DISCUSSION PAPER

Research Policies and Strategies of Five Industrial Nations, and Implications for the United States

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Editor's note: From time to time, we intend to publish papers drawn directly from the practice of science policy analysis. We were pleased to invite the present contribution as a first instance. Discussion of the issues raised here is welcome in the form of letters to the editors or longer comments.

This article is drawn from a background paper prepared for the Government-University-Industry Research Roundtable. This body was convened under the auspices of the National Academy of Sciences, with membership from the scientific community, industry, and government, to examine the organization and conduct of research in the United States in light of current and future needs of, and demands on, science. To help in this exercise, the Roundtable has considered what aspects of the research policies and strategies of other advanced industrial nations might be relevant for United States science.

The article examines similarities and differences among the research systems, strategies, and policies of France, Japan, Sweden, the United Kingdom, and West Germany, and the United States; their government research funding systems and coordination mechanisms; efforts to assess the effectiveness and results of research; some research outputs; and dissatisfactions currently being expressed in most or all of these countries. The paper concludes by posing some questions for consideration in science policy discussions in the United States. A comparative table shows selected data on the distribution of funding, performance, type of research and development (R&D) personnel.

General Similarities and Differences

The research systems of the six nations have some broadly similar features. Governments provide the bulk of academic research support and distribute it through a mix of agencies whose central function is the support of science, and through mission agencies which support science as part of their responsibilities in health, education, agriculture, and the like. All governments have some mechanisms for negotiating a balance between governmental and scientific interests in setting research directions and priorities. In all nations, academia conducts most fundamental research and trains future scientists and engineers; industry performs most applied research. All governments provide big science facilities for use by academic scientists and engineers, and also maintain government laboratories. (2,3,4,9)

The European nations and Japan share some features that distinguish their research systems from that of the United States. The governments of these nations have traditionally supported higher education and academic research as a means of transmitting and enhancing the national culture. Therefore, national, government supported university systems are the norm, and private universities and colleges are rare. In all nations but the United States and Japan, all qualified students have a right to higher education, pay no or low tuition costs, and often can receive stipends or subsidized loans. Nonetheless, a smaller proportion of the European college-aged population participates in higher education than is the case in the United States and Japan. In both Europe and Japan, higher education is less tightly coupled to research training than in the United States. (1,2,4)

European and Japanese governments support academic research through general, formula based operating funds that recipient universities distribute among their various functions, including research. This general support pays for academic salaries, research facilities, major equipment, and some support services. It is supplemented by competitive awards for investigator initiated work, and by funding for strategically targeted research. Under this dual support mechanism, questions regarding the allocation of research time and the proper accounting of indirect research costs are less prominent than in the United States. (1,2,4)

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The faculty members of European and Japanese institutions of higher education are lifetime civil servants subject to a uniform salary structure. Their salaries are paid from general operating funds and are not affected by, or paid from, project or program support. Compared to the United States, the mobility of academic researchers—and those in other sectors—is low. The governments regard the level of mobility as an impediment to the transfer of research results and techniques, and several have started providing incentives to encourage greater movement between sectors and into strategically targeted R&D areas. (1,2,4)

In practice, the various dual support systems for academic research are being modified by several developments. Demands for costly instrumentation are forcing a shift of some research costs from general academic operating funds to research program budgets. Moreover, overall growth of academic research budgets has been curtailed as the European nations have placed greater reliance on targeted research and strategic research initiatives. (1,2,4)

In contrast to the United States reliance on shortterm project support, the European and Japanese governments tend to support research groups, programs, or laboratories for periods from 3-5 or even 10 years. They also make greater use of block grants, senior investigator awards, and special collaborative efforts. (2,3,4)

In some nations, notably France and West Germany, much of what in the United States would be academic science is conducted in systems of institutions that are allied with, but administratively independent of, the universities (e.g., CNRS Laboratories, Max Planck Institutes). (2,4)

The importance of mission agencies in funding research is especially pronounced in the United States. A major difference between the United States and the other nations, except the United Kingdom, is the large proportion of United States government R&D resources allocated to defense, now over 75 percent. However, when development expenses are subtracted, defense related research represents only about 22 percent of total federal research support and is exceeded by government research support for health. (2,4)

In Europe and Japan, a broad consensus exists for the principle of government support for research targeted on general economic development objectives. In contrast, the United States government funds industrial research primarily in support of mission agency purposes. The European nations and Japan are targeting national research efforts on specific commercial areas that governments consider important for future economic development, such as electronics, biotechnology, materials research, and informatics. In these endeavors, governments regard the existence of strong industry-university relationships as a key to success. While these ties have traditionally been weaker than in the United States, all governments, including that of the United States, have formulated policies intended to strengthen them. The proportion of direct government funding of industrial R&D is quite variable, ranging from 2 percent in Japan to about 30 percent for the United Kingdom and the United States. (1,2,4)

The European countries and Japan expend a greater portion of central government R&D funds on international cooperative research than does the United States. The size of the United States science establishment permits economies of scale that have made possible the operation of national big science facilities for United States scientists, and a basic research effort that is of significant magnitude across all S&E fields. (2,9,10)

The appendix provides selected comparative data on the distribution of funding, performance, type of R&D, and science and engineering personnel for all six nations. Although the focus of this paper is on research, comparable data separating research from development in these countries are very limited. Thus, total R&D is shown to round out the picture. It should be pointed out that the research portion (basic and applied) is lowest in the United States (37 percent) and highest in France (54 percent).

Coordinating Mechanisms

We now turn to brief discussions of the government research funding systems of specific nations, their coordinating mechanisms, efforts to assess the effectiveness and results of research, and some research outputs.

There is general agreement that the United States R&D system and organization are at the pluralistic and less centralized end of the spectrum, the French at the more planned, centralized, and strategically targeted end of the spectrum, and the other nations somewhere in between. The United States system is seen as more market oriented, flexible, and is thought to adjust more easily to changing demands than those of the other nations, which are more stable overall and tend to provide longer term research support. (1,5,6)

In the United Kingdom, the bulk of research funding is provided by the central government. Major performers are the universities, government laboratories, and private industry. Academic research is supported largely by the central government through block grants from the University Grants Council (funded by the Department of

Education and Science), and competitively awarded research grants from five autonomous Research Councils. The Research Councils also operate government supported laboratories that are accessible to university scientists. The Department of Trade and Industry, with cost sharing by industry, supports research activities with potential benefits for industry. The government is also stimulating joint efforts of industry, academe, and government in manufacturing and information technology, optoelectronics, and other specially targeted areas. (2,3,4)

No strong central coordinating body exists in the United Kingdom's science system. A decade ago, offices of Chief Scientists were created in major government agencies. The Cabinet Chief Science Advisor's office produces an annual review of government-funded R&D and coordinates major government initiatives. An Advisory Board for the Research Councils (ABRC) advises the Secretary of Education and Science on allocation of research funds; efforts are underway to increase its role vis-a-vis the Councils in resource allocation decisions. Major advisory groups include the Advisory Council on Applied Research and Development (ACARD), which directs attention to areas of emerging commercial importance; the Department of Industry Requirements Board, and similar bodies in the mission agencies, which identify and recommend support of R&D linked to industrial needs; and the National Research and Development Corporation, a quasi-governmental body, which identifies and promotes inventions with industrial applications.(2,4)

In Sweden, the government performs little in-house research, only a few mission agencies maintain their own laboratories, and there are no national laboratories. The national universities are the main performers of research and house large laboratories. Government resources for academic research are provided in the form of general operating funds from the education ministry; supplemental competitive project and program support flows through three Research Councils. The National Swedish Board for Technical Development provides funding for applied academic research and applied research and development in industry. (3)

The Swedish government's Council for Planning and Coordination of Research coordinates the research of three Councils that support fundamental research. The government periodically formulates comprehensive science policy plans which are enacted by the Parliament (e.g., 1984 Research Policy Bill). It has undertaken two major initiatives: encouraging more industrially relevant research by universities; and directly providing funds and other support to industry through the National Swedish Board for Technical Development (STU), which also supports applied academic research.(3)

In Japan, most government academic research support is provided by the Ministry of Education, Science, and Culture (Monbusho), principally to national universities and their affiliated laboratories. Other major funders are the Science and Technology Agency (STA), the Ministry for International Trade and Industry (MITI), and several other mission agencies. A key STA effort supports interdisciplinary teams of scientists from industry, academe, and government in a program of breakthrough science.. MITI carries out industrially relevant R&D in its own laboratories; promotes privately supported research institutes that carry out nonproprietary R&D in certain product areas (e.g., semi-conductors, new synthetics); undertakes focused R&D initiatives; and provides low interest loans. Industry in Japan is more important than elsewhere as both a supporter and performer of research. (1,4)

Japan's fundamental coordinating mechanism is cultural; it rests on the setting of national policy through an emerging consensus judgment. The most important formal coordinating body is the Council for Science and Technology in the Prime Minister's Office, composed of educators, industrial managers, scientists, and engineers. Special councils are formed periodically to assess progress in different fields and recommend priorities. Agencies use advisory councils and industry associations to ensure consonance of government research with industry interests, and they plan and conduct research in cooperation with industry. MITI's National Project System targets national priority areas, with R&D mostly funded and conducted by industry. Efforts are under way to strengthen the weak university-industry linkage. (2,4)

The French national government provides a larger share of national R&D funds than the other governments. About a third of central government funds are disbursed by the National Center for Scientific Research (CNRS) under the Ministry of Research and Technology. CNRS laboratories are the main locations for the conduct of academic research, and most of these laboratories are located on higher education campuses but administratively seperate organizations. Research funds are also provided by the mission agencies, for example, CNES (space), CEA (atomic energy), ANVAR (industrial), INSERM (health and medicine), IFREMER (oceans and fisheries), INRA (agriculture), and AFME (renewable energy). (2,3,4)

French government research priorities are stated in 5-year R&D plans. The Ministry for Research and Technology oversees resource allocations for civilian R&D agencies and advises on research programs of nationalized firms. Coordination may be facilitated by longer term block support, joint operation of big science laboratories by mission agencies, and government involvement in industrial R&D through subsidiaries or direct participation. CNRS (as well as other research agencies) has a Committee for Industrial Relations that strives for closer articulation of CNRS work and the R&D needs of French industry.(2,4)

In West Germany, there is extensive joint funding by federal and Laender (state) governments, with federal funds predominating for major national laboratories, and Laender funds for regional applied research institutes. The Research and Technology Ministry (BMFT) provides the bulk of federal funds, with major additional resources coming from the ministries of defense, economics, and education and science. Several legally autonomous societies, jointly funded by federal and Laender governments, allocate government science funds: the German Research Society (DFG) to academia, the Max Planck Society (MPG) for in-house research and to its associated basic research institutes, and the Fraunhofer Society, half of whose funds come from industry, to its applied research institutes. (2,3,4)

West Germany achieves a degree of coordination of basic research without direct government control by supporting the DFG and the MPG. For applied research and work in the national laboratories, the Association of Big Science Establishments (AGF) participates in setting research directions. A Science Council advises government, DFG, and MPG. No formal government-industry coordinating bodies exist, but the Ministry for Research and Technology (BMFT) and the Science Council plays a coordinating role. Federal, Laender, and industry priorities are reflected in the applied research of the jointly funded Fraunhofer institutes. Industry and government collaborate in selected national laboratory research activities.(2,4)

Research Evaluation

All nations make some attempts to assess the effectiveness and quality of their research systems, and many are trying to increase their evaluation efforts. In principle, research assessments can be carried out at all levels. In practice, assessments of the performance of national science systems are rare. More frequently, attention is given to determining the quality of science in a given discipline, or sometimes in groups of institutions or broad fields of science or application.(2,3,4)

Assessments rely largely on peer review, but all countries are seeking a broader range of inputs and are examining the usefulness of bibliometric techniques. All nations have found that peer review assessments work better for disciplinary research than for cross-disciplinary work, programs with fundamental and applied components, or comparisons across areas of science. Some evidence suggests that the United States devotes more effort to determining the prospective quality of research, based on proposal peer review, while other nations tend to focus on assessing progress and outputs. This may reflect other nations' greater reliance on longer term support to entire institutions or research programs. (2,3,4)

Perhaps the most ambitious assessment efforts exist in Sweden. Peer evaluations span basic and applied research and cover programs, research teams, institutions, and fields of science. Their focus is on specific fields of science and application. Results are available to all and feed into decisions about R&D strategies, research directions, and support levels. Comparison is made with other countries, and foreign scientists and engineers play a key role as members of the peer review teams. (3)

Research Outputs

Only rough comparisons can be made of the nations' research outputs. The number of publications by a nation's scientists in various fields can serve as a measure of the quantity of output. For all fields combined, the United States accounts for about 35 percent of the publications included in the *Science Citation Index* set of S&T journals, although the share varies by field. The United States share exceeds the other nations' combined total, with Japan, France, France, and the United Kingdom contributing between 5 and 9 percent each, Sweden less than that, reflecting its smaller science establishment. (7,10)

A rough impression of output quality can be derived by examining whether the share of references to that nation's published output falls short of, approximates, or exceeds its share of publications. In each major discipline, the United States share of references received exceeds the United States share of publications, with substantial variation among disciplines. In a number of specialties (e.g., physical chemistry, solid state catalysis, organic synthetic chemistry) the United Kingdom, West Germany, or Japan appear to hold leadership positions. (10)

The United States awards more first university degrees in the natural sciences than the five other nations combined (over 100,000 in 1983). Data on advanced degrees are broadly consistent with data on undergraduate degrees. In the United States, West Germany, and the United Kingdom, first degree graduates in the natural sciences exceed those in engineering. In contrast, engineering graduates exceed those in the natural sciences by a considerable margin in Japan and Sweden. Engineering degrees are a smaller portion of total first degrees in the United States than is the case for the other countries. Japan graduates a larger number of first-degree holders in engineering than does the United States, but the United States graduates more doctorate-level engineers than does Japan. Better than half of the recipients of United States engineering doctorates are foreigners. (7)

Dissatisfactions

All six nations are attempting to improve their international competitive position. The following briefly lists some dissatisfactions currently being expressed in most or all of the other countries. Expressed inadequacies include:

- too little cooperation between academia and industry in research, education, and exchange of information; (3,6)
- insufficient flexibility and responsiveness of academic and government research institutions; (3)
- insufficient transfer of research skills and information due to low mobility of researchers; (3,6)
- aging faculty and few positions available for young researchers; (2,3)
- inadequate coupling of academic research with teaching, resulting in graduates ill equipped to operate near state-of-the-art; (2,3) and
- variable quality and relevance of government laboratories' work. (3,6)

To address these perceived shortcomings, the European and Japanese governments have taken a number of steps. All are targeting certain research areas based on anticipated future economic returns and international competitive potential, including biotechnology, electronics and computers, informatics, materials, production technology, and environmental research. Most are emphasizing a user orientation in government supported (especially applied) research. (3,5,6)

In the United Kingdom, West Germany, and Sweden, real growth in academic science budgets has been reduced or stopped in favor of strategically targeted programs. In contrast, the Japanese central government intends to increase basic research support. It is also providing incentives for increased university-industry-government laboratory cooperation, and greater mobility of research personnel from one sector to another. In France and Germany, modest programs are under way to provide academic positions for younger researchers. All governments are seeking increased funding for industrial R&D, especially in smaller enterprises, through direct and indirect mechanisms. Governments also are giving more attention to assessing the quality of their nation's research in specific science and application areas, relative to that of other countries.(2,3,4,6)

Lessons for the United States

Given United States needs and problems, no straightforward lessons can be drawn for United States science from the other nations' experiences. While a number of countries appear to have brought aspects of their policies and strategies a little closer to those of the United States, the elements of individual national science systems form a whole, fit into a particular national context, and are not necessarily transferable. Since little objective information exists that could reveal what works better or worse under given circumstances, the advantages and disadvantages of different policies and strategies are not clear. Positive and negative consequences of a particular option frequently depend on how it is implemented.

The following list of questions should be considered with these cautions in mind.

- Should the United States move toward longer term, programmatic science support? This is one of the most striking differences between the United States and the other nations. (2,3,4)
- Should the United States more directly support graduate students in fields with strongly growing demand which exceeds supply? Project grants are the main federal support vehicle for United States S&E graduate students; the other governments use stipends and subsidized loans. (3,5,6)
- Should alternative mechanisms be considered for supporting academic research facilities and equipment? Governments elsewhere treat research facilities and equipment as a capital investment; in the United States, they are paid for through project support, special programs, or indirect research costs. This may be an especially difficult issue for the United States, because of the prominence of federal mission agencies in the research support system. (2,4)
- Should the United States provide greater government support for nonproprietary research addressing industrial needs, especially in areas of increasing international technological competitiveness? European and Japanese governments undertake such actions based on a national consensus; in the United States, no agreement exists on the issue. (5,6)
- Should the United States expand international cooperative research, especially where facilities and equipment costs are high? This would require careful consideration of advantages and disadvantages to the United States of various forms of cooperation (bilateral, multilateral) in particular science fields. (2,4)
- Should the United States move toward greater centralization or coordination of government re-

search? Recent proposals have included establishment of a Cabinet-level Department of Science and Technology, a Department of Science, a National Technology Foundation, a National Institute for Research and Advanced Studies, and a National Applied Science Administration. Centralization is not synonymous with coordination or quality, and no good evidence can be drawn from the experiences of the countries examined to support the greater efficacy of more centralized vs. more pluralistic systems. (1,2,4)

REFERENCES

1. Jarlath Ronayne, *Science in Government* (London: Edward Arnold, 1984). Covers: U.S., Canada, U.K., FRG, Belgium, Japan, Australia.
2. Bruce L.R. Smith and Charles Kidd, "Research in Europe and the United States," in *The 5-Year Outlook on Science and Technology 1981*, Volume 1, Source Materials (Washington, DC: National Science Foundation, 1981), 255-284. Covers U.K., France, FRG.
3. Leonard L. Lederman, "Recent Changes in Science and Technology Policy, Priorities, Practices on Programs in France, Federal Republic of Germany, The Netherlands, Sweden and United Kingdom," unpublished paper based on interviews and documentary sources, National Science Foundation, January 31, 1985.
4. C. Ailes et al., "Performer Organizations and Support Strategies for Fundamental Research in Six Countries," SRI International, April 1985. Prepared for the National Science Foundation, Division of Policy Research and Analysis. Covers basic research for U.S., FRG, U.K., France, Japan, USSR.
5. John Irvine and Ben R. Martin, *Foresight in Science, Picking the Winners* (London: Francis Pinter, 1984) Covers basic and strategic research; France, FRG, U.S., Japan.
6. *Science and Technology Policy Outlook, 1985* (Paris: Organization for Economic Cooperation and Development, 1985).
7. *International Science and Technology Data Update, January 1985* (Washington, DC: National Science Foundation, Directorate for Scientific, Technological and International Affairs, Division of Science Resources Studies).
8. *Recent Results-Selected S&T Indicators 1979-1984*, OECD Science and Technology Indicators-Basic Statistical Series (Paris: Organization for Economic Cooperation and Development, 1984).
9. *Science and Technology Indicators—Resources Devoted to R&D*, (Paris: Organization for Economic Cooperation and Development, 1984).
10. *Science Indicators 1982*, (Washington, DC: National Science Board, 1984), 1-37.

SELECTED COMPARATIVE DATA

Data is for a year in the 1980-1984 period depending on country and item.

	U.S.	*Japan*	*FRG*	*France*	*U.K.*	*Sweden*[1]
4.1. *Total R&D by Source of Funds*	100%	100%	100%	100%	100%	100%
Industry	50	64	55	42	42	57
Government[2]	47	26	41[3]	57	49	40
Other	3	10	3	1	8	3
4.2. *Total R&D by Performer*	100%	100%	100%	100%	100%	100%
Industry	72	62	70	57	61	67
Government[2]	13	10	14[3]	25	22	7
Higher Education	12	24	16	16[3]a	14	27
Private Nonprofit	3	4	—	1	3	—
4.3. *Total R&D by Character*	100%	100%[1]	100%	100%	100%[1]	100%
Basic Research	13	14	22	21	12	23
Applied Research	24	25	78	33	25	17
Development	64	61		46	63	60
4.4. *Research Expenditures by Performer*	100%	100%	100%	100%	100%[1]	100%
Industry	51	47	n.a.	35	39	24
Higher Education	29	37	n.a.	29[3]	28	64
Government[2]	14	12	n.a.	34	30	12
Nonprofit	6	4	n.a.	2	2	—
4.5. *Basic Research Expenditures by Performer*	100%	100%	100%	100%	100%[1]	100%
Higher Education	57	61	60	67[2]	55	88
Industry	19	26	18	9	13	8
Government[2]	16	11	22[3]	22	30	4
Private Nonprofit	8	2	1	3	2	—

	U.S.	Japan		FRG		France		U.K.		Sweden[1]
4.6. *Government[2] R&D Funding by Objective*	100%	100%		100%		100%		100%		100%
Defense	64[4]	2	(5)	10	(15)	33	(40)	49	(59)	22
Advancement of Knowledge[5]	4	46	(4)	44	(14)	27	(15)	21	(13)	36
Space	6	6	(12)	4	(9)	5	(9)	2	(5)	8
Energy	7	17	(26)	15	(21)	8	(8)	5	(7)	8
Health	11	6	(6)	3	(9)	4	(5)	4	(2)	6
Industrial Growth	0.3	7	(12)	12	(12)	12	(8)	7	(4)	4
Agriculture	2	11	(25)	2	(3)	4	(4)	5	(5)	2
All Other	6	5	(10)	9	(17)	8	(11)	7	(5)	13
4.7. *Industrial R&D Expenditures[1] by Industry*	100%	100%		100%		100%		100%		100%
Electrical Equipment	22	25		24		24		31		23
Machinery & Computers	13	10		14		8		11		13
Chemicals/Allied Products	12	17		22		15		16		10
Motor Vehicles	9	14		14		11		5		21
Aerospace	22	—		6		18		20		
Instruments	7	3		2		1		2		2
All Other	16	31		18		22		15		31
4.8. *Government[2] Percent of Industrial R&D Expenditures*										
Electrical Equipment	37%	1%		13%		25%		46%		11%
Machinery & Computers	14	1		10		5		10		8
Chemicals/Allied Products	6	1		4		4		1		3
Motor Vehicles	11	0		3		1		4		19
Aerospace	75	1		76		68		68		
Instruments	15	0		11		14		4		7
4.9. *Scientists & Engineers Engaged in R&D by Sector*	100%	100%[1]		100%		100%				100%
Industry	74	59		60		41		n.a.		57
Higher Education	13	32		24		38		n.a.		34
Government	9	7		15		18		n.a.		9
Private Nonprofit	4	2		1		2		n.a.		—
4.10. *First University Degree by Field*	100%	100%		100%				100%		100%
Natural Sciences[6]	10	3		16		n.a.		25		4
Engineering	7	19		14		n.a.		16		11
Agriculture	2	4		4		n.a.		2		1
Social Sciences	11	41		29		n.a.		29		10
All Other	71	33		35		n.a.		29		74
4.11. *Doctoral Degrees by Field*	100%	100%		100%		100%		100%		100%[7]
Natural Sciences[6]	35	12		20		42		42		24
Engineering	9	19		8		12		18		13
Agriculture	3	8		3		[8]		3		2
Social Science	19	1		10		16		37		23
All Other (includes MD)	35	60		59		30				38

[1]Natural sciences and engineering only; all other figures include social science and humanities; the U.S. excludes humanities.
[2]In the U.S., the government sector is federal only; in other countries, government includes all levels. Data in parentheses exclude general university funds and are thus more comparable to distribution of U.S. separately budgeted Government supported R&D.
[3]In France, the CNRS R&D is classified as higher education in performance data but as government source of funds data; in FRG the Max Planck Institutes are classified as government.
[4]1983; 66% in 1984, estimates are 68% in 1985 and 73% in 1986.
[5]General purpose research; including an estimated portion of general university funds (except U.S.).
[6]Includes Mathematics and Computer Scientists/Specialists
[7]Includes Master Degrees
[8]Included in Natural Sciences

—Sources for all data are OECD and NSF and country data.
—Figures may not add to totals due to rounding.