U.S. Science and Technology Policy: the Effects of a Changing International Environment

Eugene B. Skolnikoff
M.I.T.

Paper prepared for project on Future Role of
Science and Technology in Brazil.

March 10, 1993

CONTENTS

I. General Setting 4
A. Political/economic changes: 4
B. Developments stemming from scientific and technological change 6
1. Broader opportunities, choice and flexibility 6
2. Growing internationalization and globalization 7
3. Increased need for international cooperation in R&D 7
4. Inertia of large technological systems 7
5. Interlocking of societies and of economies 8
6. Alteration of factor endowments 8
7. Diffusion of physical power and capability 8
8. Increased science-dependence of technology 8
9. Increased complexity and uncertainty 9
10. Discovering problems and causes 9
11. Change made permanent 9
12. Increased significance of science and technology 9

II. Implications for S/T Policies in the U.S. 10
A. Economic returns to R&d: 10
B. International competitiveness and R&d: 14
C. The U.S. policy response to date 17
D. Policy changes proposed by the Clinton administration: 21
E. General characteristics of recent and proposed policy initiatives 27
F. Other elements affecting S/T Policy: 29
1. Altered Content of Trade-Relevant Issues 29
2. Basic Research, Competition, Dangers for the Universities . 29
3. Environment: 33

III. Implications for Developing Countries 35
A. The effects of continued advances in S/T 35
B. Effects of future U.S. policies 37
C. Implications of NAFTA and possible follow-ons 40

IV Conclusion 41

I. General Setting

A. POLITICAL/ECONOMIC CHANGES:

The momentous changes on the international scene in recent years form the essential background for an assessment of the science and technology policies of the United States: what they are and what they are likely to become. Largely as a result of evolving international relationships, the U.S., with by far the largest expenditures of any nation on research and development, is now engaged in a major reexamination of its science and technology policies, with likely substantial effects on relations between the U.S. and other nations, and particularly with the developing countries of the South.

The most obvious political change on the international scene is the end of the cold war that has greatly reduced the rationale for what has been the majority of research and development (R&D) funding by the U.S. Government (defense takes some 60% of the Federal R&D support in the current 1993 Fiscal Year), and for about 30-40% of all funding, private and public, devoted to R&D (total public and private resources devoted to R&D in FY 1993 are estimated to be about $150 billion).[1] The reduction in the overwhelming security threat comes at a time that has seen a major increase in the level of international economic competition the U.S. faces, particularly in technology-related fields. The once dominant American international trade position has given way to negative trade balances, even in high-technology products which had been considered the hallmarks of U.S. comparative advantage.[2]

The reduced security concern and the rise of economic competition have markedly altered the climate for S/T policies. The overt demand for economic returns for investment in science and technology is rapidly growing, while the funding for

[1]Statistics on R&D expenditures are not wholly accurate, nor up-to-date. However, they do provide adequate order-of-magnitude estimates. The best sources are found in OECD (Organization for Economic Cooperation and Development) reports, reprinted in The OECD Observer, for example in OECD in Figures: Supplement to the OECD Observer, No. 176, June/July 1992, and in National Science Foundation (NSF) documents, such as International Science and Technology Data Update: 1991, Special Report NSF 91-309 (Washington, D.C.: NSF, 1991).

[2]OECD in Figures, pp. 56-57.

defense-related R&D, though not likely to fall precipitously, will certainly be a smaller portion of the total and will increasingly be related to economic as well as security purposes. New programs directly related to economic goals, will be added, and existing programs will be recast or expanded to emphasize economic objectives. The election of an enthusiastic new administration committed to a greater government role in the economy will amplify this shift. (These matters will be revisited below in detail).

Other developments in the economic situation have necessarily also had significant effects on American S/T policies. The worldwide recession of the late 1980s and early 1990s and the enormous growth of annual budget deficits and accompanying increase in the national debt constrained the scale and nature of government funding for R&D, though not as much as might have been expected; gross resources devoted to R&D outstripped inflation steadily until the current fiscal year (according to President Bush's budget, which will be modified later this Spring by President Clinton).

The rise of regional trading blocs, first in Western Europe, and now slowly in the Western Hemisphere also may over time alter the context in which policies for S/T are considered. The European Community has organized a wide array of cooperative R&D projects among its members, at times with exclusion of participants from outside the Community. If that pattern continued, and NAFTA (with a possible extension to the whole Western Hemisphere) materialized, it is possible that R&D policies in general would become more focused on regional economic, trade and cooperation opportunities. Failure of the Uruguay Round of trade negotiations would carry the danger of unleashing protectionist forces that would make this retreat to regionalism more likely to come about.

Working in the opposite direction is the unprecedented degree of international integration of national societies that has become one of the defining characteristics of today's world. It is particularly relevant in economic matters, but is evident in essentially all facets of modern life, including social, cultural, technological and environmental dimensions. Whether it be called integration or interdependence, the phenomenon is well recognized by governments, by analysts and by the public at large. Science, always considered by its practitioners to be an international endeavor, nonetheless also is affected in innumerable ways by this new level of inescapable interaction among states.

Conflicting views of the future can be drawn from this steadily more intense integration that is characteristic of the world scene. Will it mean the ultimate erosion of the nation-state accompanied by the rise of non-state institutions (governmental and non-governmental) with enhanced authority and responsibility? Or, conversely, will an aggressive nationalism develop, with a return to hegemonic rivalries and emphasis on achievement of national, as opposed to international, goals perhaps organized in a regional structure? Or, some combination of both?

This is not the place to attempt to forecast which view, or whether some combination, is the one more likely to materialize, and when.[3] However, it is important to observe, notwithstanding dramatically intensified international integration, that science and technology continue to be supported through a process that is primarily national, that the motivations for the support provided by governments are intended to serve the objectives of the state, and that by and large the motivations for private-sector support also are oriented to the purposes of the state since the fortunes of firms, even in an era of growing internationalization of industry, are dependent on the well-being of the nation in which they are primarily based.

Thus, the underlying fact is that the resources allocated for science and technology--public or private--are still dominantly national in purpose, are determined in a national policy process, and are allocated to serve national goals. This pattern will undoubtedly remain as it is well into the future.

B. DEVELOPMENTS STEMMING FROM SCIENTIFIC AND TECHNOLOGICAL CHANGE:

The fact that international political and economic developments influence the environment in which S/T policies must be considered is self-evident. The reverse--the recognition that technological change influences political and economic developments--is as obvious, but the nature of the effects of technological change are usually considered explicitly only in specific subjects or situations. There are some

[3]The relationship of science and technology to the evolution of the international political system will have a great deal to do with which future is likely to emerge. This subject is explored in my book: The Elusive Transformation: Science, Technology and the Evolution of International Politics (Princeton, N.J.: Princeton University Press, 1993). See also Mark W. Zacher, "The Decaying Pillars of the Westphalian Temple: Implications for International Order and Governance," in James N. Rosenau and Ernst-Otto Czempiel, eds., Governance Without Government: Order and Change In World Politics, (Cambridge: Cambridge University Press, 1992).

general observations about those effects, however, that deserve brief presentation; they form an important backdrop to an appreciation of the influence continued progress in science and technology will have on both S/T and on broader social and economic policies. In summary form, they include the following.

1. Broader opportunities, choice and flexibility

A key effect of advances in S/T is to offer a wider range of options for governments and industry to achieve specific goals. As one important result, R&D can increasingly be targeted on the design of technologies that will modify or undermine the basis for existing international economic relationships (e.g. natural resources dependencies).

2. Growing internationalization and globalization

As technology is developed that expands capabilities of size, distance, and power, it becomes increasingly international in its reach, either because it must be deployed in an international setting (e.g. space systems), or because its effects have unavoidable international impact (e.g. atomic weapons or communications technology), or because efficiencies of scale dictate international deployment (e.g. information networks). Growing international effects also result from the cumulative externalities of countless small decisions about uses of technology that cause consequences reaching beyond national borders, and increasingly to the planet itself. The emergence of an increasing number of global-scale issues, such as global warming or destruction of the ozone layer, both stemming from effluents of widely used and essential technologies, are obvious examples.

3. Increased need for international cooperation in R&D

A concomitant of the expanding reach of technology and its effects, along with the higher costs of equipment and research, is the increased requirement for international cooperation in the conduct of R&D. Research costs increasingly are higher than nations, even wealthy ones, can manage alone; international problems require multinational cooperation to understand causes and ameliorative measures; and development of mitigation technologies often require bringing to bear resources and competence beyond what one nation can do alone.

4. Inertia of large technological systems

As capabilities of technology expand, it becomes possible and efficient, often necessary, to link technologies in steadily larger systems that are now increasingly international in scope. Once the systems are in place, however, the sunk costs and fixed installations tend to reduce flexibility since change can only come slowly and at substantial cost. The global energy system, now so wedded to fossil fuels, provides an apt illustration of a massive system with major environmental implications that can be altered only gradually over many years.

5. Interlocking of societies and of economies

The result of expanding technological systems and internationalization of technology is to increase transnational interactions and to make economically attractive the development of multinational institutions, both serving to integrate national economies and societies. This is one of the most widely-remarked international consequences of technological change, commonly called interdependence. Examples are endless, as is the rhetoric.

6. Alteration of factor endowments

Technological change, occurring both in new systems and in the evolution of existing technologies, means that the factor inputs that determine, inter alia, the costs of manufacturing processes, or the demand for raw materials and energy, will be correspondingly changing. Indeed, one of the characteristics of continued technological development is to bring down, often dramatically, the costs of the inputs required for a particular function, as R&D leads to expanded output per unit of input. Technological advance that alters factor costs is not a new phenomenon, but the continuousness and breadth of change in technology introduces a fluidity to factor costs, and hence factor endowments, that in turn means rapid and continuing change in the economic potential of states and in their comparative advantage in the international trading system.

7. Diffusion of physical power and capability

The certain spread of knowledge and capability to package physical power in small volumes, with large yields, able to be delivered with high accuracy at a distance, at low effective cost, represents a development that makes all-but inevitable the diffusion of physical power to nations, to insurgents, to groups, or even to individuals. Physical power need not only imply military applications: the ability of nations or corporations or rogue groups to perform (or misperform) activities on a scale that has direct effects on other nations, or on global conditions, is also growing. Deforestation of tropical rain forests, continued operation of poorly designed and maintained nuclear power plants, introduction of computer viruses that can be written by a single programmer and can lead to malfunction of large international systems, or the plans (now suspended) for reversing the flow of Arctic rivers in the Soviet Union, all illustrate the phenomenon.

8. Increased science-dependence of technology

The closer relation between the basic research laboratory and the commercial marketplace (in some fields) means, among other implications, that the health of science and the results of fundamental research have greater significance for technological progress and economic competitiveness of nations than at any time in the past.

9. Increased complexity and uncertainty

Synergisms among technologies, increased sophistication of science and technology, and inevitable uncertainties in R&D processes mean that technological outcomes and their societal interactions are certain to be of growing complexity and to continue to be impossible to foresee in detail.

10. Discovering problems and causes

Specific outcomes from R&D may not be foreseeable in detail but, ironically, powerful new analytical methodologies for probing complex issues, growing ability to construct complex models to forecast future conditions, and improvement in technologies for measurement and computation will create their own problems for public policy. Use of these capabilities will result in finding problems the world did not know it had, will increasingly challenge desirable goals by detailing undesirable consequences of attempting to achieve those goals, will raise the need for potentially costly measures to deal with long-range phenomena not yet physically observable in daily life, and will complicate public issues with disturbing conclusions, the details of which are accessible only to experts.

11. Change made permanent

Governments and industry in this century have institutionalized a capacity for continued innovation which guarantees that the future technological environment, and thus the social environment, will never be static. New capabilities, new opportunities, altered competitive balances, unexpected problems, full-blown surprises will continue to lead to changes in the structure of societies and of issues, not least international affairs.

12. Increased significance of science and technology

Finally, it is worth recording the obvious, that the manifold interactions of science and technology with the social system have had the effect of increasing their importance in the functioning of society, and in the policy processes concerned with their governance. Science and technology have become part of almost all issues of social affairs, sometimes only a minor part, sometimes of central importance. They are now significant factors relevant to the making of policy in many areas of national interest, including particularly economic and foreign policy.

All of these general effects of R&D are taking place in a world in which competence in science and technology is growing and diffusing on a worldwide basis. No longer is one nation, the U.S., dominating S/T as it has since World War II. Notwithstanding its larger commitment of resources for R&D, there is much greater equivalence of capability today, shared by many countries. The U.S. may have the broadest general competence, but it is no longer the case that leadership in any given field will be found in that country. This is particularly relevant as esoteric defense technologies lose their significance, and as commercial technologies have in general become more advanced than those developed in a military context.[4]

This new world situation has significant repercussions in economic affairs, especially in trade relationships, and puts a premium on viable national policies for S/T, for promotion of effective international transfer of technology and for measures to move knowledge rapidly and profitably from the laboratory to the commercial marketplace. It is to those that we now turn.

II. Implications for S/T Policies in the U.S.

[4]John A. Alic, et al, Beyond Spinoff: Military and Commercial Technology in a Changing World, (Boston: Harvard Business School Press), 1992, p. 73.

The recognition that economic growth and competition must now have a central position in the setting of S/T policies may be widespread, but that is a far cry from leading to agreement as to what those policies should be. In fact, the nature of the desired policies are controversial in most countries, not the least in the United States.

There are many dimensions to these controversies, several of which bear directly on the question of how nations manage their scientific and technological enterprises in this new, interdependent, post-cold-war world.

A. ECONOMIC RETURNS TO R&D:

One deceptively straightforward question relates to the economic returns to be expected from investment in R&D, and particularly from the resources committed to basic science. Presumably, if economic payoff is the intention, an economic return on investment should be anticipated, so that a reasonable cost/benefit analysis can be made and alternative expenditures compared.

But, the return on investment in research is peculiarly difficult to measure, so that much of the claim of economic benefit is made through qualitative, rather than quantitative arguments.[5] Even if estimation of the return on investment is possible for overall R&D (the best attempts at evaluation indicate social rates of return in excess of 50%), it is not possible in advance to quantify the economic payoff of specific research endeavors.[6]

---

[5]An excellent detailed summary of economic theory on the subject and of the primary writings and issues is given in "A Background Review of the Relationships between Technological Innovation and the Economy" in Technology, Trade, and the U,S. Economy, Report of a Workshop Held at Woods Hole, MA, Aug. 22-31, 1976 (Washington, DC: National Academy of Sciences, 1978) pp. 18-48. An Office of Technology Assessment study: "Research Funding As An Investment," Science Policy Study Background Report No. 12, House Committee on Science and Technology, 1986, summarizes the state of knowledge of the returns to R&D investment up to the time of publication.

[6]Edwin Mansfield, "Estimates of the Social Returns from Research and Development," Margaret O. Meredith, Stephen D. Nelson, and Albert H. Teich, eds., AAAS Science and Technology Policy Yearbook 1991, Committee on Science, Engineering, and Public Policy, (Washington, D.C.: American Association for the Advancement of Science, 1991) pp. 314, 315.

Thus, the very basis of support for R&D, when economic benefit is the primary criterion, cannot be pinned down and is open to dispute. Even when there is rough agreement on the amount that should be invested by government, the specific allocations among different fields, and among basic science, applied science, and development, are inevitably subject to personal judgment, bureaucratic competition, vagaries of the budgetary and policy processes, and lobbying from interested parties. Some nations formulate and implement their science policies in the face of these uncertainties with considerable aplomb and apparent clarity of view; others exhibit serious difficulties as they try to face an inherently complex situation with policy processes that discourage development of a coherent overall perspective. The U.S. is too often an exemplar of the latter.

Notwithstanding this rather fundamental difficulty in determining the economically appropriate allocation of resources, the U.S. Government has continued to increase overall funds for R&D at least equal to or ahead of inflation, until this current 1993 fiscal year.[7] Disagreements arise within the overall allocations, with "small" science in traditional fundamental fields of physics and chemistry suffering relative reductions, while big science spectaculars (space station, superconducting supercollider, human genome) continue to grow.[8] And, defense-related appropriations, remain in excess of 60% of the total Federal R&D budget, only modestly reflecting in President Bush's budget proposal the changed security threat.

The continued overall Federal support for S/T in the face of growing budgetary problems and uncertainty of economic return can be attributed to several factors. The most important is simply the deeply-held conviction, established during and after World War II, that support for science and technology will eventually provide benefits that more than repay their cost, either in the private consumer marketplace or in public goods such as superior weapons, improved medical care, or

---

[7]Eliot Marshall and David P. Hamilton, "R&D Budget Collides with the Deficit," Science, 258, 9 Oct. 1992, pp. 208-209. Note that these allocations were decided in the last Congress; the Clinton Administration will seek to change them; the new FY 1994 budget will be released April 5, 1993 though some elements have already been publicly forecast (see later in text).

[8]Ibid., p. 209. The Clinton Administration has decided to continue both the space station and the superconducting supercollider, though with changes that are intended to reduce their costs in later years (Malcolm W. Browne, "Clinton Backs Funds for Science Projects," New York Times, Feb. 23, 1993, p. C2). However, there is reason to believe these programs could prove to be vulnerable in the actual budget debates later this year.

higher agriculture productivity. The technological strength of the U.S. in the cold war competition, and the astonishing blossoming of consumer technology that greatly enhanced the American standard of living, seemed to demonstrate beyond question the validity of the conviction. President Reagan, in a rather perverted testimonial to that sense that technology can bring any benefits asked of it, introduced the Strategic Defense Initiative in 1983 that envisioned a wholly unrealistic impermeable barrier against ballistic missiles.

Other more prosaic factors are also responsible for the generally unwavering support for S/T. Federal R&D expenditures on the order now of $75 billion, even though only 5% of the Federal budget, have developed significant political support in the districts in which the funds are spent. In addition, the fact that upwards of 2/3 of government R&D funds in the postwar period were justified on security grounds meant that challenges to those expenditures were not likely to have much success. And, the nature of the budgetary process in governments (powerful inertia to continue programs once they are in place, a particularly virulent characteristic of the U.S. budgetary process) makes it difficult to introduce sudden changes--especially reductions--in any specific category of expenditures.

From the general perspective of R&D resource allocation, what changes might be expected in the future? Certainly, the challenges to continued growth of R&D funding are likely to become more severe, for several reasons. One is the much greater consciousness today of the negative effects of technological change that result from unanticipated externalities and the mixed costs and benefits of the societal changes that accompany the introduction of new technologies. Coupled with recent exposure of apparent misbehavior of scientists and universities with regard to scientific norms of behavior and to the use of public funds, the general public attitude is likely to be more skeptical of the presumed benefits that R&D will bring.

The reduction in overall resources for defense will add to this negative pressure on R&D funding. The argument that defense R&D should be protected, even increased, as a hedge against the future while hardware purchases and troop levels are cut back may make excellent sense, but is not likely to be successful in political terms. Almost certainly, defense-related R&D will be reduced, though quite likely proportionally rather less than other aspects of the military effort.

On the other side of the coin, the importance of economic goals, especially as enunciated by the incoming administration, will serve to support increased budgets in R&D areas perceived to be relevant to those goals (as discussed below). But this will mean, whatever the rhetoric, greater pressure to reduce the support for undirected basic research as funding agencies and Congress push for the primacy of economic goals.[9]

A recent disturbing trend is the falloff in what had been the steady increase in industrial R&D. Presumably a result of the recession and of a changing view of the value to the individual firm of support of basic research in central research facilities, R&D support in industry, except pharmaceuticals, will be flat or possibly fall in 1993.[10] This development may indicate a changed perspective on the part of industry of the economic value of basic research to the firm, and a general drift in the private sector toward support of research only when the economic benefits can be forecast with considerable clarity. At the moment, the possibility of a permanent change in industrial attitudes toward support of research is speculation only, but current trends do show the significance of economic payoff as the dominant motive in the climate in the U.S. for support of research.

B. INTERNATIONAL COMPETITIVENESS AND R&D:

The economic competitiveness issue that has come to dominate the formulation of U.S. policies for the support of R&D is played out in the arena of international trade in goods and services. The rules of the game may be controversial and in flux, but the central concept of a liberal trading system has been that each trading nation will use its comparative advantage to export what it can produce at lower cost than others and import products and materials for which others have a comparative advantage. When working properly, all nations benefit from what should be a positive-sum game.

Perhaps the most significant change that has taken place in the underlying principles of a liberal trading system, and one that relates directly to S/T, is the evolution in the determinants of comparative advantage. In traditional economic

---

[9]Heads of basic research agencies, Congressional leaders, the National Science Board, and the President's Council of Advisors on Science and Technology in the previous administration all indicated movement in this direction ("In Science Policy, Too 'It's the Economy, Stupid'," Science and Government Report, Jan. 15, 1993, pp. 5-6).

[10]David Swinbanks, "Recession Grips Industrial R&D," Nature, 361, 7 Jan. 1993, pp. 5-6. A quarter of permanent industrial companies in a survey reported in this article plan to cut R&D budgets; 36% said they would spend less on equipment and facilities.

theory, the sources of comparative advantage are the relative endowments of a nation in the factors of production: natural resources, agricultural land, labor, and capital. Now, comparative advantage, or what many analysts would call competitive advantage, lies in a broader set of characteristics that prominently includes an economy's capacity for technological innovation to improve productivity. As a result, comparative or competitive advantage can be "created;" that is, it is a product of what an economy can produce through its human skills, its organization, and the competence and productivity of its scientific and technological base. It stems, in other words, from national policy and corporate decisions, rather than from natural endowment.[11] Though not a wholly new idea--some aspects of comparative advantage were always derived from a nation's ability to improve its human and capital resources--its emergence as a major factor does alter appreciably one of the standard measures of a nation's international status and position, and places a premium on the quality and effectiveness of domestic policies, including in particular its policies toward science and technology.

Trade in high-technology products constitutes a growing share of the trade in manufactured goods: from 1966-86, technology-intensive goods grew from 14 to 22% of world manufactured exports, reaching 42% of U.S. manufactured exports and more than 33% of Japan's in 1987.[12] In 1988, Japan and Germany had significant favorable high-technology trade balances, while the U.S. had slipped to a negative balance (exports/imports of 86%).[13] The U.S. position improved somewhat by 1990, though it is not clear whether this will be a continuing trend.[14]

---

[11]Michael E. Porter, "The Competitive Advantage of Nations," Harvard Business Review, March/April 1990, p. 78; Laura D'Andrea Tyson, Who's Bashing Whom? Trade Conflict in High-Technology Industries, (Washington, D.C.: Institute for International Economics, 1992), Chapter 2.

[12]Quoted in Tyson, Who's Bashing Whom?, chapter 2.

[13]OECD, OECD in Figures, Supplement to the OECD Observer, 170, June/July 1991, pp. 56-57.

[14]OECD, OECD in Figures, Supplement to the OECD Observer, 176, June/July 1992, pp. 56-57. Data for various high-technology industries are given in: National Science Board, The Competitive Strength of U.S. Industrial Science and Technology: Strategic Issues, NSB-92-138, Washington, DC: National Science Foundation, 1992.

The result is that the competitive position in high technology of industrialized countries has changed greatly from what it was in the 1960s. U.S. technological leadership has been challenged by Japan as the latter has become a major exporter of high technology products, reaping substantial economic gains in the process. Europe has yet to alter its position appreciably, or to show what its capabilities may be, particularly in the post-1992 market. The U.S. remains the overall technological leader, but has been overtaken in many economically-important technological areas.

This new competitive situation has led to considerable soul-searching in the U.S. (as in other nations) as it seeks to find the appropriate policies to improve its technological performance, and hence its competitive advantage. A major difficulty is that though the importance of improving the technological position may be clear, how to do it--especially in an economy apparently losing its competitive edge--is not. Proposed measures are controversial because they involve political and economic interests that go far beyond technological matters alone.

The debate in the U.S. has tended to focus on the extent to which the government should intervene in the economy, and in particular whether it should select commercially-important technological fields for special support. The issue is usually couched in the context of "industrial policy," with strident views that touch on deeply-held ideological, economic or political convictions.[15] Some would support the general position that government should not intervene directly in industry, but should help in creating the essential education and competitive home environment that will spawn creative, innovative companies.[16] In this view, companies are basically national in orientation, whatever the level of their international activities and ties, and are crucially dependent on their home environment and particularly on the internal vigor and competitiveness of that environment. Others call for an industrial policy that would involve varying degrees of intervention in the economy, adopting special

---

[15]Even the relatively interventionist Clinton Administration has avoided using the term "industrial policy" (see later).

[16]Porter, The Competitive Advantage of Nations; "When the State Picks Winners," The Economist, Jan. 9, 1993, pp. 13-14.

measures targeted to improve the technological performance of economically-significant high-technology industries.[17]

Proponents of what has come to be called strategic trade theory argue that there are "strategic" sectors in an economy, high technology being a prominent example, that receive a higher return to investment or generate social benefits for a society that are not reflected in the prices paid to producers. Thus, contrary to the traditional assumption of free-market economists that market prices are the sole appropriate guide to the allocation of resources, the positive externalities of those strategic sectors for society as a whole would justify biases in government policy in their favor. Paul Krugman sums up the argument with regard to high-technology industry:

> "Because of the important roles now being given to economies of scale, advantages of experience, and innovation as explanations of trading patterns, it seems more likely that rent will not be fully competed away--that is, that labor or capital will sometimes earn significantly higher returns in some industries than others. Because of the increased role of technological competition, it has become more plausible to argue that certain sectors yield important external economies, so producers are not in fact paid the full social value of their production.
>
> What all this means is that the extreme pro-free-trade position--that markets work so well that they cannot be improved on--has become untenable. In this sense the new approaches to international trade provide a potential rationale for a turn....toward a more activist trade policy."[18]

It may be reasonable to accept the idea of such strategic sectors, but as Krugman notes, that does not mean it is either easy or obvious how those sectors can be identified, or what policies ought then to be followed. Michael Porter argues that

---

[17]Competitiveness Policy Council, Building a Competitive America, First Annual Report to the President & Congress (Washington, D.C.: Competitive Policy Council, Mar. 1, 1992); Chalmers Johnson, ed., The Industrial Policy Debate (San Francisco: Institute for Contemporary Studies Press, 1984); F. Gerard Adams and Lawrence R. Klein, eds., Industrial Policies for Growth and Competitiveness (Lexington, MA: Lexington Books, 1983).

[18]Krugman, Strategic Trade Policy, p. 15.

it is more important in any case for governments to follow policies that support incentives, effort and competition in industry, not subsidies or protection.[19] In fact, national governments have for long been providing explicit or implicit support of one kind or the other for their high-technology industries, and continue to do so. Whether it be direct government intervention in Japan, or indirect support through defense R&D in the U.S., governments have been involved.

It is worth noting that, alone among advanced technological nations, the U.S. has been unwilling to adopt comprehensive industrial policies until now. Notwithstanding the extensive support in the U.S. for basic science and for large-scale R&D to serve the public objectives of defense, space, agriculture, and public health, the U.S. Government has not been willing to make a substantial commitment to use public funds to advance commercial technologies, though even the Bush Administration had been quietly moving in that direction. Other advanced industrial nations that are the chief competitors of the United States, notably Japan and Germany, have been quite willing to embrace commercially-oriented S/T policies, providing support for development of commercial technology, for the diffusion of technology, and for strengthening industrial capacity to absorb technological information.

C. THE U.S. POLICY RESPONSE TO DATE:

The opposition in the U.S. to comprehensive "industrial" policies has not meant that there have been no policy innovations relevant to technological development for economic purposes. Various programs have been introduced in many administrations, and for long the commitments to defense and space R&D were assumed to be significant contributors to commercial technologies.[20] More attention has been given to technology policy in recent years, with the Carter Administration introducing several important policy departures, and the Reagan and Bush Administrations, both ideologically opposed to intervention in the marketplace, also adding significant new measures. Some of the latter were the result of Congressional action, some were launched slowly and reluctantly, some are the product of legislation only in 1992, but the cupboard resulting from the last decade is not bare. These new policies put in place since 1980 deserve mention, for many of the Clinton

---

[19]Porter, The Competitive Advantage of Nations, p. 30.

[20]Whatever the value of "spinoff" in the past, there is now general acceptance of the view that it is no longer a substitute for civilian commitments to R&D (Beyond Spinoff).

Administration proposals build on those legislative and program innovations, and form the legal and programmatic base actually in place at the time of writing. A sampling of these policies include:

1. Programs were instituted to endeavor to make the competence of the National Laboratories relevant to the civilian marketplace. There are 726 of these laboratories that receive roughly 1/4 if the total U.S. R&D budget (some $22 billion in FY 1991), the largest being the atomic energy weapons laboratories now in the Department of Energy, the laboratories of the National Aeronautics and Space Administration, the in-house facilities of the National Institutes of Health, and a variety of large Defense Department laboratories.[21] By legislation in 1986, extended in 1989 to include contractor-operated laboratories, provision was made for cooperative agreements between them and industry for joint development of promising technologies developed in the laboratories that might be suitable for commercial exploitation.[22] These agreements, dubbed CRADAs, have begun to be implemented, and are growing rapidly in number (an exact count is not available, but they now number in the thousands).

2. Changes in patent policy were legislated in 1980 and 1984 to allow non-profit institutions, including the universities, to take title to patents derived from government-sponsored research.[23] By allowing ownership of patents, it was hoped that those institutions would have greater financial incentives to license the patents for productive use. This policy appears to be succeeding in stimulating greater patent and licensing activity, at least in some institutions.[24]

3. The National Institute of Standards and Technology (NIST, formerly the National Bureau of Standards) in the Department of Commerce was authorized in 1988 to launch several new activities: an Advanced Technology Program (ATP) to provide public funds in response to industrial proposals to develop technological ideas

---

[21]Council on Competitiveness, Industry as a Customer of the Federal Laboratories, Washington, DC, (no date).

[22]Beyond Spinoff, pp. 79-80.

[23]Bayh-Dole Patent and Trademark Laws (PL 96-517).

[24]Eugene Skolnikoff et al, "The International Relationships of MIT in a Technologically-Competitive World," Faculty Study Group, MIT, Cambridge, MA, May 1, 1991.

to the pre-competitive stage; "industrial extension" programs, modelled after agriculture extension stations; and manufacturing technology centers to spur attention to this neglected subject in U.S. industry and universities. All of these are presently small in size, but capable of growth; NIST's overall budget was increased 55% in the last Congress to $384 million.[25] The Clinton Administration intends to build heavily on NIST, as is detailed in the next section.

4. Anti-trust legislation was modified to make possible industrial R&D consortia without fear of prosecution and threat of punitive damage awards. The result has been the growth of many industry programs of cooperation on generic or pre-competitive technologies--over 100 such consortia by 1992.[26] In addition, the Department of Defense has provided $100 million per year, the other half of a $200 million budget coming from industry, for the largest of these--Sematech--which is concerned with advancing the manufacturing process for semiconductors.[27] Sematech is generally considered to be successful (though the basis for that judgment is not clear); the others are too new to know the results.

5. The National Science Foundation (NSF) has instituted several programs, such as the creation of manufacturing research centers at universities, designed to stimulate scholarly research on manufacturing processes and to assist industry in giving greater attention to that phase of commercialization of technology. In addition, NSF is singling out four fields of "strategic" research for special R&D support: manufacturing, advanced materials and processing, biotechnology, and high-performance computing and communications.[28] These latter programs create some

---

[25]"NIST; Firing Up U.S. Industry," Science, 259, 1 Jan. 1993, p. 19; Technology and Economic Performance: Organizing the Executive Branch for a Stronger National Technological Base, A report of the Carnegie Commission on Science, Technology, and Government, New York: Carnegie Commission, Sept. 1991.

[26]Wendy Schacht, Cooperative R&D: Federal efforts to promote Industrial Competitiveness, CRS Issue Brief, Congressional Research service, Library of Congress, Washington, DC, Sept. 24, 1990.

[27]General Accounting Office, "Federal Research: SEMATECH's Technological Progress and Proposed R&D Program," GAO/RCED-92-223BR, Washington, DC, July, 1992.

[28]Christopher Anderson, "Strategic Research Wins the Day," Science, 259, 1 Jan. 1993, p. 21.

controversy in the scientific community since they compete within NSF for funds that might otherwise go for basic research.

6. The concern about so-called critical technologies has led the Congress, with reluctant agreement of the Bush Administration, to establish a Critical Technologies Institute (CTI) to report to the Office of Science and Technology Policy (OSTP) in the White House with funding from NSF.[29] The actual role of CTI is not clear, except that it is supposed to identify those essential technologies in which the U.S. is weak, and propose measures to improve the situation. More likely, it will be used as an analytical staff arm by OSTP. The Rand Corporation has been awarded the contract to establish the CTI, which if it lasts will become a novel "think-tank" arrangement at the level of the Presidency. There are many reasons to believe such an arrangement at the pinnacle of government is politically precarious and will not survive over the long term.

7. In the Defense Department there are several existing and new programs related to economic objectives. The most prominent of the existing programs is embodied in DARPA (Defense Advanced Research Projects Agency), a widely acclaimed advanced technology-development agency. Operating with a $1.4 billion budget, it has been responsible for spurring the development of technologies important for defense that also had important commercial impact; computers are the most notable example. Limited to subjects with military interest, DARPA has in recent years consciously worked on technologies with "dual-use" character. Its success has led to proposals either to broaden its charter to include development of commercial technologies, or to copy it in a new civilian-oriented agency outside the Defense Department.

More recent programs in the Defense Department cover a wide gamut. The 1993 Authorization and Appropriations bills, for example, include the following:

- establishment of regional (in the U.S.) technology alliances to promote application of dual-use technologies in which there are regional clusters of strength;

---

[29]"The Critical Technologies Institute: Informing Technology Policy for the Twenty-First Century," Critical Technologies Institute, Washington, DC, Feb. 1993.

- provision for defense manufacturing extension programs to support existing manufacturing extension programs on a cost-shared basis;

- establishment of a program to assist defense-dependent companies to acquire commercial-oriented capabilities, a major goal in the conversion from defense to commercially-oriented industry;

- development of dual-use critical technology partnerships with industry to be administered by DARPA;

- encouragement of commercial-military partnerships to foster development of commercial technologies likely to be needed in the future by the military;

- establishment of advanced manufacturing partnerships with industry to improve manufacturing technology; and

- provision of assistance to universities, in cooperation with NSF, to develop manufacturing education programs.[30]

All of these and some related programs amount to a shift of some $1.4 billion of defense R&D funding toward programs designed to transfer defense-oriented capabilities to the commercial marketplace. The majority are new efforts that will require implementation by the incoming administration.

D. POLICY CHANGES PROPOSED BY THE CLINTON ADMINISTRATION:

On February 22, 1993, President Clinton announced the substance of his proposals for a new technology policy.[31] They are comprehensive in nature, but short on details or, in some cases, on budgetary implications. It is likely that most of the

---

[30]Senator Jeff Bingaman, Chairman, Subcommittee on Defense Industry and Technology Committee on Armed Services, Press Release, Oct. 8, 1992.

[31]President William J. Clinton and Vice President Albert Gore, Jr., "Technology for America's Economic Growth, A New Direction to Build Economic Strength," White House Press Release, Feb. 22, 1993. The specific material that follows is drawn from this document, except when noted.

proposals will be enacted in some form, especially since many involve expansion of activities already in place. Caution is necessary, however, for the programs will be debated in a politicized climate that could substantially alter budgetary totals and the specifics of programs. In fact, the political dynamics are so askew that a kind of reverse feeding frenzy has developed as Congressional committees compete to outdo the President in spending reductions.[32] These cuts will be reexamined when the budget details are considered later in the session, but if larger cuts are voted, they will inevitably reduce the size of the new programs proposed by the President.

Several general comments need to be made, aside from the nature of the political and budgetary process this year. The first is that technology policies will inevitably be subsumed under broader economic policy interests and results. For example, the export performance of the U.S. economy, especially vis-a-vis Japan, will directly affect the scale of resources devoted to technology programs, the steps taken to shield technological industries from foreign competition, and the attitudes toward sharing of information with foreign corporations. In addition, non-technological economic developments such as the movement of long-term interest rates will be a key determinant of the actual scale of technology policies that are seen to be required, and the extent to which those policies depart from past assumptions about the role of government.

Second, the Clinton Administration in proposing these policies appears to be generally intent not only to reverse the long-standing laissez-faire view of government's role in the economy, but also to repair the traditional adversarial relations between business and government that have been so costly to the U.S. in international economic competition. The rhetoric of the proposals makes clear that the Administration believes government has an important role, but it is a role in partnership with industry, and industry must take the lead in selecting which are the important technologies. How this rhetoric will be carried out in practice remains a question, though some of the important appointments (Robert Reich at Labor and Laura Tyson at The Council of Economic Advisors in particular) have a prior commitment to these general ideas.

Third, there is a commitment to carrying out the technology policies on the basis of merit-based allocation of resources with the intent to avoid, to the extent

[32]Michael Wines, "Clinton Bows to Political Inevitability, Trimming $55 Billion More Spending," New York Times, March 9, 1993, p. A15.

possible, the political distribution of spoils commonly referred to as pork barrel expenditures. There is considerable skepticism about whether this will ultimately be possible in the American system in a time of recession, deficits, and the absence of a major security threat. The growth of Congressional "earmarking" in the distribution of funds for science facilities, is not an encouraging sign in this regard.[33]

Fourth, an explicit commitment is made to basic science, "the foundation on which all technology policy is ultimately built." There is no doubt of the sincerity of this commitment but, as noted earlier, the pressures on the level of support for basic science may in fact inhibit fulfillment of the pledge over time.

With these comments, the key elements of the Clinton proposals can be presented. The proposed programs (only the highlights) will be grouped and summarized according to the Administration's outline, and where relevant tied to existing programs.

Industry-government cooperation and support for commercial R&D

- a commitment to reduce the defense portion of R&D funding to less than 50% of the total by 1998.

- expansion of the Advanced Technology Program (ATP) of NIST in the Department of Commerce that provides funds for cooperative development of pre-competitive technology with industry. There would be a large expansion of the ATP budget, $103 million added to the $68 million in the current year, to $758 million by 1997.[34] NIST itself would go from $381 million to $1.37 billion by 1997, with the implication that NIST would become the chief civilian agency for implementation of technology policy.[35]

- rename and redirect DARPA to emphasize dual-use technology development. The new name would be ARPA, with the D (defense) dropped, though it

[33]Colin Norman, "Brown Turns Up the Heat on Pork," Science, 259, 19 Feb. 1993, p. 117.

[34]Budgets, except where noted, come from a Feb. 16, 1993 White House public release.

[35]Edmund L. Andrews, "Clinton's Technology Plan Would Redirect Billions From Military Research," New York Times, Feb. 24, 1993, p. A14.

would remain in the Defense Department. This is in contrast to campaign documents that called for a "civilian" DARPA.

- manufacturing R&D will be emphasized by all agencies.

- National laboratory budgets in Departments of Defense and Energy and in NASA will be examined with the goal of devoting 10-20%, "where appropriate," to technology-development partnerships with industry. CRADAs--cooperative agreements for development of commercial technology between the national labs and industrial firms--will be given greater support ($47 million in the current year). It is too early to evaluate results of the existing CRADAs, though there is justification for skepticism that the culture of the national labs will allow for substantial transfer of knowledge from them to the civilian sector or for much successful cooperation between the labs and industry.[36] The threat of major budgetary cutbacks in the defense sector and the allocation of funds to be used only for cooperative purposes will act as powerful spurs, however.

- the current NSF budget will be increased by $207 million, representing a 14% increase over FY 1992. More than half the increase will go to "strategic research" subjects previously chosen (advanced manufacturing, biotechnology, materials research, computing and communications, and global change research).[37]

- new programs to improve productivity of energy use in industry, transportation and buildings, along with renewable energy emphasis, to be mounted by the Department of Energy.

- technology policy machinery in the White House will be strengthened, particularly OSTP and the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET). The Council is chaired by the President's Science Advisor.

---

[36]Edmund L. Andrews, "Swords to Plowshares: The Bureaucratic Snags," New York Times, Feb. 16, 1993, p. D1.

[37]Browne, "Clinton Backs Funds for Science Projects," New York Times, Feb. 23, 1993, p. C2

Commercialization

- encouragement of regional technology alliances to emphasize regional clusters of strength. This idea apparently stems from the work of Harvard Professor Michael Porter who has argued that clusters of industries and universities able to interact on a face-to-face basis are more important for competitive strength than the globalization that presumably had eliminated the importance of geography in the conduct of business.[38]

- encouragement of "agile manufacturing" programs that allow complementary firms to work together in temporary programs to exploit fast-changing market opportunities.

Access and Use

- support for a national network of manufacturing extension centers.

- other efforts to spread knowledge and training about manufacturing processes and management.

Business and investment environment

- make permanent the research and experimentation tax credit, which is intended to encourage increased industrial funding of R&D.

- extend anti-trust modifications to allow joint production, not just joint research consortia among firms.

- ensure that trade policy strengthens high-technology industry, specifically that industry have full access to overseas markets and effective protection of intellectual property rights (IPR). This is likely to be one of the more contentious issues over the coming years.

- in general, improve the financial environment to encourage increases in availability of capital, long-term investment, and investment in equipment.

[38] Dan Morgan, "Think Locally, Win Globally," Washington Post, March 5, 1993, p. H1.

- examine regulatory policy to minimize cost and encourage investment.

Education and training

- a variety of programs to improve the teaching of mathematics, science and engineering at all levels.

- promotion of manufacturing education.

- establish software and communications standards for education and training.

Information highways

- increased R&D on supercomputers, faster computer networks, and more sophisticated software, with equipment to be built by the private sector.

- promote information infrastructure efforts by industry.

- increase dissemination of Federal information.

Transportation and other infrastructure

- investments in highway and transportation systems (a "new generation of automobiles"), R&D on civil aviation technologies, prototype maglev and high-speed rail systems, and smart highways R&D.

Basic science, mathematics and engineering

- the goal is specified as "world leadership," with commitments for continued strong support of basic research in universities and national laboratories, and support for space science (working with foreign partners) and for environmental research.

These represent the highlights of the programs presently announced, though others could appear. For example, there have been proposals to attempt to avoid what is seen by many as the major stumbling block to successful policies--the vulnerability of new spending programs to a pork barrel approach in the Congress. One of the more innovative proposals, mentioned with interest in another forum by the President, is for the creation of a quasi-public entity, a "Civilian Technology Corporation," that would receive a one-time appropriation of $5 billion. It would fund projects in cooperation with industry, as in the ATP of NIST, but would (it is argued) be able to be insulated more successfully from parochial political pressures.[39]

Vice-President Gore has been given primary responsibility for implementation, with OSTP in that capacity effectively reporting to him (the science advisory role of OSTP, not completely separable and thus possibly leading to future problems, remains focused on the President).

Some of the proposed initiatives do not have substantial pricetags; others would be quite costly, and would therefore run up against the problem of increasing spending in the face of the pressure for deficit reduction. What will survive, in what form, and at what scale is presently far from determinable. The overall subject of technology policy to support America's competitive position, however, is sure to be at or near the front of the domestic and international agendas for much of this administration.

E. GENERAL CHARACTERISTICS OF RECENT AND PROPOSED POLICY INITIATIVES

The policies already in place and those proposed are and would be substantial innovations from the past. Those initiated during the Bush Administration would certainly not have been expected of a Republican administration at the beginning of the 1980s, and the new proposals go much farther in spirit and resources. They reflect several general characteristics of considerable importance that deserve to be noted:

1. Many of the programs are focused on manufacturing technology in the conviction--a valid conviction--that both industry and academia in the U.S. have accorded low prestige, and hence little funding or talent, to the technological problems of high-quality manufacturing processes. This is in sharp contrast to America's major high-technology trading competitor, Japan.

2. Investment is a key word, intended to emphasize President Clinton's conviction that the U.S. has been suffering from inadequate attention to the long-term

[39]The proposal was produced by a panel of the National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, chaired by Harold Brown (Harold Brown and John Wilson, "A New Mechanism to Fund R&D," Issues in Science and Technology, Winter 1992-93, pp. 36-41).

development of its scientific and technological skills and infrastructure. The payoffs of almost all the programs will be long-term, thus making the immediate problem of committing resources in the face of budget deficits particularly difficult.

3. Those programs dealing directly with technological development focus on so-called generic or pre-competitive technology, in the generally shared conviction that the government is never in a good position to pick technological winners and losers, and would be bound to do poorly if it tried to deal directly with a marketplace technology. There is ample historical evidence for this view (e.g. the commitment to the development of commercial nuclear power technology, the Kennedy administration efforts to spur technological development in traditional industries, the abortive efforts to build a supersonic transport), though the line between pre-competitive and market-ready technology is not always as clear as the distinction implies. The result, however, is that emphasis is placed on "partnerships" and industry "leadership," rather than government choice of technologies. Nevertheless, this is a substantial change in spirit, accepting clearly the appropriateness of government intervention in the economy.

4. International competition is a central concern, which in turn implies that the programs will be particularly sensitive to trade issues such as reciprocity of access, effective IPR protection, and trade performance.

5. Many of the initiatives are based on the scientific and technological competence of the defense establishment of the U.S., and represent a desire to reorient that competence toward economic objectives. The goal is laudable on its own, but also reflects political pressure from affected local and scientific communities anxious to see existing laboratories and facilities remain when the defense budget is reduced.

6. The defense orientation has two (at least) other effects: a) it mandates attention to those subjects that can be portrayed as having a military, as well as commercial, use, hence the emphasis on "dual-use" technologies; and b) it makes possible larger funding allocations simply because the defense budget is so large that programs measured in the tens of millions of dollars are barely noticeable, and "reallocation" in this way seems to be a less painful way of reducing defense budgets.

7. The programs, even if fully funded, will be of small size in relation to the magnitude of the task of influencing a $6 trillion economy. Size is by no means an adequate measure of significance, but it does raise the concern as to whether this or

any administration is likely to be able to secure sufficient resources to make a genuine difference in the economy.

8. Finally, in typical U.S. fashion, the policy process results not in one or a few large programs, but a wide array of programs that represent many different views of what is needed, and that are being managed within many different government agencies. That may be an effective way to experiment to determine what works; it may also be a route for scattering of scarce resources across an array of sub-critical efforts. Time will tell.

F. OTHER ELEMENTS AFFECTING S/T POLICY:

1. Altered Content of Trade-Relevant Issues

One of the direct consequences of the new appreciation of the determinants of a nation's competitive advantage in high-technology is a significant expansion of issues relevant to trade negotiations; no longer can trade talks be confined to traditional matters such as tariffs, quotas, and direct export subsidies. National policies and practices in areas that previously received little attention in trade negotiations are now directly relevant. As David Mowery and Nathan Rosenberg observe: "Because of their effects on trade flows, domestic subsidies for R&D, government procurement, intellectual property regimes, investment subsidies, patent policies, regional development policies, and other policies that historically have received little scrutiny from trade policymakers are now central to trade negotiations."[40] Other subjects become relevant as well, such as the traditional relationships among business, government, scientific, and financial communities. In effect, the structural differences among nations become, in Laura Tyson's terms, a major element of trade conflict in technology-intensive industries.[41]

The result has been that a set of subtle and particularly difficult issues has become a necessary part of international trade negotiations. New rules, agreements, and perhaps new kinds of relationships that reach deeply into national styles and

---

[40] David C. Mowery and Nathan Rosenberg, Technology and the Pursuit of Economic Growth (New York: Cambridge University Press, 1989) p. 277.

[41] Tyson, Who's Bashing Whom? chapter 2.

cultures will be necessary to maintain a "level playing field."[42] Technological competitiveness has thus resulted in a trading system that now directly challenges national structures and styles, not just traditional trade issues.

2. Basic Research, Competition, Dangers for the Universities

It is relevant to S/T policy that in this new competitive context, basic science has become a more immediate factor in a nation's international position. The greater scientific content of some technologies means that basic research that might be related to commercially strategic fields comes closer than ever before to being an instrument of international competition. The result is growing pressure to limit the free dissemination of research results and to constrain the traditional openness of university laboratories where most basic research is performed in the U.S.[43] Suddenly, principles of open communication, deemed by scientists to be fundamental to the progress and health of science, are jeopardized by the perceived relationship of science to the economic competitiveness of nations.

This may prove to be a divisive issue in the new administration, for the emphasis it is giving to the nation's competitive position in technology carries with it an overtone of "managed trade," and perhaps a degree of protectionism. President Bush was completely committed to a free trade position; President Clinton and Vice-President Gore argue the same, but on condition that a "level playing field" exists, which might be defined with regard to R&D as equal access to the products of research in each country.[44] If it is believed that the nation's competitors, and particularly Japan, have access to the open research at American universities without reciprocity, there could be attempts to restrict that access or to retaliate in some other way.

The issue at one level has a spurious simplicity: if research is supported by the state for the economic benefits it will bring, then it can be argued, and many do, that

---

[42]Tyson, "Managing Trade Conflict," p. 6; C. Fred Bergston and Edward M. Graham, "Globalization of Industry and National Governments," (Washington, DC: Institute of International Economics, 1992).

[43]An MIT Faculty Study analyzed the many issues involved in foreign access to American universities (Skolnikoff et al, "The International Relationships of MIT")

[44]Keith Bradsher, "Split Goal on Trade," New York Times, Feb. 27, 1993, p. 6.

competitor nations or companies should not have equal access to the results of the research. Since most government-supported basic research in the U.S. is conducted in university laboratories and in other public research institutions, that view implies imposing some restrictions on access by foreign visitors and foreign students to those universities and institutions.

There would be several costs of taking such a step, a policy that is being seriously proposed by some in the U.S.[45] One is a result of the spread of quality research and scientific and technological competence throughout the world. That means that to maintain frontier research in any subject, scientists must have access to information generated by scientists and laboratories wherever they may be located. Any restrictions are not only undesirable, but counterproductive; they would eventually erode the vitality of the scientific enterprise itself which it is hoped will be the source of new knowledge for industrial exploitation. It is the quality of a nation's S/T enterprise that is the key to its long-term value for the nation, and that quality can be served best by maintaining an open research enterprise that is fully integrated into the worldwide scientific community.

Moreover, it is not the timing of industry's access to new knowledge but the competence of a nation's industrial structure to translate the results of the laboratory into competitive products that is the primary key to the commercial exploitation of knowledge. The focus must be on improving the ability of industry to convert knowledge to product, rather than on damaging the sources of knowledge, a view that is echoed in the Clinton Administration policy proposals.

The argument is easy to make at this level of generality. In practice, however, the issues become somewhat clouded because of asymmetries in the structure of the research enterprises in different countries. In the U.S., the basic research conducted in universities and public institutions constitutes the majority of the basic research performed in the country. It is conducted with open access and rapid publication of results. In Japan, however, and in some other countries, relatively less basic research

[45]"Is Science for Sale?: Transferring Technology From Universities to Foreign Corporations," Twenty-Eighth Report by the Committee on Government Operations, Oct. 16, 1992, U.S. Government Printing Office, Washington, DC, 1992. Sen Shelby (D-Alabama) proposed on Feb. 17, 1993 a prohibition on the sharing of information from NSF or NIH-funded research with representatives of foreign corporations or their American subsidiaries before publication. He withdrew the proposal on the promise of hearings to be held on the subject within two months.

is performed overall, with industry dominating the research scene and the universities playing a much less significant role. Japanese industry follows the practice of industry in all countries of restricting the flow of information from their laboratories, so that reciprocity of access is difficult to realize in practice.

The Japanese have relied heavily on the results of basic research in the West, a dependency they have begun to correct by increasing the support for basic research at their universities. But given the existing situation, and Japan's success in high-technology trade, the apparent one-sided access of Japanese industrial visitors to research laboratories in the West not surprisingly arouses political reaction and strident calls for imposition of restrictions on access to those laboratories. There is particular concern in those fields, such as molecular biology, in which the time-lag between the laboratory and commercial exploitation appears to be particularly short.

The universities respond--though not as an organized group--that the problem is much exaggerated and is, in any case, primarily a problem of shortcomings of industry rather than of ease of access to knowledge; that there is more actual reciprocal exchange of knowledge with Japan than the asymmetrical structure of research establishments would imply; that effective transfer of technology is much more difficult than is assumed; and that, most importantly, the supposed cure (imposing restrictions) would be much more costly to economic competitiveness than the disease. Even if access to some of the more applied work at universities does assist foreign industries, so the argument is made, that knowledge is equally available to domestic industries, and there would be no way to apply restrictions only on commercially-relevant research without damaging the whole research enterprise.[46]

Whatever the resolution, if there is ever "resolution," of this issue of unfettered access to basic research at the universities, the perceived economic relevance of university research will certainly increase the pressure for universities to be more attentive to the need for economic returns to R&D, and to devise ways to improve the effectiveness of knowledge transfer to American industry. Not surprisingly, this has raised concern among scientists, who believe using economic objectives to determine basic research objectives is not only undesirable from the perspective of science, but also doomed to failure. That is, that the most likely economic benefits will be achieved through the unexpected advances of knowledge

---

[46]Skolnikoff et al, "The International Relationships of MIT."

and synergisms among fields, not by research toward specific economic applications, which will inevitably be limited in imagination.

Programs to stimulate more effective transfer of knowledge are, however, more acceptable at the universities, and many of the leading research institutions have taken advantage of the new patent arrangements to mount aggressive patent and licensing programs. Industrial liaison programs at universities are now common, though those that include foreign companies as members have run into the criticism of transferring knowledge too readily to foreign competitors. Universities have also responded to the importance of improving education and research in manufacturing technologies. Federal government support has helped, but industry itself recognizes the need and has provided considerable support for some programs at leading universities.[47] However, the general and growing pressure on realizing economic benefits of research at universities will undoubtedly lead to policies that will challenge some of the cherished principles of operation American universities believe to be essential both to their independence and to their productivity.

This challenge will also put into bolder relief a larger and in the long run a potentially more dangerous issue: the possible changes in national attitudes and policies toward science and the universities. In the U.S. there is a growing skepticism about science and technology, with the distinct possibility that the "social contract" between the government and the scientific community crafted during and after World War II may now be unravelling.[48] The combination of the end of the cold war which removes the security need for large-scale funding and the justification for merit-based allocation of research funds, a continuing fragmentation of national politics that erodes central authority, a divisive new populism that is skeptical of the role of scientists and of elite universities, and a growing wariness of the externalities of

---

[47]The Leaders for Manufacturing Program at MIT may be the most ambitious. A joint program between the Schools of Management and Engineering, it is supported by 13 companies, and is training some 45 students per year to be able to work in the manufacturing sectors of American industry. Judith V. Stitt, "Leaders for Manufacturing, with a 'Big M'," MIT Management, Fall 1992, pp. 2-30.

[48]There was no formal contract, but there was rough acceptance of the idea that government would provide unfettered support for science, to be divided following the norms of the scientific community, in return for which benefits would be realized both for the nation's security and its economy. Vannevar Bush (Science the Endless Frontier: A Report to the President on a Program for Postwar Scientific Research, (NSF 60-40), NSF, Washington, DC, 1945) provided the underlying rationale for the relationship.

technology could result in the U.S. in a wholly new approach to science that no longer accords it the privileged apolitical status in the policy process that it has enjoyed for so long.

Many scientists are seriously worried about this situation and its likely evolution, though it is not yet near a crisis stage. It is most likely, however, that the U.S. will at the least be undergoing a quite fundamental reevaluation of its basic science policies over the next few years, with the possibility of major restructuring to follow. President Clinton and Vice-President Gore appear to be fully supportive of the traditional postwar norms of the government/science relationship, but the press of events, especially changes in the economic situation, may lead them to be less sympathetic.

3. Environment:

The incoming administration enters office with a strong electoral commitment to the environment. That will have several consequences, but for this review, the major effects will be to increase environmentally-related R&D, and no doubt to increase regulations based on the results of that research.[49]

The question that follows will be whether the nation's economy and its international competitive position will suffer from the commitment to more environmental technology and regulation. The evidence is in dispute. Vice-President Gore and others argue not only that there no conflict between the economy and the environment, but that environmental technology can be a major contributor to economic health.[50] A contrary view sees environmental regulation as a cost to be carried by American products that foreign-made products are not assessed, while offering little in the way of direct technological opportunity.

---

[49]It is estimated that U.S. environmental regulations cost the economy approximately $120 billion in 1991 (Robert Repetto and Roger C. Dower, "Reconciling Economic and Environmental Goals," Issues in Science and Technology, Winter 1992-93, p. 29).

[50]Ibid, pp. 28-35. A study at MIT showed that American states with more stringent environmental regulations were actually doing better economically than those with weaker regulations (Stephen M. Meyer, "Environmentalism and Economic prosperity: Testing the Environmental Impact Hypothesis," MIT Project on Environmental Politics and Policy, Oct. 1992).

The resolution of this controversy is not certain, though it is worth observing that the Japanese government has made a substantial commitment to the development of technologies to meet environmental regulations in the apparent belief that there will be a substantial market for such technologies.[51] The Clinton Administration is now proposing an increase of $272 million over four years for the Environmental Protection Agency to support private-industry development of environmental technology.[52]

A substantial proposal for greater international focus on environmental research made by the Carnegie Commission on Science, Technology, and Government may have a good reception in Washington and has already aroused considerable international interest. The Commission proposed creating an international Consultative Group for Research on Environment that would sponsor a network of environmental research centers, parallel in concept to the International Agricultural Research Centers.[53] Such a network could be of great value both to industrial and developing countries in future attention to environmental problems. The ties between the Carnegie Commission and the new administration, and the similarity of interest on this subject, make it probable the proposal will receive favorable attention.

III. Implications for Developing Countries

There are many implications for third world nations that can be drawn from the discussions above, stemming both from the developments to be expected in science and technology, and from the likely direction of U.S. S/T policies. This paper is not a suitable vehicle for laying out the policy choices developing countries ought to consider, but some of the more important implications deserve to be highlighted. In particular, the signal importance for developing countries, and especially for the larger NICS (Newly Industrializing Countries), of building indigenous capacity in

[51] David Swinbanks, "Going for Green Technology," Nature, 350, 28 Mar., 1991, pp. 266-67.

[52] John Markoff, "Clinton Proposes Changes in Policy to Aid Technology," New York Times, Feb. 23, 1993, p. 1.

[53] Carnegie Commission on Science, Technology, and Government, International Environmental Research and Assessment: Proposals for Better Organization and Decision Making, Carnegie Commission, New York, July, 1992.

science and technology is the one overwhelming implication that emerges from almost all of the relationships and changes discussed in this paper.

A. THE EFFECTS OF CONTINUED ADVANCES IN S/T

We saw, earlier in the discussion, a schematic exposition of the likely societal effects of continued development of science and technology. Many of those will have important implications for developing countries, requiring the ability to respond to those effects and, at least as important, the ability to participate appropriately in the international relationships that grow from them.

It was noted, for example, that the nature of new technologies makes necessary or stimulates the creation of large international technological systems. To be able to take part effectively in the design of the systems, which will often determine who will benefit most from them, and to take a measure of operational and policy responsibility, will require technological knowledge and capability on the same order of competence as the other participating nations. Knowledge will be a necessary prerequisite for ensuring receipt of a fair share of the benefits of the systems.

Similarly, the rising importance of global issues and the increased interaction and integration among economies, so much of it technologically based, mean that indigenous technological capability is essential in order to participate effectively and to the net advantage of the nation in the innumerable negotiations and relationships that arise. Competence is necessary to understand the issues, to determine where the national interest lies, and to negotiate successfully with other nations, many of whom will have larger scientific and technological communities. These global issues can enhance the bargaining power of third-world countries (since third-world country adherence is will be essential to deal with many of them), but the issues must be thoroughly understood to capitalize sensibly on that power.

Other implications of technological change may reduce bargaining power, for example the growing ability to target R&D to produce technologies with specific desired characteristics that will allow scientifically advanced nations to design around resource or other dependencies.[54] This capability cannot be prevented, but anticipating

[54]Fossil fuel dependencies are the major exception, but only because of the scale of the energy industry and its fundamental nature for all economies. However, the potential is there to eventually reduce fossil fuel requirements through development of alternatives and improved efficiency; the time scale will be much longer, however, than for other resource

its consequences and moderating its impact will require scientific and technological knowledge necessary for development of realistic policy options.

Closely related, the effects of technological change that alter factor costs of production may reduce the present advantages of third world countries as sites for industrial production. The ability to compensate for such technological change, to create alternative incentives, even to determine just where the national interest lies, for example in judging the risks of lower environmental standards, similarly requires significant indigenous S/T competence.

And, quite obviously, the increasing science dependency of new technologies means that any nation hoping to be able to compete in world markets in technology must develop a science base adequate to support the rapid pace of technological evolution set by the technologically advanced countries.

Other examples could be drawn, but the overall implications for third world nations are simple and rather clear:

1. The traditional comparative advantages of third world countries in international trade are in general decreasing. That is, with the exception of fossil fuels, industrialized countries are less dependent on the resources or formerly favorable factors of production of those countries. (This, of course, says nothing directly about the markets those countries provide now or potentially). Thus, the bargaining power of developing countries that is based on traditional comparative advantage is deteriorating.

2. The other side of that coin is that the growth of global-scale technologies and problems does serve to enhance the bargaining power of developing nations, especially the NICs and large, populous states whose participation is essential for dealing with the technologies or the problems.

3. Finally, and overwhelmingly, a competent indigenous capacity in science and technology is essential in order to participate in modern international technologies, to be able to negotiate effectively on increasingly complex international issues, to take advantage of enhanced bargaining leverage or to offset declining leverage, and to be competitive in high-technology trade.

---

dependencies.

These lessons may be simple to state, but, of course, achieving that competence in indigenous science and technology is not a simple matter.

B. EFFECTS OF FUTURE U.S. POLICIES:

The changes in U.S. S/T policies introduced during the Bush Administration and the far-reaching proposals of the Clinton Administration will necessarily have repercussions on developing countries; some of the more important effects that are relevant to S/T may come from other policy areas, however.

For example, one change in direction already accomplished by the new administration is the modification of U.S. policy toward international population planning programs. The former ban on U.S. contributions to international programs that include abortion counseling has been lifted by Executive Order of the President. This will certainly signal a more aggressive U.S. population policy in general, with a return to the policy stance of the Carter administration on this subject.

A more positive policy toward multilateral institutions can also be expected, with the needs and issues of those institutions put higher on the foreign policy agenda, especially for those involved in global-scale issues. The preliminary budget revisions pledged to make the U.S. "current in its legal obligations to multilateral institutions." However, it is not at all likely that greater interest will be accompanied by large increases in funds, either for the organizations or for their regulatory and technical assistance efforts. The scale of the American budget deficit, the problems of the domestic economy, and the inward-looking preoccupation of the American public preclude large increases in resources for foreign activities. If there is an exception, it will be for international security functions of multilateral organizations, which will take precedence over technical assistance or environmental roles; immediate security needs always crowd out longer-range goals with lower political visibility.

There may also be a move to review and change the basic foreign aid legislation, which has remained essentially the same since the Agency for International Development (AID) was created in the Kennedy Administration. In fact, funding for AID has been "cut pending reorganization of that agency." If that is carried out, science and technology will probably be accorded a larger place in the new structure, but there is little reason to expect a fundamental change along the lines of the proposed Institute for Scientific and Technological Cooperation (ISTC) that almost came into being under President Carter.[55] A recent report of the Carnegie Commission on Science, Technology, and Government called for a thorough revamping of the U.S. policy process for foreign aid, greater attention to U.S. private and public sector capabilities in S/T in efforts to assist development, and a general approach of creating partnerships (domestically and internationally) in aid of development.[56] It is too early to forecast what impact this report will have, but the subject is not likely to be accorded high priority in the Clinton Administration.

It is also possible that the sheer scale of U.S. interactions with other countries and the concomitant difficulty in coordinating those activities through the Department of State or the White House will result in greater independence in the international operations of each government department. That is, there may be greater acceptance in the executive and legislative branches of the limitations and costs of coordination, and appreciation of the advantages of allowing the expertise of technical ministries to have more flexibility in their international activities. That is not the current tendency in the American policy process; in fact, there is more interest in tight coordination than decentralization of policy, but pressures of scale and need may force eventual movement in the direction of decentralization.

Large increases in direct resources for foreign aid are not at all likely for many years into the future, except in the most unlikely event that the U.S. was forced to such a move by a global issue that threatened catastrophe. The pressure of domestic economic problems and the continuing unpopularity of foreign aid in the American public, make substantial resource increases out of the question.

What may be possible, however, is the gradual development of alternative routes for the transfer of resources from North to South in the context of global problems. For example, funds for improving the efficiency of use of fossil fuels in order to reduce CO2 emissions might be authorized to be spent by the appropriate government agency wherever they are most cost/effective. With that authorization, funds would more likely be actually spent outside the U.S., not in the context of foreign aid, but to serve an environmental goal. Tradeable emission permits would

[55]Agency for International Development, "FY 1981 Congressional Presentation, Institute for Scientific and Technological Cooperation," Submitted as Annex IX of the Congressional Presentation of AID, 1980.

[56]Carnegie Commission on Science, Technology, and Government, Partnerships for Global Development: The Clearing Horizon, Carnegie Corporation: New York, 1992.

also have that resource transfer characteristic that would bypass traditional foreign aid bureaucracies. The interest of the new administration in global environmental issues makes this development more likely in the next few years than would otherwise be the case.

With regard to the impact on developing countries of S/T policies themselves, the most significant effect of the increased focus on economic competitiveness is likely to be felt in a more aggressive trade stance. As noted, President Clinton has endorsed a free trade position, but it was accompanied by an insistence on reciprocity with regard to markets and on effective IPR protection. The U.S. has had many disputes with third-world countries about access to markets and IPR and those are likely to continue, perhaps grow. In general, policies with serious protectionist overtones are much more likely in the new administration than in the preceding Bush and Reagan years. Much of that new assertiveness will be directed at Japan and, to a lesser extent, Europe, but some will certainly affect developing countries.

This will be particularly so for those countries, like Brazil, that are striving to industrialize rapidly, and in the process may be following policies to which the U.S. objects, such as infant industry protection, large subsidies for specific industries, or demanding policies on intellectual property rights. Given the deeper determinants of competitive advantage today, the U.S. stance in international trade negotiations,may prove to be both tougher and more concerned with "domestic" issues not previously a part of those negotiations.

There seem to be few other direct implications of U.S. S/T policies for developing countries, other than the general appreciation that if the policies are successful, the U.S. will be a more formidable technology competitor in the future, making it harder for newer entrants to compete. On the other hand, a more prosperous U.S. will be a more valuable trading partner, offering markets for developing country exports and an easier attitude on transfer of resources.

Successful policies in the education and training area could also have the effect of reducing the current need for foreign scientists and engineers to staff American universities and industry, thus possibly reducing the so-called "brain drain."[57] This

---

[57]National Academy of Engineering, Foreign and Foreign-Born Engineers in the U.S. (Washington: NAS, 1988), p. 3. National Research Council, Summary Report 1989: Doctorate Recipients from U.S. Universities (Washington: NAS, 1990), p. 46.

cannot confidently be predicted, however, for the success of the education policies may be harder to achieve than any other aspect of the policy package, and in any case a thriving technological economy would be likely to attract even more students from abroad who elect to stay in the U.S.

C. IMPLICATIONS OF NAFTA AND POSSIBLE FOLLOW-ONS

The S/T policy implications of NAFTA and its possible later extensions follow from much of what has been covered above. The essential point is that whatever benefits the agreement may accord to the developing countries of the Western Hemisphere that stem from increased low-cost and low-skill labor opportunities are likely to be fairly short-lived. Technological trends will gradually make those advantages less important, at least in high-technology production, as technological advance alters factors of production in favor of the more advanced industrial nations.

Similarly, apparent possibilities for creating pollution havens in poorer countries will also not last for long, as increased R&D on environmental matters and increased attention to environmental issues in the new administration will likely reduce the need or the incentive for relocating production from the U.S. In any case, NAFTA will probably not be approved by the new administration without parallel agreements on limiting the creation of environmental refuges.

Finally, the effort of the U.S. to improve its technological competitiveness against nations in Europe and the Far East, will unavoidably also put pressure on those aspiring nations in the Hemisphere that are trying to develop their own competitive skilled industries. It is clear, again, what a premium there is on the ability of the less-developed nations of the Hemisphere to build their indigenous competence in S/T as fast as they sensibly can do so.

IV Conclusion

The science and technology policies of the United States are clearly entering a new phase, not only because of the change in administration, but also because of the manifold changes in both domestic and international affairs, and because of developments in science and technology themselves. Economic issues have come to dominate the agenda, and that is reflected in substantial new attitudes toward the roles of S/T, with a host of new programs already underway that are likely to be substantially expanded and added to by the new President. The general thrust is likely to increase the role of the federal government in creating the necessary conditions for economic innovation. The intent is to develop partnerships with industry, though the extent of intervention by the government and the reliance on industrial leadership will be determined only as the policies are legislated and implemented.

Whether the S/T policies will be successful or not in improving the nation's competitive position is obviously not certain, but the extent of the changes proposed, and the new spirit in evidence, gives ground for optimism. In any case, the policies are likely to make the U.S. a more formidable trading partner against all but the most effective economies, which may mean only Japan for now, and thus a challenge to third-world countries aspiring to improve their technological position. The policies will undoubtedly also create some problems within the U.S., especially with relation to the support for fundamental science, and carry the danger of introducing protectionist strains in areas previously immune, for example, in university-based research.

With regard to developing countries, the single most important S/T-related need is to build indigenous capacity in science and technology that will allow them to participate adequately in the host of new technological, competitive, and environmental issues they will have to face in the near future. Some help for this may be provided by the industrialized countries, but the political environment, especially in the U.S., remains unreceptive to devoting substantial increased resources in that direction. The need for developing country cooperation in international technological systems and on emerging global-scale environmental problems, however, may increase the bargaining power of those countries, forcing expanded movement of resources over time from the countries of the North to those of the South.

Overall, it can be said that the world is entering a new era in science and technology policy, as it confronts a host of new problems in almost every sphere of social and political affairs. The developments in the U.S. will not be unique, but the size of the U.S. economy will magnify the international impact of whatever changes that nation makes. The beginning of a new administration at this time with new ideas is appropriate; the results are far from assured, but the energy that has been shown and the initiatives proposed make the future brighter than it has been.