolution of S&T policies is presented before sketching the main actors that perform research, the policy making bodies, and the domains of intervention of public authorities. Innovation policy, which is now a central concern for policy makers, is also presented, since science, technology, and innovation are much closer today than they used to be. The international dimension of S&T policy is underlined. The theme article of this section of the Encyclopedia concludes with some possible future directions in S&T policy.

## 1. Introduction

Science and technology policy covers the public sector measures designed for the creation, funding, support, and mobilization of scientific and technological resources. S&T policies cover a very broad range of knowledge producing activities. These include public but also private sector activities, research as well as productive activities. The scope, aims, subjects, and mechanisms of S&T policies have varied widely over time. This theme section of the EOLSS will try to give a broad overview of the main issues at stake today and some understanding of the evolution of S&T policies. It will review the role of performers and policy making bodies, and the policy making processes. It will emphasize the radical changes that we have experienced in the last years which have profoundly affected the making of these policies, rather than proposing a collection of precise recipes on how to manage science and technology.

We have also opted in this theme introduction not to present detailed statistics to show the importance of the scientific or technological activities, but more precise indicators can be found in the articles that follow. We invite the interested reader to refer to the publications of UNESCO and the OECD. Among the best statistical presentations of the state of science and technology are the *Science and Engineering Indicators 2000* of the National Science Foundation (USA) and the *Indicateurs 2000* of the French Observatoire des Sciences et des Techniques (OST), which are essential for precise overviews (see *Bibliography*).

## 2. Questions of definitions

Questions of definition are a highly academic exercise. But, as Lewis Branscomb states in *Investing in Innovation*:

they lie at the heart of public policy debates about technology policy, not only because science is both a source and a product of technology, but because the boundaries between research that leads to new technical knowledge and research that leads to scientific understanding are obscure and often misunderstood. Before one can create a policy for public investment in research, one must know more about the goals of the work, who its intended beneficiaries might be, and how these results might reach those who can use them beneficially. These are the attributes that should determine the role of government in funding technical work, not the narrow distinctions between science and technology.

### 2.1. Science and technology, R&D, and other statistical categories

In the science policy literature, the usual definitions and distinctions between various types of scientific activities serve mainly statistical purposes. Manuals such as the *Frascati Manual* produced by the OECD, the *Science and Technology Policy Manual* of UNESCO, or policy documents of NSF present these definitions in some detail. Suffice to say here that all these manuals accept that research and development (R&D) comprises basic research, applied research, and experimental development. When looking at a scientist at work, however, it is quite difficult to know the exact brand of research he is involved in, and it is not really necessary to distinguish one type from another. As the Frascati Manual remarks, the only criterion that distinguishes all R&D from other technical activities is that the former contain some novelty, the degree of which varies from case to case.

*Science and technology* refers here to all technical and knowledge production activities, whether novel or not. *Scientific* activities are mainly aimed at producing organized knowledge about physical, chemical, and natural phenomena. It is difficult to give a definition because science is a polysemic word with a long history, covering multiple types of activities. Compare the work of a botanist, an archeologist, a nuclear physicist or a statistician. All differ in the object of research, its scope, and concepts. Epistemology has tried to give precise definitions of what is scientific and what is not. The question seems somewhat pointless, and there is no real need to proceed to this boundary definition work. In fact, scientists at the frontiers of knowledge constantly redraw the boundaries of what belongs to their domain of competence and what does not. For the policy makers, it suffices to note that this boundary work is unfolding all the time and that these boundaries may be moving. Policy is also about boundaries of competencies and means that are mobilized. Policy makers and scientists alike now accept this fact and no one can claim to have absolute truth or be entirely in the right when controversies or conflicts of interests appear.

"Research and development" (R&D) refers usually to research, both *basic* and *applied*, and *technological development* activities in the sciences and engineering, as well as in R&D plants in businesses. The term is commonly used to refer to research activities in firms. Some institutions, for instance the European Union, prefer to use the abbreviation RTD.

*Research* is systematic study directed toward fuller scientific understanding of a subject. It is commonly classified as either *basic* or *applied research*, on the basis of either the objectives of the work done, or the objectives of the institution that carries it out or the agency that sponsors it. The latter approach to distinguishing between basic and applied research appears more realistic, because in practice it is difficult to distinguish them. None the less, definitions proposed by the Frascati Manual or the American Association for the Advancement of Science (AAAS) – to take only two examples – insist on defining the nature of the research activity by its *purposes* and *objectives*.

In *basic research* the objective of the sponsoring agency is to gain fuller knowledge or understanding of the fundamental aspects of phenomena and of observable facts without specific applications toward processes or products in mind.

In *applied research* the objective of the sponsoring agency is to gain knowledge or understanding necessary for determining how a recognized and specific need may be met.

*Development* is the systematic use of the knowledge or understanding gained from research for the production of useful materials, devices, systems, or methods, including design, development, and improvement of prototypes and new processes. It does not include quality control, routing product testing and evaluation.

*Source*: adapted from the OECD Frascati Manual and definitions proposed by the National Science Foundation, Federal R&D Funding by Budget Function Fiscal Years 1994-96, NSF 95-342, 1995, and other NSF publications.

Box 1. Definitions of research

*Technology* is knowledge produced around technical artifacts. The most elegant definition of technology is probably this: "practical knowledge." Rather than looking for a precise definition, it is more useful to see what technology is composed of. It comprises three interdependent components: i) material artifacts, usually machinery and pieces of equipment, that are used as tools; ii) knowledge and information on the productive processes where this equipment is used; and, iii) people – "human resources," that is technicians, engineers, workers, scientists – who operate the equipment and put the practical knowledge into action. Technology is neither exclusively hardware, nor exclusively software; it is a combination of software, hardware, and discourse (*logos*) that ties these elements in practical processes. Not all the knowledge produced is explicit. Technology always contains *tacit knowledge,* that is, knowledge embedded in the hands and the minds of people who use the technical artifacts. This "tacit" component is usually rather important as without it one does not have a clue to the correct use of a piece of equipment or a software.

Today the more sophisticated technologies need more scientific knowledge. For example, biotechnologies, polymeric materials, and automated equipment all need a fine-grained knowledge of chemical reactions, processes, biological functions, and software development. Some scientific disciplines are mainly built on disciplinary boundaries. Research laboratories that work on medical imagery for example would combine physics, biomedicine, engineering, and informatics. New technologies include large amounts of tacit knowledge, that is, know-how acquired through use. This boundary research, which we might call "*basic technological research*," turns out to be more common and more important than "basic" or "applied research."

*Innovation* is an entirely different matter. Innovation is the introduction of a *novel* product or process (and can also relate to organizational matters). Innovation mainly occurs in enterprises, although various types of actors might be associated to it. But the single most important feature of innovation is that it is an economic process. It does not rely exclusively on research but makes heavy use of it. According to the 1994 survey of innovative companies in the United States, 84 percent of all innovators undertook R&D in 1992, and 91 percent of innovators plan to do so during 1993–5. Innovators report similar figures in all countries. But managing innovation does not just mean managing R&D. It also includes other activities that are complementary to it, and might draw its energy from sources other than R&D. In fact, versatility and diversity of sources are intrinsic to the innovation phenomenon. Successful innovations combine R&D and other activities such as sound management practices and strategic analyses that allow innovators to visualize simultaneously their market positions and technical possibilities.

### 2.2. The multiple dimensions of the research endeavor

S&T can no longer be considered as unidimensional activities. It is possible to distinguish the different roles of research, the value given to their production and the logic they will follow. Scientists and scientific teams can act in various ways.

1. They produce scientifically certified knowledge. Scientists follow the logic of scientific competition and seek scientific recognition; the value of their knowledge – originality, quality, and so on – is certified by their peers.

2. They participate in productive activities. Scientists engage in economic activities and their work will be linked to innovation and technology diffusion.
3. They participate in general interest activities, where the objectives of their research are neither purely scientific, nor purely economic. Political judgment is what gives value to this kind of research.
4. They are involved in training at universities or research centers. This activity, usually mandatory for university researchers, follows the logic of the educational system.
5. They can diffuse knowledge to the general public or carry out expertise functions for specific publics. The value of knowledge depends on the public that is targeted, and the way scientists will exercise their expertise will be very much dependent on the activity (for example participation in environmental activities or in scientific museums and exhibitions, writing articles for the lay public, testifying for a tribunal or an inquiry committee). It should also be emphasized that scientific knowledge is more and more called in by the judiciary.

Scientists can act in all these possible knowledge-producing dimensions. They can, on the other hand, perform only one of these roles. Frequently, however, research needs to act in at least two of these dimensions. It is important to stress that these are *interdependent activities*. Even though an individual can decide to specialize in a specific topic and in a particular dimension, a larger understanding of how research is performed, used, and supported needs to focus on all these dimensions. This goes beyond the usual distinction between basic, applied or technological research. It even goes beyond the distinction between academic or innovation activities, which are usually seen as opposed.

### 2.3. The real scope of science and technology policies

The spectrum of possible domains of intervention for public policy is wider than mere support for research laboratories owned by the state. Science policy is more than the management of R&D, just as innovation is more than simply fostering R&D activities in firms. The management of an innovation policy or the design of a scientific policy will differ, and they need to be considered as complementary activities. All these different activities concern *knowledge production*, which is the core objective of S&T policies.

Knowledge production is not limited to research laboratories. Schools, firms and other institutions produce, use, and pass on knowledge. The dissemination of knowledge relies in its absorption and mastering by those who learn from it by using it. Technology transfers, schooling, and education, the development of the informational infrastructure, access to sources of information are all essential aspects for knowledge production. Thus S&T policies need to facilitate *knowledge diffusion*.

Knowledge is always produced by interacting social actors. Its creation does not depend only on science, nor solely on technical know-how. It depends on the links that may be forged and developed between different sorts of users of a particular knowledge. A “knowledge base” is always a set of interactions. Thus, *science and technology policy always concerns the management of extended techno-economic networks*. It has to understand and manage the interconnection of scientific and technical capabilities, taking into account economic and technological constraints. This *co-ordination* work has become crucial in areas such as the management of scientific information databases and of useful data, the definition of quality and security norms, the establishment of sound design principles in technological and scientific matters, and more generally the normative and regulatory action of authorities with regard to knowledge and its use.

## 3. The new social and institutional framework

Research has changed because the institutional environment has been profoundly modified. In recent years, many authors have tried to understand the meaning of these changes; they have designated the new mode of knowledge production as "mode 2", as opposed to the older mode of knowledge production or "mode 1." The background document of the UNESCO World Conference on Science in the Twenty-first Century also tried to understand the implications of these changes for policy, mainly from the perspective of scientists, and produced an agenda for a new social contract between scientists and society (see Annex: *A New Social Contract for Science*). We will review some new factors that directly affect science policy making before sketching an overview of the historical evolution of the science policy making processes.

### 3.1. Science and technology as closer endeavors

Scientific discoveries are occurring ever more quickly and modes for producing new knowledge are changing, thereby making the use of technology in knowledge production more necessary than ever before. The development of technological innovation is increasingly dependent on scientific discoveries. New "generic technologies" in the realms of information and communication, biotechnology, energy, and new materials have appeared. These technologies rely heavily on automation, basic scientific research (also named "basic technological research"), and innovative skills. Specific leading industrial sectors are concerned with these technologies and are usually identified by catchwords such as "high-tech industries" or "strategic sectors": aeronautics, electronics, pharmacy, electrical equipment are among the more important ones, and, to a lesser extent, the automobile and chemical industries. The sectors that consume the greatest amounts of "high-tech" goods are education, communications, and information. In recent years the high-tech industries have been the major exporting industries: they represent more that 37 percent of the exports of the United States, 36 percent of Japan's, 32 percent of the United Kingdom's, and between 21 and 25 percent of the exports of France, the Netherlands, Germany, and Sweden. The OECD claims that 50 percent of gross domestic product in the major OECD economies is now "knowledge based."

These changes have blurred the traditional distinction between science and technology. This affects the approach to policy making on transfers of technology from research environments (laboratories and research institutions) to productive environments (enterprises). We used to think of this relation as linear, with the development of productive innovations and new technologies following a temporal sequence that begins in research activities, continues through a phase of product development which then leads to the potential production and marketing of innovative goods. In this linear model science precedes technology, which in turn precedes innovation. The model has been profoundly challenged and an alternative interactive model has been proposed, based on the idea that the relations between knowledge production and the end-users (be they in the markets or elsewhere) are more important than they were. At each step of the process of innovation, outcomes are uncertain. Central to the success of innovation is the continuous interaction between marketing and the invention of new designs. Innovation may rely on new uses of an old technique, it may come from research results or it may emerge from technological problems that need to be solved. All of these at some point need an interaction with users in the knowledge process. R&D needs continuous feed-back from productive areas. The way a new idea or a new artifact will be received has a long-term effect on its further form and uses.

The implications for research are important as soon as we take into account this non-linear model of innovation. R&D appears as a complex activity, basically relying on frequent interactions between research, technology, and markets. S&T policy must therefore enhance this continuous interaction between those who conceive and those who use the technologies.

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**Bibliography**

***Journals***

Many books and readings have been proposed at different periods on the theme of science and technology policy, but journals are the best. *Research Policy* and *Science and Public Policy* are among the best journals in the area. Useful mate-rial can also be found in more sociologically oriented journals such as *Social Studies of Science* and *Science, Technology and Human Values* (the journal of the Society for the Studies of Science). Other journals with more specialized scope exist such as: *Minerva, Research Evaluation, Technology and Culture, Science, Technology and Society, The Journal of Technology Transfers, Issues in Science and Technology*. Economics, engineering, sociology, and management journals have in the recent years been more open to debates on S&T policy.

***Books and articles on the state of science***

[Many books provide a description of the state of the cientific forces]

NATIONAL SCIENCE BOARD/NATIONAL SCIENCE FOUNDATION. *Science and Engineering Indicators.*[Essential reading for all policy makers, contains the basic indicators on science and technology in the United States and some international comparison. The 2000 edition has an interesting comparative analysis of the main themes in science policy making in the United States since 1949.]

OBSERVATOIRE DES SCIENCES ET DE TECHNIQUES. 1999. *Science et Technologie. Indicateurs 2000. Rapport de l'Observatoire des Sciences et des Techniques*. Paris, Economica. 463 pp. [Reports all known science indicators for France. Overview of Europe. Comparison with United States and Japan. The 1999 edition contains overviews of science in Brasil, India and China. OST reports have been published every two years since 1994.]

OECD. 1970. *Manuel d'inventaire du potentiel scientifique et technique national (Manuel de Frascati)*. Paris, OECD. [Contains the main definitions and guidelines for gathering statistics on inputs for scientific and technological research.]

OECD. 1992. *Oslo Manual*. *OECD Proposed Guidelines for Collecting and interpreting Technological Innovation Data*, OECD/GD (92)/26). Paris, OECD. [Manual used in defining the standard for innovation surveys; contains basic definitions.]

UNESCO. 1998. *World Science Report*. Elsevier and UNESCO Publishing. 288 pp. [This book contains an overview of the state of science in the world with specific chapters for countries and regions of the world.]

***Some web resources on the state of science***

USA: National Science Foundation: http://www.nsf.gov

Science and Engineering Indicators 2000: http://www.nsf.gov/sbe/srs/seind00/start.htm

Canada: Observatoire des Sciences et des Technologies (Québec) – Contains an excellent list of links on the subject: http://www.ost.qc.ca/OST/index.htm

France: Observatoire des Sciences et des Techniques http://www.obs-ost.fr

The OECD Site contains some publications on-line, in particular the Science, Technology and Industry division: http://www.oecd.org/dsti/sti

UNESCO Site on the World Science Conference contains the Declaration on Science and the Use of Knowledge: http://www.unesco.org/science/wcs/eng/declaration_e.htm

***Books and articles***

[It is impossible to produce a comprehensive *short* bibliography on the theme of science and technology policy because of the variety of different situations around the world, the range of specific dimensions such as innovation policy, energy, health, environment, and the complexity of the science policy theme itself. The bibliography of article 1.30.3 contains many items specific to the United States of America. We focus here on the more general aspects.]

AMABLE, B.; BARRÉ, R.; BOYER, R. 1997. *Les Sytèmes d'Innovation à l'Ere de la Globalisation*. Paris, Economica. 401 pp. [A comprehensive analysis of innovation systems from the social, political and economic point of view with an extensive overview of the literature and comparative analysis of innovation systems.]

AMSDEN, A. 1989. *Asia's Next Giant: South Korea and Late Industrialization*. London, Oxford University Press. 379 pp. [This book is one of the best introductions to the debate on the growth of East Asia and the role technology learning has played in economic development. Although its view has been challenged, this analysis is fundamental for part of the debate on the need for innovation and technology policies.]

ARVANITIS, R.; GAILLARD, J. (eds.) 1992. *Les Indicateurs de Science pour les Pays en Développement* [Science Indicators in Developing Countries]. Colloques et Séminaires. Paris, Editions de l'ORSTOM. 670 pp. [This collection of articles on indicators in developing countries offers a broad overview of issues and methods.]

ARVANITIS, R.; VILLAVICENCIO, D. (eds.) 1998. Comparative Perspectives on Technological Learning. Special issue of *Science, Technology & Society*. New Delhi, Sage. 264 pp. [Contains examples of the link between technological learning and innovation, mainly in Asian and Latin American countries. Also a useful introduction to the concepts that are used in innovation policy.]

BASTOS, M-I; COOPER, C. 1996. *Politics of Technology in Latin America*. Maastricht, Routledge and UNU/Intech studies in new technologies and development. 258 pp. [This book contains many examples of a political approach to science and technology policy in Latin America.]

CALLON, M. 1994. Is science a public good? *Science, Technology, and Human Values*, Vol. 19, No. 4, pp. 395–424. [A most insightful analysis of the notion of public goods in science and technology. The author has proceeded to examine the science policy consequences in "Four models for the dynamics of science," in S. JASANOFF, G. E. MARKLE, J. C. PETERSEN and T. PINCH *Handbook of Science and Technology Studies*, pp. 29–63, London and New Delhi, Sage.]

CALLON, M.; LARÉDO, P.; MUSTAR, P. (eds.) 1995. *La Gestion Stratégique de la Recherche et de la Technologie: L'Evaluation des Programmes* [The Strategic Management of Research and Technology: Program Evaluation]. Paris, Economica. 477 pp. [A good overview of new evaluation methods for programs with examples of how the work can be done.]

CALLON, M.; LASCOUMES, P.; BARTHE, Y. 2001. *Agir dans un Monde Incertain: Essai sur la Démocratie Technique*. Paris, Le Seuil. [A very lively and novel way of discussing the problem of technological democracy and of users participation in the making of research programs. This book draws on an extensive primary literature on cases of scientific and technological controversies.]

COZZENS, S. E.; HEALEY, P.; RIP, A.; ZIMAN, J. (eds.) 1990. The Research System in Transition. Dordrecht, Kluwer Academic. 420 pp. [Overviews of the many debates around the changes that research underwent in the 1980s.]

DE BRESSON, C.; WALKER, R.; UTTERBACK, J. M. 1991. Networks of innovators. A special issue of *Research Policy*, Vol. 20, No. 5, pp. 363–514. [Special issue which contains an overview of the concept of networks in innovation policy and economics, as well as many examples.]

ELZINGA, A.; JAMISON, A. 1995. Changing Policy Agendas in Science and Technology. In S. JASANOFF et al. *Handbook of Science and Technology Studies*, pp. 572–97. London and New Delhi, Sage. [Excellent overview of the agendas, mainly through the OECD proposals on S&T and innovation policies.]

ETZKOWITZ, H.; LEYDESDORFF, L. (eds.) 1997. *Universities in the Global Knowledge Economy: A Triple Helix of University–Industry–Government Relation*s. London, Pinter. 184 pp. [Contains examples of how the changes in the institutional context have affected the relations of Universities to the economy.]

GIBBONS, M.; LIMOGES, C.; NOWOTNY, H.; SCHWARTZMAN, S.; SCOTT, P.; TROW, M. 1994. *The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Society*. London, Sage. 179 pp. [This famous book can be seen as a manifesto for a renewed analysis of the role of S&T in the knowledge economy.]

IRVINE, J.; MARTIN, B. 1989. *Research Foresight: Creating the Future*. Ministerie van Onderwijs en Wetenschappen [Netherlands Ministry of Education and Science]. 324 pp. Also published in an earlier version by Pinter (London), in 1984. [A useful overview of concepts of research and technology foresight exercises and the practice of foresight in different countries.]

JASANOFF, S.; MARKLE, G. E.; PETERSEN, J. C.; PINCH, T. (eds.) 1995. *Handbook of Science and Technology Studies*. London/New Delhi, Sage. 820 pp. [This handbook contains indispensable articles on science studies and some policy-oriented articles.]

LATOUR, B. 1987. *Science in Action*. Cambridge, Mass., Harvard University Press. 274 pp. [Although not a "science policy" analysis book, *Science in Action* is a good methodological introduction to the analysis of science in the making. A necessary book in order to understand the difficulties inherent to science policy analysis.]

LUNDVALL, B.-Å. (ed.) 1992. *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning.* London, Pinter. 342 pp. [The authors have tried to figure out the theoretical aspects of the notion of system of innovation.]

NELSON, R. R. (ed.) 1993. *National Innovation Systems: A Comparative Analysis*. New York, Oxford University Press. 541 pp. [Contains examples of national innovation policies in many countries.]

OECD. 1992. *La Technologie et l'Economie: Les Relations Déterminantes* [Technology and economy: the determinant relations]. Paris, OCDE. 364 pp. [Versions in French and English. Final report of the technology and economy research program at OECD which marks a turn in economic studies.]

OFFICE OF TECHNOLOGY ASSESSMENT (OTA). All documents that were issued by this groundbreaking institution are available on-line at http://www.wws.princeton.edu/~ota/.

PICKERING, A. 1995. *The Mangle of Practice: Time, Agency, and Science*. Chicago, Chicago University Press. 281 pp. [Although the book appears an esoteric discussion between sociologists of science, particularly in its introductory parts, it contains examples and a synthesis that tries to overcome common difficulties in understanding where science is going in today's world.]

RIP, A.; BAREND, J. R. VAN DER MEULEN. 1996. The Post-modern Research System. *Science and Public Policy*, Vol. 23, No. 5, pp. 343–52. Also published in R. BARRÉ et al. (eds.), *Science in Tomorrow's Europe*, pp. 51–67. Paris: Economica International, 1997. [Compares the relations between the research systems and the patterns of interactions between actors in the making of science in a number of national research systems.]

SALOMON, J.-J. 1973. *Science and Politics*. Cambridge, Mass., MIT Press. 277 pp. [Pioneering work, first published in France in 1970, on the political role of scientists, the weight of scientific affairs on national and international issues, the irreversible links between knowledge and power.]

SALOMON, J.-.J.; SAGASTI, F.; SACHS-JEANTET, C. (eds.) 1994. *The Uncertain Quest: Science, Technology, and Development*. Tokyo/Paris/New York, United Nations University Press. 532 pp. [This is a recent sourcebook on science policy.]

SCLOVE, R. E. 1995. *Democracy and Technology*. New York, Guilford. 338 pp. [From an early advocate of citizen's participation in science policy making and founder of the Loka Foundation; contains a good overview of the issues at stake.]

TIDD, J.; BESSANT, J.; PAVITT, K. 1997. *Managing Innovation: Integrating Technological, Market, and Organizational Change*. Chichester and New York, Wiley. 377 pp. [This textbook is one of the best introductions to the economic and management issues of innovation.]

VONORTAS, N. S. 1997. *Cooperation in research and Development*. Holland, Kluwer Academic. 288 pp. [One of the most complete economic analyses of alliances and cooperation for innovation and R&D in the United States.]

WAAST, R. (ed.) 1994. *Sciences Hors d'Occident*. Paris, Unesco/ORSTOM. [This series of 6 volumes with many contributions contains a large overview of the development of science in the developing world.]

WORLD BANK. 1999. Knowledge for Development: World Development Report 1998–1999. Washington D.C., The World Bank. 252 pp. [This edition of the annual report of the World Bank focuses on the knowledge economy and its economic consequences, particularly for the developing world.]

ZIMAN, J. M. 1994. *Prometheus Bound: Science in a Dynamic Steady State*. Cambridge, Cambridge University Press. 289 pp. [One of the very first attempts to grasp the implications of the changes in the nature of scientific research.]



**Biographical Sketch**

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