APPENDIX D

Academic and Basic Research Decisionmaking in Other Countries[1]

Compared to the United States, other countries have implemented vastly different organizational structures for their research systems. OTA has surveyed research decisionmaking practices in nine countries, including the United Kingdom, the Federal Republic of Germany, France, Japan, the Netherlands, Sweden, Canada, Australia, and India. It is clear that the institutional structures of policymaking and funding are critical determinants of the way in which governments support basic research, and provide a powerful context to which any new methods of selection of basic research must be adapted.[2] The reasons for this influence are at least twofold.

First, institutional structures strongly reflect the particular political, economic, and, more generally, cultural history of a country. While there maybe certain universality in science, this does not carry over to science policy. Thus, it is essential for any comparative study of international science policies to place them in the context of national culture.

A striking example of these contexts is the heterogeneity of different national research systems. As Ziman noted in the United Kingdom and the United States, the academic department-". . . a multi functional organizational entity responsible for all teaching, research and other activities in a broadly defined scientific discipline . . . "3-is the predominant form of scientific organization. In contrast, France with its Centre National de la Recherche Scientifique laboratories and Germany with its Max Planck Institutes have research institutes, staffed by full-time researchers working in a designated problem or disciplinary area, as the most common model of research organization.

Second, decisionmaking structures themselves reflect in part previous processes of selection of basic research. Some claim, for example, that:

> . . . the Big Sciences such as high-energy physics and astronomy, which were funded generously in the past are now, as a result, well represented on decision-making bodies. There has, therefore, been a tendency for early established sets of priorities and research interests to become "frozen in" the decisionmaking structure,[4]

In this section, the research systems in nine countries will be highlighted and their priority-setting mechanisms examined (see table D-1 for a summary). Unfortunately the only comparable figures on the funding of research are aggregated with development. Figure D-1 shows the United States, West Germany, and Japan with comparable total research and development (R&D) funding levels as a percent of GNP, but West Germany and Japan at much higher levels for nondefense R&D. The United Kingdom and France spend less on R&D in both categories. For ease of comparison to the United States, the focus of this appendix will be on academic research, the bulk of which is carried out in the national universities of each country.[5] Some generalizations about methods of priority setting will be drawn first between the nine foreign countries studied, and then applications to the U.S. research system will be discussed.

United Kingdom

Three main themes run through the United Kingdom's government support of civilian academic science: the importance of maintaining and enhancing quality in science, increasing the economic and social returns from science, and better management through greater concentration and selectivity of science activities. Strenuous efforts have been made to introduce new policies to achieve those objectives.

The government reviews its R&D funding annually, but there is no overall R&D budget. The system is highly decentralized and each academic department determines its own R&D programs in the light of its own policy objectives and priorities. Recent decisions to exclude the public funding of near-market research led to some

[1]This appendix is based on Ron Johnston, University of Wollongong, Australia, "Project Selection Mechanisms: International Comparisons," OTA contractor report, July, 1990. Available through the National Technical Information Service, see app. F. The work on this contract was completed before East and West Germany united. Also see Leonard L. Lederman, "Science and Technology Policies and Priorities: A Comparative Analysis," *Science, vol.* 237, Sept. 4, 1987, pp. 1125-1133.

[2]'Institutional structures'' refer t. the bodies—often administrative agencies, advisory councils, and review panels-that implement policies for priority setting and funding in science.

[3]John Ziman, *Restructuring Academic Science* (London, England: Science Policy Support Group, 1989).

[4]J. Irvine and B. R. Martin, "~t Direction for Basic Scientific Research,'' *Science and Technology Policy in the 1980s, M.* Gibbons and A. Udgaonkar (eds.) (Manchester, England: Manchester University Press, 1985).

[5]Except in Canada, where research is conducted in provincial universities.

Table D-l—Recent Approaches to More Selective Support of Basic Research

Country/agency	Steering device	Priority setting: Method	Priority setting: Decisionmakers	Status
UK				
UFC	Selective core funding to universities	NA	NA	Government appointed
ABRC	Interdisciplinary Research Centers (1988)	Submissions and internal discussion	Panels	Appointed
SERC	Directorates (7 years) and Program (5 years)	Internal discussion	Council (peers and users)	Appointed
ESRC	Centres (5-15 years)	Internal discussion	Council (peers and users)	Appointed
FRG				
DFG	Priority programs	Bottom-up discussion	Researchers	Elected
MPG	Priority research areas institutes	Bottom-up discussion	Researchers	Elected
France				
MRT	Programmed mobilisateurs	Identification of generic technologies	CPE and department officials	Elected and appointed
CNRS	Annual strategic plans	Identification of leading researchers	Council peers and department officials	Elected and appointed
Japan				
Monbusho	Priority research areas (3-6 years)	Identification of areas of strong scientific opportunity and social need	Monbusho Science Council	Appointed
	Specially promoted research (5 years)	Selection of 2 key fields and program leader	Science Council	Appointed
Netherlands				
MES	Conditional funding of university research	NA	NA	Appointed
NWO	Second flow funding	Identification of future needs and priorities	RAWB (appointed) and NWO	Elected
Sweden				
Cabinet	Research policy bill	Wide consultation, symposia, reports over 2 years; and government departments, scientific societies, researchers	Effective consensus	NA
NFR	Consortia	Invitations to consortium of university departments to propose interdisciplinary programs	Council (appointed and elected)	Appointed and elected
FRN	Priority fields	Identification of societal problem, then elaboration of research needs and opportunities	Council and committees (research and users)	Appointed and elected
Canada				
ISTC	Decision framework for science and technology	Computation of agencies' research priorities, identifying strengths and gaps	ISTC	NA

Continued on next page

transitory increase in funds for research. However, the funding outlook has now dimmed.[6]

The major source of funds for academic research is the Department of Education and Science (DES). It provides general support for university teaching and research through the Universities Funding Council (UFC) and five research councils, in what is commonly referred to as the ''science budget. The DES-supported research councils provide funds on a competitive basis to university researchers and in most cases maintain their own research centers. The research councils have a high degree of autonomy in establishing their own priorities and procedures. The Advisory Board of the Research Councils (ABRC) also plays an important role in advising DES on the overall budget and on the allocations to the five councils.

[6]For example, see Jeremy Cherfas, "Deficits Trip U.K. Science Funding Agencies," Science, vol. 250, Dec. 14, 1990, pp. 1504-1505; and Peter Aldhous, "UK Nuclear Physicists Fear SERC's Cuts$" *Nature*, vol. 349, Jan. 31, 1991, p. 357.

Table D-l—Recent Approaches to More Selective Support of Basic Research—Continued

Country/agency	Steering device	Priority setting: Method	Priority setting: Decisionmakers	Status
NSERC	Strategic grants program	Identification of 30 themes in the 3 national priority areas by consultation, analysis, and workshops	Science Council of Canada	Appointed
SSHRC	Strategic research program	Biennial seminars and commissioned reviews	Council (department officials and researchers)	Appointed
Australia				
ARC	Priority research areas	Submissions consultation and internal discussion	Council (researchers)	Appointed
NH&MRC	Priority research fields	Internal discussion and consultation	Council (researchers) and panels	Appointed
India				
National Development Council	Five-year Science and Technology Plan	Expert reports, consultation, draft reviews	Council (government officials)	NA
SERC	Thrust area programs	National exercise of working paper preparation, review, national seminar	Council and program advisory committees (scientific experts and government officials)	Appointed
	Intensification of research in high-priority areas scheme	Thrust area identification exercise	PACS	Appointed

KEY:
ABRC = Advisory Board of the Research Councils
ARC = Australian Research Council
CNRS = Centre National de la Recherche Scientifique (National Center of Scientific Research)
CPE = Centre de Prospective et Evaluative (Prospects and Evaluation Center)
DFG = Deutsche Forshungsgemeinschaft (German Research Society)
ESRC = Economic and Social Research Council
FRG = Federal Republic of Germany
FRN = Council for Planning and Coordination of Research
ISTC = Industry, *Science* and Technology Canada
MES = Ministry for Education and Science
Monbusho = Ministry of Education, Science, and Culture
MPG = Max Planck Gesellschaft (Max Planck Society)
MRT = Ministry of Research and Technology
NA = Not available
NFR = National Science Research Council
NH&MRC = National Health and Medical Research Council
NSERC = Natural Sciences and Engineering Research Council
NWO = Netherlands Organization for Scientific Research
PAC = Program Advisory Committee
RAWB = Science Policy Council of the Netherlands
SERC = Science and Engineering Research Council
SSHRC = Social Sciences and Humanities Research Council
UFC = Universities Funding Council
UK= United Kingdom

SOURCE: Ron Johnston, "Selection of Basic Research: An International Comparison," OTA contractor report, June 1990, table 3. Available through the National Technical Information Service, see app. F.

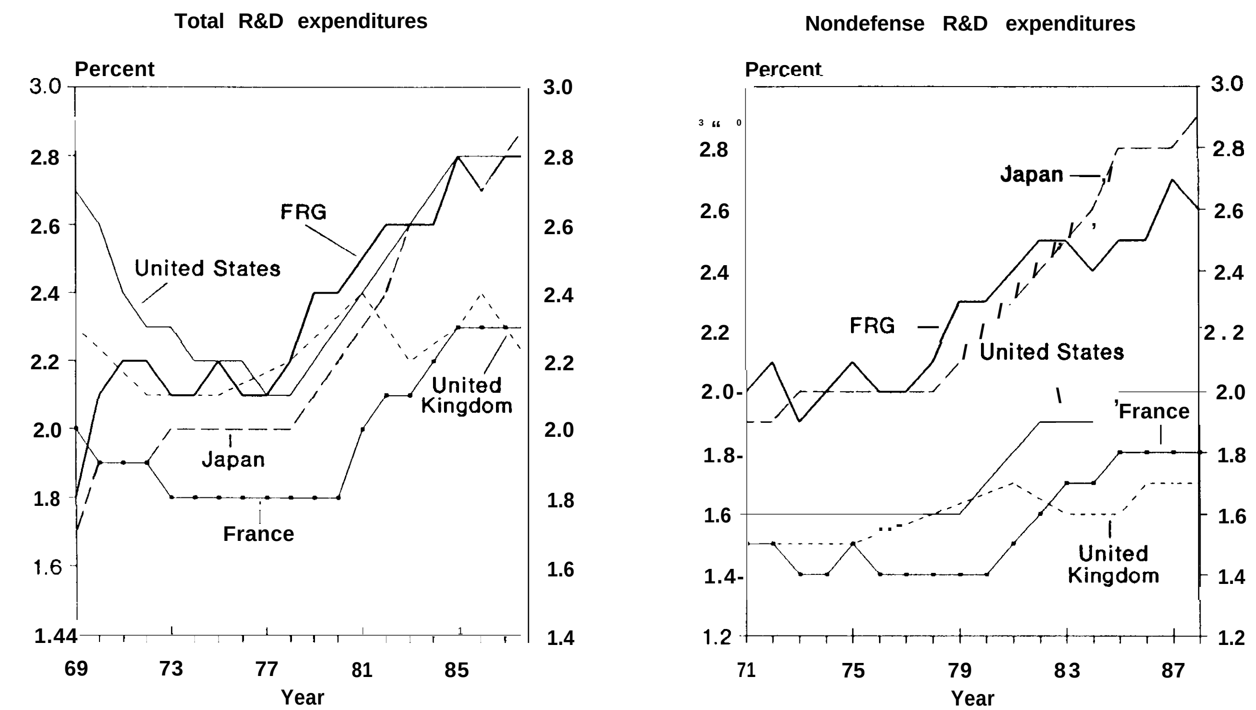
Recently UFC introduced a system of ranking academic departments on their research capability as part of the determination of support.[7] General University Funds are distributed by UFC, one component of which is for the support of research, though universities may use these funds for education as well. Since 1986, the formula to determine how much should be given to a department favors those institutions judged to have high-quality research. In 1989, UFC further ranked departments within universities on a scale of 1 to 5. The criteria used to determine ratings were: 1) publications, 2) success in obtaining research grants and support for students, 3) success in obtaining research contracts, and 4) the professional judgment of advisory group and panel members. There is considerable debate on the efficiency of this approach.[8]

ABRC has also initiated or encouraged a number of new procedures in the allocation of support for academic research. The first has been to increase the proportion of funding flowing to "directed programs" which have increased from 19 to 32 percent of the councils' grants since 1980. These are designed to help coherent programs of research in selected areas or to stimulate research in fields judged to require more effort in the national interest. The second initiative has been to increase the proportion of program grants, as opposed to project grants, from 15 percent in 1980 to 20 percent in 1989. Program grants are generally larger, support a bigger team of researchers, and last for a longer period (5 years) than project grants. Thirdly, in 1985, it recommended a set of six criteria to be adopted by the research councils in determining funding (excellence, applicability, timeliness, pervasiveness, sig-

[7] See "British Science Indicators, *Outlook on Science Policy, vol. 11,* November 1989, pp. 112-1 13; and M.P. Carpenter et al., "Bibliometric Profiles for British Academic Institutions: An Experiment To Develop Research Output Indicators," *Scientometrics*, vol. 14, Nos. 3-4, 1988, pp. 213-233.

[8] See Peter Aldhous, "University Funding Plan Collapses in Chaos," *Nature,* vol. 348, Nov. 1, 1990, p. 3.

Figure D-l—R&D Expenditures as a Percent of Gross National Product, by Country



KEY: FRG = Federal Republic of Germany.

SOURCE: National Science Foundation, *National Patterns of R&D Resources: 1990,* final report, NSF 90-316 (Washington, DC: 1990), tables B-18 and B-19.

nificance for education and training, and exploitability), which have been applied by some of the councils.

The most recent initiative, together with the research councils, UFC, and DES, has been the establishment of Interdisciplinary Research Centers (IRCs). Funded for 6 years, their objectives are: 1) greater concentration of research effort; 2) more interdisciplinary collaboration; 3) increased effort in areas of ''strategic' science, i.e., important for economic progress; 4) stronger interface between strategic research in higher education and industry; 5) more positive and purposeful management of research within higher education; and 6) more effective collaboration between universities and the research councils in the deployment of research resources.

Thus, the general approach to academic research selection in the United Kingdom can be summarized by two statements: 1) there is an increasing degree of priority setting, the priorities emerging from interaction between peer review committees and various advisory bodies;[9] and 2) there is a move to concentrate research resources by provision of larger and longer grants to programs and centers.

Federal Republic of Germany

In contrast to the United Kingdom, the most striking feature of German science policy is the indirect influence of government, which funds virtually all academic research but accords significant autonomy to research-performing and research-promoting, institutions.[10] The freedom of research is expressly established in the Federal German constitution. In this context, and that of a generous and growing budget for research, it is apparent that there is little expressed need for, and indeed some hostility to, notions of directed research or priority setting.

Research is performed primarily in three sets of institutions: the 50 universities, the 60 institutes of the Max Planck Gesellschaft (MPG), and the 13 national research centers. Decisionmaking about research project selection is largely made within the research institutions or by the Deutsche Forschungsgemeinschaft (DFG-the German Research Society).

DFG is the central, self-administering, academic research support organization (spanning basic, applied, and strategic research) in the Federal Republic of Germany. It receives its funds from the federal and state governments,

[9]Working Group on peer Review, *peer Review,* a report to the Advisory Board for the Research Councils (London, England: November 1990).

[10]This section has benefited from Leonard hale- Scientific and International Affairs Directorate, National Science Foundation, personal communication, December 1990.

and as the primary source of "drittmittel''-the additional funds for research-it exerts influence on the profile of research. The function of DFG resembles that of the research councils in the United Kingdom. It is organizationally independent of government, but financially dependent on it. It is a scientific society whose membership includes the universities, other research institutions such as the Max Planck institutes, seven of the national research centers, and prominent scientific associations. The president and senate are elected, as are the approximately 400 expert consultants who hold office for 3 years, to provide expert peer review.

DFG shapes the profile of German academic science from the bottom up, augmenting government funding of salaries, instrumentation, facilities, and MPG initiatives. The resistance to direction of research by DFG is clear: ''DFG officials are determined that targeted funds should not exceed 10% of overall expenditure since this might give rise to renewed alarm about academic autonomy and flexibility. "[11]

The functions of MPG are to undertake research in areas of particular importance, newly emerging areas, or where a concentration of effort is required. Its legal status is that of a private nonprofit organization despite most of its finance coming from the government. Proposals for new institutes are received each year and undergo an extensive evaluation process. Judgments are made by the MPG senate on scientific merit, fruitfulness, appropriateness to MPG (as opposed to universities), and the availability of an outstanding scientist to fill the position of leader. Once established, an institute is subject to review every 2 years by a visiting committee and every 7 years by a prestigious panel of overseas experts. Occasionally an institute is closed.

The national research centers were established as essentially big science institutes in fields such as nuclear, aviation, and space research where a large concentration of very expensive infrastructure was necessary. Some of these centers are now facing the challenge of missions completed or no longer relevant, and are seeking new orientations.

OTA concludes that basic research selection in the Federal Republic of Germany rests essentially on bottom-up proposal pressure and peer review. Priority setting is used mainly to achieve concentrations of effort through cooperative teams or centers. The unification of the former German Democratic Republic and the Federal Republic of Germany may offer opportunities of international importance for research, but it is too soon to tell.[12]

France

The French approach to decisionmaking for academic research, as for all areas of the economy and society, rests on a traditional commitment to centralized planning. In the area of research, the strong emphasis is on economic goals, and priority is given to industrial research.[13]

The Ministry of Research and Technology is responsible for recommending and implementing government policies in the field of science and technology, and for determining priorities for research, with the advice of the Research and Technology Council. The performance of basic research occurs primarily in the Center National de la Recherche Scientifique (CNRS) laboratories located alongside the universities and within the universities, which receive core funding from the Ministry of National Education and CNRS. CNRS maintains its own laboratories, independent of universities. The French system relies on block grants to the laboratories and research groups, rather than specific project grants to individual researchers. But there is growing academic criticism of CNRS's favored "inhouse" position as a research performer.

CNRS finances the entire range of academic research from the physical sciences to the humanities. Annual strategic plans are prepared, which rely as much on the identification of leading research individuals and groups as on promising areas of research. In addition, CNRS has conducted a range of prospective studies that feed into the planning process.[14]

The French Government has recently mounted a major initiative to promote the strategic application of foresight and evaluation to the national research system. A National Research Evaluation Committee (CNER) was established in response to the government's decision to institute the systematic periodical assessment of all research-performing institutions. This follows the experience of the National Evaluation Committee of the Universities, founded in 1985, which has assessed the research of 25 universities on a voluntary basis.

CNER is responsible for the evaluation of the organization and results of a national technological research and development policy. To achieve this goal, the committee ensures the periodic assessment of institutes, programs,

[11] B.R. Martin and J. Irvine, *Research Foresight* (London, England: Frances Pinter, 1989), p. 80. Despite the pronouncement, targeted funds are suspected to exceed 10 percent.

[12] See Rolf H. Simen, ''Research Landscape Requires Careful Gardeners: Science in Unified Germany—Experts' Opinions During Villa-Hugel Talks,'' *German Research Service Special Science Reports, vol. 7,* January 1991, pp. 11-13.

[13] For an overview of France's 24 research agencies, see ''FAST Guide to French Government R& D,' *French Advances in S&T,* vol. *4, No.* 1, winter *1990-91,* pp. *3-6.*

[14] See Martin and Irvine, op. cit., footnote 11, PP. 47-50.

and incentives of all kinds financed from the civilian technological R&D budget.

In summary, there is a strong emphasis on planning and direction of research toward technological objectives in the French research system.[15] The attempt is made within the universities to set basic research directions largely on the grounds of scientific excellence. However, within CNRS, scientific departments put forward proposals that are judged internally on grounds of merit and relationship to priority areas.

Japan

The dense population, a deep commitment to the values of the group, and the spiritual principles of Confucianism have produced a culture that emphasizes the values of harmony, respect, and decisionmaking by consensus, even if the process is protracted.[16] These values permeate the decisionmaking structures and procedures with respect to science.

Within the government, the Prime Minister's Office and its key policy body, the Council for Science and Technology (CST), exercises the highest level of control over the direction of scientific and technical research.[17] Four main government agencies in Japan support and target R&D: the Science and Technology Agency (STA); the Ministry of Agriculture, Forestry, and Fisheries; the Ministry of Education, Science, and Culture (Monbusho); and the Ministry of International Trade and Industry (MITI).

STA is responsible for the overall coordination of science policy among the different ministries and agencies. It is also responsible for big science and includes research institutes to fill this function.

While STA is the agency primarily responsible for basic research, MITI has had considerable influence over research policy in Japan through its emphasis on applied R&D. MITI runs 16 national research laboratories and develops research programs with industry. These programs are most often in technological areas in which Japanese industry is considered to be weak, into which no single company would enter alone, or which are for the public good and not necessarily commercially valuable. While MITI is most involved in raising the technological level of Japanese industries, this is small compared with STA's activities.[18]

Monbusho is responsible for the promotion of research across all fields and for the national university system. In formulating policies, Monbusho consults its science council, consisting of 27 eminent scholars whose names are put forward by the academic societies but appointed by the Minister. In addition to general research funds for divisions of university faculty, construction, and equipment monies, Monbusho has a new program in which the Science Council chooses a research field for priority funding (generally two a year).

The Science Council is a democratic body established by law as the representative body of Japanese scientists and engineers. It has the right to make recommendations directly to the government on the ways and means to promote science and technology. Among its major successes was the establishment of nine interuniversity research centers. However, in recent years its influence has waned in favor of CST. The role of CST in integrating and coordinating research has been considerably strengthened through the establishment of a Science and Technology Promotion Coordination Fund, which is used in part to support basic research in special priority fields designated by CST.

Thus, the essential process of research selection in Japan is through the time-honored mechanism of a committee of wise men. Priorities are established by this consensual process, involving varying degrees of interaction with an influence of academic researchers on the one hand and government officials on the other.[19]

Netherlands

The Dutch are among the leaders in formulating science policy in Europe and have carried its implementation much further than many other countries. The major emphasis of science and technology policy has been on a more effective planning and linking of strategic and applied research to national economic and social needs.

The Minister for Education and Science has recently produced a discussion document, "Towards a Science Policy for the Nineties, " As a result, the government has once again decided to elevate science on the Dutch

[15] See Remi Barre, "Strategic processes and S&T Indicators: Towards a Key Role in R&D Management systems, " *The Research System in Transition,* S.E. Cozzens et al. (eds.) (Dordrecht, Holland: Kluwer, 1990), pp. 227-239. For the past 2 years, the Center for Technology Forecasting and Assessment in the Ministere de la Recherche et de la Technologie, in conjunction with the Commission of the European Communities, has published an *R&D Evaluation Newsletter,* which reports the results of research evaluation efforts throughout the world. Stressing evaluation has not overtly affected plarming or resource allocation decisions.

[16] See Genevieve J. Knezo, "Japanese Basic Research Policies," *CRS Report for Congress* (Washington DC: Congressional Research Service, Aug. 1, 1990).

[17] See Council for Science and Technology, Policy Committee, Prime Minister's Office, and Committee on Guidelines for Research Evaluation *Basic View on Research Evaluation* (Tokyo, Japan: 1986).

[18] See Johnson Chalmers, *MITI and the Japanese Miracle* (Stanford, CA: Stanford University Press, 1982).

[19] See John Irvine et al., *Investing in the Future* (Worcester, England: Billings & Sons Ltd., 1990).

political agenda. The three major objectives for the 1990s are: 1) establishment of a more effective scientific basis for key societal functions; 2) achievement of an important role of research in the process of internationalization; and 3) the well-balanced development and application of science and technology to economic, social, and cultural needs.

The independent Science Policy Council of the Netherlands (RAWB) is the central advisory body on science policy. It has had significant influence on priority setting and resource allocation through its reports on future needs and opportunities in particular fields. RAWB also undertakes assessments.

Basic research is performed essentially in the universities that are funded by the Ministry of Education and Science (which administers over one-half of the government R&D budget) and in the institutes established by the Netherlands Organization for Scientific Research (NWO). The latter also funds some research in universities.

Before the latter half of the 1970s, university research was largely considered in relation to educational policies, with particular emphasis placed on the close relationship between academic research and university teaching. Gradually there has been a shift in approach developed in the last decade or so, and academic research objectives are increasingly related to external economic and social requirements. The scope for effective planning and steering of the direction of university research in the context of science policy has been constrained in the past by the funding structures for university R&D. The Netherlands is now experimenting extensively with these structures and performance assessments.

A feature of policy in the last few years has been the move gradually to transfer responsibility for research from government departments to universities or to institutes operated by NWO. This represents one element in a developing strategy to reshape the existing national R&D system, which is widely seen as lacking the degree of integration and coherence that is needed if the country is to maintain an internationally competitive effort in key areas over the next decade.

In summary, the Dutch Government and universities have been particularly active over the past decade in reshaping their science and technology policy decisionmaking procedures and capabilities. While this effort has been directed to technology development, there has been some attention as well to methods of project selection for research. Experimentation with these methods has allowed new policy alternatives to emerge. In particular, these new methods allow more funds to be allocated on a competitive basis and in priority areas. The priorities are determined by traditional committee methods where scientific and government interests meet and negotiate from their own perspectives.

Sweden

There is a long tradition of extensive government involvement in decisionmaking in a range of research areas in Sweden, grounded in a lengthy process of consensus formation, planning, and evaluation. R&D has been strongly directed, particularly through the central establishment of priorities and funding levels every 3 years in a Government Research Policy Bill.

Policies are developed through an interactive process between funding agencies, departments with responsibility for R&D, and a group in the Cabinet Office, with overall responsibility vested in the latter. There is a strong bottom-up element in the decisionmaking process, which is set against the background of the Bill on Research. That this bill is programmed into the legislative process allows all the players to develop their initiatives in the period leading up to the consideration of the bill. Background studies, monitoring of overseas developments, and symposia that bring together representatives from academia, industry, and the government all form part of the process.

This extensive consultation and debate ensures that all interested parties have an opportunity to make their views known and that the community in general is committed to the areas and issues identified in the research bill. In the February 1990 bill, the priority areas were: 1) strengthening basic research in universities; and 2) increasing research in five target areas-environment, marine processes, public health, industrial safety, and cultural research.

Basic research, roughly one-quarter of Swedish R&D, is conducted almost entirely within universities-there is virtually no government research capacity. Three research councils play a major role in determining research areas and resource allocation: the Medical Research Council, the Natural Science Research Council, and Council for Research in the Humanities and Social Sciences. Each council has a large degree of autonomy. A fourth council, the Council for Planning and Coordination of Research, is not a' 'research council' per se. It assists in government research planning and coordination, public understanding and participation in this process, and the assessment of Swedish research capabilities.

Strong direction setting characterizes Swedish strategic research.[20] Less direction is given to basic research, but its

[20] See George Ferne, Science *and* Technology in Scandinavia (London, England Longman, 1989). Not only is the research evaluation tradition strong (perhaps the strongest in Western Europe), but it also involves the participation of foreign scientists and much public discussion of decisions. See Michael Gibbons, Organisation for Economic Cooperation and Development, Evacuation *of Research in Sweden* (Manchester, England: University of Manchester Press, 1984).

priorities are affected through the connection to strategic initiatives. The 3-year research bill provides a strong framework for this connection.

Canada

Canadian science policy has been marked in the past decade by a high level of debate, conflict, and change. The major pressure for this change has been the heavy reliance of the Canadian economy on its resource-based industries and the recognition that such economies are becoming increasingly vulnerable and noncompetitive. Canada has a reputation for scientific excellence and long-established central government laboratories.

Canada is a federal system, with the special requirements for coordination that such a system implies. The higher education sector is funded almost entirely from taxes collected by the national government and allocated to the provincial governments.

There is a large set of advisory and decisionmaking bodies in the Canadian science and technology system. Three of the most important are: 1) the National Advisory Board on Science and Technology, which advises the Prime Minister on overall guidelines; 2) Industry, Science, and Technology Canada (ISTC), which coordinates industry and academic research; and 3) the Science Council of Canada (SCC), which provides independent advice on science and technology. SCC has been a long-time advocate of systematic research priority setting, and ISTC compiles the Decision Framework for Science and Technology, which requires departments and agencies responsible for R&D to prepare annual lists of priorities.

Nevertheless, while there has been a strong push toward linking research more effectively to national needs,[21] this has been resisted in the case of basic research. The overall framework of planning thus far impinges only indirectly on basic research.

Australia

Australia is in many respects similar to Canada, with its federal structure and its drive to broaden and deepen the technological intensity of its predominantly agricultural and minerals-reliant economic base. There is also a long tradition of commitment to internationally excellent research, with a particularly strong government research capability.

In recent years Australia has developed a sectoral model of science policy, with major R&D funding and performing responsibilities spread across a number of major departments. To overcome problems of fragmentation, a Coordination Committee of Science and Technology, made up of senior officials of the departments, has been appointed. In addition, the Prime Minister receives advice from the Science Council-composed of ministers, industrialists, and a minority of scientists, and the Australia Science and Technology Council-composed of appointed academics and industrialists.

With nearly 70 percent of research in the public sector, there has been a considerable emphasis on restructuring to give greater priority to strategic research directed to medium- and long-term industrial needs.[22] The universities, which are established under state legislation but funded by the federal government, are also under increasing pressure to serve national interests.

In Australia the principles and practice of priority setting have been effectively established for strategic and applied research.[23] As in Canada, planning for basic research has met with a degree of resistance from researchers and universities, who have seen it as a challenge to their autonomy. Hence, priorities have been applied to basic research only to a modest extent.

India

Science and technology (S&T) in India has grown under strong and sustained political support. Even before India became independent in 1947, the national leaders had recognized the role of S&Tin national development. Nehru's vision of S&T came to be accepted as an instrument not only for industrial and economic development, but also for transforming a tradition-bound society into a progressive nation.[24]

In line with the concept of socialism, the state continues to be a strong supporter of S&T, providing 80 percent of the funds for all R&D. It also shoulders the responsibility for directly guiding and planning the activities of an extensive network of S&T institutions. R&D activities are carried out by institutions that come under central and state government departments, industrial units, professional bodies, and by university-type structures. The

[21] See Baha Abu-Laban *(cd.), University Research and the Future of Canada* (Ottawa, Canada: University of Ottawa Press, 1988).

[22] J. Ford, "Australia Tilts Its R&D Towards Industry, " New Scientist, vol. 116, No. 1580, 1987, p. 19.

[23] M. Dodgson, "National Policies--Research and Technology Policy in Australia: Legitimacy in Intervention,'' Science *and Public Policy, vol. 16, No. 3,* June 1989, pp. 159-166; and Australian Science and Technology Council, *Setting Directions for Australian Research* (Canberra, Australia: Australian Government Publishing Service, June 1990).

[24] A. Jain, ''Science and Technology Policies in India, ' *Science Policies in International Perspective: The Experience of India and the Netherlands,* P.J. Lavakare and J.G. Waardenburg (eds.) (London, England: Frances Printer, 1989), p. 139.

universities carry out research and provide human resources for research institutions.[25]

Though the basic orientation of national S&T policy has been, and still is, to treat S&T as an integral part of socioeconomic development, there have been several changes in organization and planning strategies over the years. For example, the Industrial Policy Resolution of 1948 allowed considerable scope for introducing foreign technology into the country, but had little influence on linking the imports with the indigenous S&T structure. Under this policy ethos, an extensive government-dominated research infrastructure emerged during the next 20 years, almost undisturbed by economic developments. Priorities in S&T were set by the leaders of science, but efforts at formulating policy instruments and plans to couple S&T capabilities with requirements of agriculture, industry, and other economic sectors were weak.

The Prime Minister of India has always been the minister-in-charge for S&T, with three advisory mechanisms at his or her disposal: the scientific adviser, the adviser for technology missions, and an independent 1 l-member Science Advisory Council. India's planned approach for the development of S&T became part of the national planning exercise. The Planning Commission plays a central role in formulating the national S&T 5-year plan with the involvement of scientists, technologists, and representatives of concerned agencies and departments.

International Comparisons

From the discussion above, it is clear that the methods used for selecting basic research for government support vary greatly among countries. For example, Canada and Australia are pluralistic and strongly averse to directing research initiatives, while there is growing pressure in the United Kingdom for priorities to be determined centrally, a tradition long observed in France.

OTA finds that in every one of the nine nations examined there has been a substantial development of methods for effective targeting of strategic and applied research to national economic needs. This push for greater economic payoff from research has also led some countries to increase their proportions of strategic basic research at the expense of undirected basic research. There has also been considerable experimentation with new methods to identify strategic avenues of high promise. However, the development and application of new selection methods for basic research has generally been approached with considerable caution by research funding agencies and been met with considerable opposition from researchers. Also, there is no evidence that government targeting of research has increased economic payoffs.[26]

Another finding is that the extent of direction of basic research is apparently directly related to the need to do so-the most important factor is the availability of resources to support basic research. In countries like Germany and Japan where there appears to be little shortage of funds to support basic research, there is no great enthusiasm for more central direction of research—even though both countries have elaborate mechanisms for targeting strategic research and linking it to industrial and commercial opportunities. At the other extreme, countries suffering a significant squeeze on funds available for basic research, and who have been less successful in establishing mechanisms for pursuing an adequate level of strategic research with a strong application orientation, e.g. the United Kingdom, are striving hard to achieve greater government influence over the direction of basic research.[27]

The major vehicle used to influence the direction of basic research has been the setting of priorities. Evidence of its effectiveness, however, remains limited. Priority setting has generally involved the identification of research areas of special interest through interaction between the academic members and professional staff of research funding agencies and varying degrees of consultation with the research community. In some countries fixed sums are allocated for competition in priority areas; in others, the priorities become simply another criterion to be considered in the evaluation of proposals.

A recent Organisation for Economic Cooperation and Development report noted the broadening of the concept of priorities to include not only "thematic" priorities (e.g., identifying areas and problems that deserve greater attention such as optics), but also "structural" priorities (e.g., creating new institutes or research teams, or purchasing equipment and facilities) .28 Indeed the report

[25] The number of universities has grown from *20 in 1947* to 160 in 1987. Less than 10 percent of national research and development expenditure goes to the university system for research, a proportion far smaller than that in the other countries reviewed here.

[26] This is a conclusion drawn by economist Harvey Averch in his survey of the literature. See Harvey Averch, "Policy Uses of 'Evaluation of Research' Literature: Post-1985 World Research Evaluation," OTA contractor report, July 1990, annotated bibliography. Available through the National Technical Information Service, see app. F.

[27] Lederman, op. cit., footnote 10, cautions that "striving hard" is not the same as succeeding. No country will soon become as centrally controlled as France. And there is a culture of criticism in some cultures that masks policymaking tendencies. The UK, Canada, and Australia, like the United States, have a tradition of criticizing government. Germany, Japan, and Sweden have little open criticism although problems and dissatisfactions of researchers may be as widespread as in other countries.

[28] Gibbons, op. cit., footnote 20.

argues that the two are 'indissolubly linked, ' as thematic priorities cannot be implemented without adequate structural support.

In the nine countries reviewed here, the major form of structural priority is greater concentration of research resources through an increase in the funds allocated to long-term programs and centers. Thematic priority setting has also been increasingly applied by the majority of the countries, though (with the exception of the United Kingdom) such priorities represent no more than 20 percent of research agency budgets. These thematic priorities have been established at a number of levels, ranging from the national arena to that of the research agency, from a set of disciplines or problem areas to individual disciplines.

Examination of the mechanisms and experiences of the nine countries in developing and implementing new approaches to the direction of basic research yields four distinct models of priority setting and implementation: structural, thematic disconnected, thematic connected, and systematic. In the following section, these models are applied to the U.S. experience.

Structural

In the United Kingdom, Netherlands, Canada, and to a lesser extent, Australia, the emphasis has been on the application of structural priorities. These have generally followed the principles of concentration, either by allocating more of the resources in larger units, and/or by increasing the small proportion of research funds distributed on a competitive basis. However, concentration alone carries the danger of freezing national capabilities around present or past historical strengths. Structural priority setting thus would not appear to be an appropriate mechanism, of its own, to identify and respond to challenges and opportunities of the future.

The British system would appear to have a particular defect in the extent to which the basis for implementation of structural priorities and determination of thematic priorities occurs behind closed doors by an appointed and nonrepresentative elite. Such a nonparticipative approach would appear to have grave dangers of engendering hostility and resentment among researchers instead of building consensus required for effective priority setting and implementation. In contrast, in the Netherlands bibliometric measures have been developed in an attempt to provide a public and objective basis for structural priorities together with an open and transparent system of evaluation.[29]

Thematic Disconnected

This model is evident in the United Kingdom, Canada and Australia, and for some programs in Japan. It describes the system in which priority setting is effectively disconnected from the priority-implementation process. In each of these countries the establishment of priorities occurs in a relatively closed process, but the implementation is through traditional methods of an open call for competitive proposals, to be evaluated by peer panels together with ad hoc referee reports. Such a system has the virtues of combining thematic priority setting with researcher freedom to develop research programs subject to evaluation. There is a real danger, however, that the priorities would serve as little more than signposts for labeling of projects, and the level of implementation of the priorities could remain quite low. The deep resistance of Canadian and United Kingdom scientists to just such a system would appear to confirm the likelihood of this problem.

Thematic Connected

This model describes systems in which the priority-setting and implementation mechanisms are tightly coupled. Within this model there are two different types. The Federal Republic of Germany represents a bottom-up form of the thematic connected model, in which the scientists themselves are primarily responsible for identifying thematic priorities, but once established, it is essentially the same researchers who are invited to prepare proposals according to negotiated criteria.

The other type is the top-down thematic connected model, which operates in France, India, and less so in the Council for Planning and Coordination of Research (FRN) in Sweden. In these cases, the thematic priorities are identified by research agencies, composed variously of researchers, users, government officials, and community representatives. Then the research agency can work with select individuals and groups to develop proposals that meet the requirements as determined by the agency. For example, though modestly funded, the Swedish FRN provides a positive model of building basic research around societal needs, articulating research problems with relevant research disciplines and specialties.

The top-down thematic connected model has considerable advantages in terms of efficiency and effective implementation. However, it is more likely to be acceptable in a nation where a culture of cooperation and planning is well established. In a more competitive culture this system could be seen as being too readily open to nepotism and political favoritism.

[29] For example, see A.J. Nederhof and A.F.J. van Raan, "An International Interview Round on the Use and Development of Science and Technology Indicators," report to the Netherlands Ministry of Education and Sciences, Directorate-General for Science Policy, June 1988.

Systematic

This model is best represented in Sweden and France, and perhaps India. In Sweden, an extraordinarily intensive systematic process of consultation, information gathering, and preparation and review of position papers and symposia leads to the drafting of a 3-year research bill that sets the national directions in research. It represents a major exercise in consensus generation that might be far less successful in countries where consensus is not a strong national feature.

Similarly in France, a major systematic effort is being directed to establishing a national capability in research intelligence, foresight, and evaluation. A wide range of foresight exercises[30] have been attempted and two public sector think tanks-the Centre de Prospective et d'Evaluation and the Observatoire des Sciences et Techniques—have been established to attempt to produce indicators, conduct evaluations, and create a national capacity in research evaluation. It remains to be seen whether the work of these units will feed into decisionmaking.

Applications for the United States

As the research economy changes in the United States, the experience of other countries in coping with their research economies can be instructive. However, the institutional structures of policymaking and funding are critical determinants of the way in which governments support basic research and provide a powerful setting to which any new methods of selection must be adapted. Hence any system operating in another country would need to be refashioned to fit another's political culture, structure, and decisionmaking practices.

There are a number of features endemic to the U.S. research system to bear in mind when considering the applicability of the experiences of the nine countries surveyed.

1. In each of the nine countries, the government pays for researcher salaries, support, equipment, and materials through general institutional grants, which are supplemented by competitive funds for research projects. In contrast, the primary funding mechanism for academic research in the United States is competitive support for specific research projects.
2. In the vast majority of the cases in the nine countries, individual researchers and research teams have only one possible source of funds to support their research beyond that available from institutional grants. In the United States, there has been a plurality of potential funding agencies for researchers.
3. In the United States, there is a very high level of absolute funding for basic research, comparable to that of Federal Republic of Germany (once defense research is excluded). In addition, all nine countries have shifted almost all of their big science into international cooperative ventures.

What, then, are the lessons for U.S. agencies? The strategies described above represent experimental alternatives for research decisionmaking.

The structural priorities model describes the Department of Defense in the 1980s and presumably the 1990s, especially in reference to the consolidation of the defense laboratories. Both the thematic disconnected and the thematic connected models might be appropriate for consideration by the National Institutes of Health, the National Science Foundation, the Department of Energy, and the National Aeronautics and Space Administration. Indeed, components of these models are already in place at these agencies. The thematic disconnected model is likely to be most appropriate when the identified thematic priority area is relevant to a range of well-established disciplines. Where a thematic priority is opening up a very new area, sitting at the boundaries of a number of disciplines, or demanding a large allocation of resources, the more directive thematic connected model might prove effective.

However, what is more important in the U.S. context is that the research agencies experiment and evaluate research priorities in a systematic and open way. At the same time, these models and research policymaking in other countries could be monitored for some possibly valuable lessons.

[30] Martin and Irvine, op. cit., footnote 11.