New Developments in U.S. Technology Policy: Implications for Competitiveness and International Trade Policy

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The science and technology policies of the U.S. government are now in flux in three important respects: changes in the organization and funding of civilian research programs are being made or considered to improve the ability of U.S. firms to realize the commercial profits from the innovations spawned by such research; defense research funding is being used to support advances in civilian technologies in order to provide eventual technological improvements for the military (a dramatic reversal of earlier patterns of funding and technological spillover); and the new science and technology policy priorities of the U.S. government and the increased salience of these issues for foreign governments have elevated the importance of science and technology issues within trade policy.

Although many of these changes began with the Reagan Administration, they have continued into the post-Reagan era. These shifts in science and technology policy are troubling for two reasons: they may have a chilling effect on the international scientific and engineering cooperation and communication that are essential to innovation in the U.S.; and policies are being proposed or implemented with little apparent recognition of their implications for other foreign and domestic policy goals.

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Growing Concern with Commercialization—The Reagan Administration entered the White House in 1981 committed to minimizing government intervention in the commercialization of new technologies. In this view, the appropriate federal role in civilian technology development was limited to funding of basic research, commercialization of which was best handled by the market.[1] By 1988, however, the Administration had launched several initiatives aimed at commercialization of new technologies. The Administration's 1987 response to the demonstration of the phenomenon of high-temperature superconductivity (HTS), the formation of the Sematech (Semiconductor Manufacturing Technology) consortium, and the 1988 development of standards and research programs for high-definition television (HDTV) are all illustrative of a shift in attitudes. Other examples of the new policy posture include the National Science Foundation programs for university-industry research cooperation, Engineering and Science Research Centers, and the transformation of the National Bureau of Standards into the National Institute of Standards and Technology. All of these initiatives were intended to increase the national economic returns to the large federal investment in basic research.

These programs represent a considerable break with the rhetoric of 1981 and depart as well from the approach to commercialization taken in other postwar Administrations. Previous federal initiatives for commercialization supported the development of technologies for which market mechanisms and incentives were deemed to be lacking or insufficient. Examples include the commercial supersonic transport, coal liquefaction and synthetic fuels, "Project Breakthrough" in residential construction, and the liquid metal fast breeder reactor.

The new policies of the past several years, by contrast, focus on raising the national economic returns from commercial development of basic research advances for which the private returns to U.S. firms are likely to be high, but only in the absence of faster commercialization by foreign firms. These programs are intended to aid U.S. firms in reaping the commercial benefits from basic research in a world in which foreign firms may commercialize applications of basic research breakthroughs more rapidly and effectively.[2] As a result, some of the recent commercialization initiatives have acquired a mercantilistic character—the results of research, rather than gold, are hoarded by a nation as a source of power, and the transfer of research results or technology is viewed by some as a zero-sum game.

There are a number of examples of the more restrictive approach to science and technology exchange in recent U.S. policies. The HTS symposium organized in 1987 by the White House Office of Science and Technology Policy and the National Science Foundation excluded foreign participants. The Administration's subsequent proposals for increased research funding for HTS development (the Superconductivity Competitiveness Initiative, submitted in January 1988) did not diverge sharply from historic precedent, being confined largely to expanded research funding that drew primarily on military sources. The proposal nonetheless did include provisions designed to prohibit or restrict foreign access to the results of publicly funded basic research in HTS where disclosure is deemed threatening to national competitiveness.[3] The recent discussions among private firms and the Department of Commerce on commercial development of high-definition television have excluded foreign firms, and the Federal Communications Commission's decision on broadcast standards for high-definition television has been interpreted by some as intended to exclude Japanese HDTV designs.[4] The Sematech initiative, the National Center for Manufacturing Sciences (NCMS), and the recently announced DARPA (Defense Advanced Research Projects Agency) research initiative in high-definition television, which are funded in part with public monies, already do or may exclude foreign firms (even those with large U.S. subsidiaries) from participation.[5]

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Although the increased concern of these proposals with commercial development of basic research is a positive development, the seemingly mercantilist flavor of many of them is not. Proposals to restrict scientific and technological cooperation fly in the face of the growing interdependence of national R&D systems. The early demonstration of HTS by a German and a Swiss scientist in a Swiss laboratory owned by a major U.S. multinational firm is an obvious example of such interdependence. Others include the establishment by Texas Instruments of a software engineering laboratory in Bangalore, India, or the reliance by Toyota and other Japanese automobile firms on their design studios in Southern California. In an era in which other industrial economies maintain increasingly sophisticated and powerful national research systems, the United States may have less to lose and more to gain through encouraging joint research and technology exchange than at any previous point in the postwar period. To the extent that U.S. policymakers design technology initiatives that ignore the increasing interdependence of U.S. and foreign scientific and technological research, U.S. competitiveness and technological development will be impaired.

Consider, for example, the implications of the proposed restrictions on disclosure of HTS research results for a multinational firm like IBM that operates research laboratories throughout the industrial world. Use by the firm of its network of foreign R&D laboratories would decline, and access to foreign government-funded research projects might well be reduced, limiting the ability of IBM and other U.S. firms to tap the scientific and technological developments of foreign economies.[6] Such restrictions could reduce the competitiveness of this and other U.S. firms. Proposals to restrict access to U.S. research facilities and findings also overlook the historic futility and ineffectiveness of such restrictions. Moreover, these proposals and policies severely undercut simultaneous efforts by the federal government to improve the access of U.S. firms to foreign publicly funded research programs.

The Changing Relationship between Military and Civilian Research— A second source of change in federal technology policies stems from the shift in the relationship between military and commercial technologies. Military technologies (and therefore military research budgets) may now be less fertile sources of commercial applications than was true during the 1950s and 1960s. This issue is not easily resolved with the limited evidence available to us, but the perception among policymakers of the relationship between military and commercial technologies unquestionably has changed,[7] and this new perception has influenced defense research funding priorities.

During the 1950s and 1960s, defense research and procurement in jet engines and airframes, semiconductors, and computers yielded important civilian applications.[8] The size and importance of the spillovers reflected the generic similarity of military and civilian requirements in the early stages of the development of these technologies. Over time, however, the size and even the direction of spillovers appear to have changed. As military aircraft moved into the world of supersonic speeds, they acquired performance and cost characteristics that were increasingly inappropriate for the cost-conscious world of commercial travel.[9] In microelectronics, declines in the military share of the market and the increasing length of time needed to insert new devices into weapons systems have made U.S. military microelectronics dependent on progress in commercial technologies.

The changing relationship between military and commercial technologies in microelectronics influenced the decision of the Defense Department to contribute as much as $600 million over six years to the Sematech research consortium. Sematech, which includes 14 U.S. producers of microelectronic components as members, is dedicated to the development of advanced manufacturing processes for commercial memory chips, not military components. Pentagon funding is also prominent in NCMS, to which DARPA is contributing $15 million (out of a total three-year budget of $40 million) over three years. NCMS includes nearly 80 firms from a diverse array of manufacturing industries and is intended to support research on manufacturing process technologies. It excludes foreign firms from membership and restricts the transfer to member firms' foreign subsidiaries of technologies developed under its sponsorship. Similar concerns led to the announcement in early January 1989 by DARPA that $30 million would be allocated to support research in HDTV technologies by U.S. firms.[10] Many (although not all) of the applications of HDTV will be in civilian markets. This program may also exclude foreign enterprises.[11]

Military funding for these programs is based on two assumptions: that technological spillovers in process and product technologies and design now flow primarily from commercial to defense applications in these sectors; and that U.S. suppliers of defense technologies cannot survive without maintaining a strong presence in commercial markets. Research support for commercial technology development within domestic consortia that exclude foreign firms is therefore necessary for national security.

Regardless of the validity of the assumptions on which they are based,[12] these initiatives undermine the basis for U.S. opposition to the large-scale technology development subsidies granted by foreign governments to such programs as the European Airbus consortium. Airbus is targeted more precisely on a specific commercial technology (indeed, on a set of commercial aircraft designs) than the recent Pentagon programs, and Airbus subsidies support production as well as development. Nevertheless, the Airbus consortium is driven in part by the desire of member governments to maintain national military aircraft industries by supporting the involvement of their firms in a major commercial project. The development of similar U.S. programs therefore appears to place this nation's trade policymakers on a rather slippery slope. If the difference between U.S. and foreign technology subsidy programs becomes one of degree, rather than kind, the limits to foreign subsidization that are imposed by U.S. opposition and persuasion are likely to be eroded still further.[13]

In addition to their implications for U.S. trade policy, of course, restrictions on foreign participation in these programs exacerbate technological mercantilism. As in the case of the proposed restrictions on HTS research, the NCMS restrictions on international transfer by member firms of NCMS-developed technologies could hamper management by U.S. multinationals of their international R&D or manufacturing operations. The extent to which these restrictions conflict with the private interests of U.S. multinationals is well illustrated by the recent decision of Texas Instruments, a major participant in Sematech, to enter a technology-sharing joint venture with Hitachi of Japan, presumably one of the major competitors of the firms participating in Sematech.[14] Efforts to impose strict limitations on international transfer or foreign participation fly in the face of international technological interdependence and may undercut the effectiveness of the collaborative research ventures currently underway.

The Merger of Technology and Trade Policies

Governments in a number of industrial and developing nations now view technology policy as an important lever for increasing national income and economic growth. The growing political salience of national science and technology policies is blurring the boundaries between technology and trade policies and complicating policy formulation in each area. The growing importance of technology issues within trade policy poses challenges to the structure of U.S. trade policy. The largely static conceptualization of trade policies and consequences that underpins U.S. trade law is incompatible with the dynamic effects of technology. In addition, many instruments of government technology policy lie outside the purview of conventional trade policies.

Why Technological Change Complicates Trade Policy—Technological innovation and technology-intensive industries fit uneasily into the framework of trade policy negotiations and law developed over the past four decades by the U.S. government. Several characteristics of innovation and the industries spawned by it are of particular importance: the tendency for costs to fall and product quality to improve over time as a result of "learning" within technology-intensive industries; the imperfect competition and increasing returns associated with many such industries; and the influence of nontariff trade barriers on the development of new technologies and technology-intensive industries.[15]

Learning effects have a number of important implications for trade policy. They provide one justification for government policies of support for the development of technologies or markets for technology-intensive industries. "Infant industries" that receive government aid and that are characterized by strong learning effects may become robust adolescents capable of survival without government support.[16] The most common forms of direct government support for infant high-technology industries are subsidies for investment or research,[17] restrictions on access by foreign producers of similar goods to the domestic market through trade or investment, or procurement policies that favor the domestic producer of a high-technology good. All of these policies can distort trade flows.

Krugman and others have noted that a number of global technology-intensive industries are characterized by high fixed costs (typically related to the very high costs of development of new products and processes) and a concentrated market structure.[18] The strategic competition that currently exists in industries like commercial aircraft, in which subsidized Airbus aircraft compete against nonsubsidized Boeing aircraft in many markets, is motivated in part by the concern of Airbus Industrie's sponsor governments over losing alternatives to Boeing as a source of commercial aircraft. If the alternative to subsidized development and production of Airbus products is a Boeing monopoly in many segments of the market, with prices to match, the economic returns to Airbus Industrie's member governments (and to airline passengers and stockholders the world over) from their subsidies may be greater than estimates of the direct employment and spinoff effects suggest. Similar arguments concerning the dangers of dependence on monopolistic foreign suppliers have been voiced in proposals for U.S. government subsidies to the domestic design and production of random-access memory chips.[19]

The combination of trade-distorting policies and strong dynamic effects means that the performance of a firm in such an industry may be influenced by government policies (subsidies or protection of domestic markets) and industry structure in earlier periods. This reality is very difficult to accommodate within a U.S. trade policy enforcement mechanism that focuses primarily on costs, pricing, and subsidies in a static, single-period framework.[20]

Technology-intensive industries also challenge the historic focus of U.S. bilateral and multilateral trade initiatives on tariffs and border measures and on assurances of procedural regularity and national treatment for foreign firms. The instruments employed by governments in support of technological development extend far beyond the border measures (mainly tariffs) that have been the subject of most trade negotiations. Because of their effects on trade flows, domestic subsidies for R&D, government procurement, intellectual property regimes, investment subsidies, regional development policies, and other policies that historically have received little scrutiny from trade policymakers are now central to trade negotiations.[21] Just as the macroeconomic policies of sovereign governments often conflict, these sectoral or microeconomic policies may also clash, producing allegations of unfair trade.[22] In many cases, longstanding domestic policies that were developed with little or no attention to their effects on international trade are now the subject of negotiations among trade policymakers.

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The growing importance of nontariff barriers to trade[23] and other internal policies with trade-distorting effects has complicated the tasks of trade policymakers. Negotiations over these policies involve a far larger community of policymakers and domestic interests than talks over border measures, which greatly increases their complexity. Tariff negotiations focused on a highly visible barrier, the operation and trade effects of which could be monitored fairly easily. The trade effects of nontariff barriers are more difficult to establish and monitor, which complicates negotiations.[24]

U.S. goals in trade negotiations on nontariff barriers and other trade-distorting policies generally focus on improving the operation of policy processes in foreign economies. Improvements in these processes include greater "transparency," meaning that policies are formulated through public processes that foreign enterprises can monitor and in which they can in some cases participate (e.g., through hearings or opportunities for comment on proposals), and "national treatment," meaning that policies and procedures are applied identically to domestic and foreign enterprises. Definition of and agreement on these desiderata for a specific set of policies, such as technical standards, nevertheless does not preclude the evasion of disciplines by the use of alternative instruments, e.g., government procurement, to achieve the same ends. The procedural focus of these negotiations thus can weaken their trade-liberalizing effectiveness.

One alternative to focusing trade policy on transparent and nondiscriminatory processes is to stipulate outcomes, as in the U.S.-Japan Semiconductor Agreement, which fixes a price floor for DRAMs and allegedly commits the Japanese government to ensure a specific market share in Japan for U.S. producers of these components.[25] By restricting imports through a quota or price agreement, such "managed trade" arrangements also provide higher profits to the affected foreign producers, which makes such import restrictions more acceptable to them and reduces the possibility of retaliation against U.S. exporters.[26] Needless to say, these agreements generally raise prices for U.S. consumers and firms. Moreover, since the agreements tend to be renewed repeatedly (as in the case of the Multifibre Arrangement, which establishes textile import quotas for the U.S. and other industrial nations), protection may persist for years, reducing pressure on U.S. producers to adjust to import competition.

The Semiconductor Agreement has produced mixed benefits for many U.S. electronics firms. U.S. computer makers now depend on foreign (mainly Japanese) suppliers of DRAM components, and new personal computer and workstation designs demand more memory components per unit. The sharp increases in the cost of DRAMs that appear to have resulted from the Semiconductor Agreement have raised the costs of U.S. computer producers.[27] Most Japanese producers of personal computers, by contrast, are vertically integrated into memory production. The Semiconductor Agreement increased the profits of these Japanese firms (current and future competitors with U.S. producers of computers) from DRAM sales and provided them with a significant cost advantage in components for computer and workstation products.

The Agreement's alleged call for an increase in the Japanese market share of U.S. producers of microelectronic components has also led a number of U.S. component firms to develop strategic alliances and other collaborative ventures with Japanese producers of systems.[28] These collaborative ventures may accelerate technology transfer from U.S. to Japanese and from Japanese to U.S. firms. If the Semiconductor Agreement thus far is an example of successful "managed trade," it is hard to know what might constitute a failure.

The difficulties of the Semiconductor Agreement illustrate the problems created for trade policy by technological interdependence. More rapid international technology transfer has made the national origins of complex products and technological innovations increasingly blurry. Obviously, this development hampers the formulation and administration of national trade policies that attempt to maximize the benefits to a national economy of international trade by restricting the import or encouraging the export of specific goods.

The increased internationalization of high-technology products also affects domestic technology policy. Consider, for example, the debate over federal policies to support the development of a domestic U.S. high-definition television industry.[29] In order to ensure that a domestic HDTV development and production program yields significant benefits to U.S. producers of semiconductor components (a key argument advanced by supporters of a large-scale HDTV program), complex domestic content regulations may be needed to mandate use of only semiconductor components from U.S.-owned firms' domestic production facilities. Moreover, if these components are not internationally competitive in quality and price, the resulting HDTV systems may not be competitive, necessitating additional protection and reducing the "technology-pull" benefits for the national economy of an HDTV development and production consortium.

The Increasing Salience of Technology Issues within U.S. Trade Policy— Regardless of the complications introduced by technology issues for trade policy, recent U.S. government actions and legislation have significantly raised the salience of technology issues within both bilateral and multilateral trade negotiations. The increasing importance of R&D and technology policy issues caused negotiations over renewal in 1988 of the U.S.-Japan Agreement on Scientific Cooperation, formerly of concern only within the scientific community, to involve the trade policy agenda and trade policymakers in both governments. The central trade-related issues in these talks concerned intellectual property rights within Japan and the assurance by the Japanese government of access by U.S. firms to publicly funded research in Japanese laboratories that was comparable to Japanese firms' access to publicly funded research in U.S. research facilities.[30] The restrictions on foreign participation in U.S.-based research consortia, many if not most of which involve significant public funds (in many cases from state, as well as federal, sources), that were discussed earlier will of course complicate U.S. efforts to achieve greater access to consortia in Japan and other industrial economies.

Technology-intensive industries now play a far more important role in bilateral disputes and negotiations. Although such mature industries as steel and textiles have been a source of significant trade tensions for a number of years, in recent years trade disputes among industrial economies have involved a growing number of high-technology industries. These industries include telecommunications equipment, which has been the object of intensive discussions between the U.S. and Japan, West Germany, and France, among other industrial nations, over U.S. firms' access to foreign markets; commercial aircraft, where the U.S. has demanded that the European Airbus Industrie consortium reform its structure and reduce its reliance on government support; computers;[31] and microelectronics.[32] These and other high-technology sectors have also been a focus of Congressional trade policymaking, including the 1988 Omnibus Trade and Competitiveness Act.[33]

A final important area in which trade policy has been influenced by the evolving agenda of technology policy is intellectual property rights. Intellectual property rights now occupy a prominent place on the trade policy agenda, for several reasons. U.S. firms increasingly depend on exports of R&D-intensive products, which may benefit from improved intellectual property protection and stronger enforcement of anti-counterfeiting laws. Bringing intellectual property issues into trade policy (through Section 301 of the Trade Act) also provides a potentially powerful enforcement mechanism—restrictions on access to the U.S. market for the products of nations that provide insufficient protection. Faced with threats in bilateral negotiations of restrictions on their firms' access to U.S. markets, foreign governments have revised domestic policies to achieve standards of protection and breadth of coverage comparable to those in the United States. As elsewhere, the case of intellectual property rights illustrates the significant extension of the reach of trade policy issues beyond the borders of trading nations into domestic policy areas.

Intellectual property rights are also on the agenda of the Uruguay Round of multilateral trade negotiations. These negotiations may make insufficient protection for intellectual property rights grounds for sanctions (including trade retaliation against the offending government) under the provisions of the General Agreement on Tariffs and Trade. Moreover, the GATT would be called on to define, through reference to other international treaties or existing national statutes, acceptable levels of protection and coverage of intellectual property rights. A successful intellectual property rights agreement in the Uruguay Round could produce a multilateral system of trade-based enforcement of these rights that resembles the bilateral framework currently employed by the U.S.

Despite the considerable U.S. investment of political persuasion and resources in the intellectual property question, the benefits for U.S. firms of a successful outcome, especially in multilateral negotiations, may easily be overstated. Not all U.S. industries benefit equally from intellectual property protection, despite the high priority accorded by the U.S. to this goal in the Uruguay Round, which spans 15 different negotiation areas. Conventional instruments of intellectual property protection—including patents, trade secrets, and copyrights—are not always sufficient to enable innovators to reap the returns to their investments.[34] Patent protection appears to be most important for innovators in the chemicals and pharmaceuticals industries.

In other industries, however, in which the critical sources of profit are marketing or production expertise, patents or other forms of intellectual property protection may be of secondary importance, no matter how much these protections are strengthened. The benefits of stronger intellectual property protection to many U.S. industries thus may not outweigh the costs of the concessions in other areas of the Uruguay Round that will be necessary to gain agreement within the GATT on this contentious issue.

Stronger intellectual property protection may also be a mixed blessing for the domestic U.S. economy. Theory provides little guidance on the appropriate balance between protection of intellectual property rights, which benefits the inventor, and support for domestic diffusion or adoption, the critical stage for the realization of the social benefits of innovation (e.g., higher incomes or productivity). The existence and nature of this conflict must nevertheless be kept in mind in formulating technology policy, to say nothing of trade policy. Science and technology policies in Japan and other industrial economies have tilted further than U.S. policies toward support for domestic interfirm flows of technological and scientific knowledge, and they have more heavily supported the domestic diffusion of new innovations. This postwar policy structure has been associated with rapid domestic diffusion of innovations and high rates of growth in income and productivity.[35]

If mercantilistic philosophy spreads more widely within U.S. science and technology policy, the results could be detrimental to the strength of the U.S. science and technology base and, possibly, to trade liberalization.

Conclusion

Like military officers who learn and refine the tactics used in the last war, science and technology policymakers in the U.S. and other industrial nations are applying the precepts of an earlier era, with results that may be quite the opposite of those intended. In developing technology and trade policies that emphasize the capture of the benefits of research for their nations, policymakers paradoxically have encouraged the growth of private international alliances—such as those between Texas Instruments and Hitachi in semiconductors or between General Electric and SNECMA of France in jet engines—for the commercial development of new technologies.[36] These consortia contribute powerfully to more rapid technology transfer and the internationalization of the global R&D system.[37]

The focus and structure of federal science and technology policy should be changed in response to these shifts in the technological and competitive environment. If the mercantilistic philosophy underpinning the initiatives discussed above spreads more widely within U.S. science and technology policy, the results could be detrimental to the strength of the U.S. science and technology base and, possibly, to trade liberalization. It is increasingly important that policymakers examine the consistency of initiatives in the technology and trade policy areas, precisely because of the growing interdependence of these policies. An alternative policy analysis and framework must be developed to supplant that of technological mercantilism.

The new environment of international economic competition also has implications for the domestic dimensions of science and technology policy. We agree that policymakers should place greater weight on the utilization and diffusion of the results of scientific and engineering research within R&D policy in order to improve the national returns to the large U.S. public investment in basic research. Support for domestic adoption and utilization of both new technologies and the results of basic research, however, seems preferable to current efforts to restrict the international flow of basic scientific and technological information and research. This latter approach will impoverish U.S. citizens as surely as restrictions on the international flow of goods and services. Nevertheless, giving greater weight to technology adoption and diffusion may require some modification in U.S. efforts to strengthen domestic and international protection for intellectual property rights.

Improving the rate and effectiveness of adoption and commercialization of new technologies requires initiatives that extend well beyond the boundaries of conventionally defined science and technology policy. Indeed, given the difficulties that many public programs have encountered in fine-tuning the U.S. national "innovation system" and in targeting specific technologies for support, broad policies that are relatively even-handed in their effects on all sectors are likely to be more effective in the long run. Since the adoption of new technologies typically places a premium on the skills of the workforce, policies to improve the educational preparation of entrants to the workforce, to remedy basic skills deficiencies in the employed workforce, and to improve the delivery of job-related training to the employed workforce are general policies that may well yield far greater payoffs (albeit in a longer time frame) than a dozen Sematechs.[38] Policies that increase the national savings rate and lower the domestic cost of capital—thereby increasing rates of domestic capital formation and the diffusion of new technologies[39]—similarly could have a greater impact on national innovative performance and productivity growth than tinkering with mercantilistic research policies.

The process through which science and technology policy initiatives are formulated and implemented also needs an overhaul. Much more must be done to highlight the interdependence of trade and technology policies so as to improve the consistency of policies in these areas. Within science and technology policy, appeals to national security and economic nationalism may easily overwhelm the very limited capacity of the policymaking structure for objective review and informed choice. In the absence of a better process for establishing priorities, the Sematech, NCMS, and HDTV initiatives will be but the first of many undertakings that claim public funds under a national security cover. In view of the serious resource limitations within future federal budgets and the complex implications of these ventures and other recent science policy developments for trade policy, a system capable of supporting a more comprehensive and rigorous evaluation of such proposals is badly needed.

References

1. Glenn R. Schleede, executive associate director of the Office of Management and Budget, commented in 1981 that "By far the most important change [made in science and technology policies by the Reagan Administration] came from this administration's redefinition of the federal role. In the R&D spectrum stretching from the most esoteric basic research out through the actual commercialization of a technology, we have drawn the line for federal intervention and support back much farther toward the basic research end. In the civilian or domestic sector, we do not think the government should be funding demonstration, product development, and commercialization efforts." Quoted in C.E. Barfield, *Science Policy from Ford to Reagan* (Washington, D.C.: American Enterprise Institute, 1982), p. 41.
2. Commenting in 1984 on this development, Nelson noted that science and technology policies in a number of industrial nations increasingly focus on transforming "leading" technologies (those with substantial spillover effects on other industries and technologies) into "strategic" technologies, which convey substantial benefits to the nation advancing them. See R.R. Nelson, *High-Technology Policies: A Five-Nation Comparison* (Washington, D.C.: American Enterprise Institute, 1984).
3. Under the terms of the proposed amendments to the Freedom of Information Act (FOIA), requests from foreign nationals for research data or results could be denied on the basis of potential harm to the competitive position of U.S. firms. The explanation accmpanying the proposals noted that "mandatory disclosure of such information under FOIA could encourage U.S. competitors to exploit the U.S. science and technology base rather than making investments in their own research and development infrastructure. Under Title IV, Federal agencies will be required to withhold information of this nature requested under the Freedom of Information Act where disclosure could reasonably be expected to harm the economic competitiveness of the United States." (*Proposed Legislation—Superconductivity Competitiveness Act of 1988,* House Document 100-169, February 24, 1988 (USGPO), p. 2).
4. See *The Economist,* October 1, 1988, pp. 17-18.
5. Dr. Robert Noyce, chief executive officer of Sematech, made this position clear in a recent interview: " 'What advantage would NEC [a Japanese electronics firm that has applied for Sematech membership] bring to Sematech?' I can think of none,' he said.

   "He hastened to point out the obvious threat of Japanese participation. 'If the trade problem were resolved and our technology was not used by foreign countries in a predatory fashion, as with TVs or semiconductors, I'd have no fear of diffusing our knowledge around the world. But now, American knowledge is being used to hurt Americans.' "

("Robert Noyce: On Sematech, Chips, and Competitiveness," *Challenges* (October 1988), p. 7).

6. Current European opposition to participation by IBM Europe in the Joint European Submicron Silicon Initiative (JESSI), a large research program funded by the Eureka program, apparently is based in part on the restrictions on European participation in the Sematech research consortium that is funded in part by the Defense Department. See S. Greenhouse, "IBM Faces Europe Bar to Chip Role," *New York Times*, May 5, 1989, p. C1. Recently, discussions between JESSI and Sematech have raised the possibility of collaboration between these ventures that would exclude Japanese firms (see "Hands Across the Chipmaking Chasm," *Business Week*, July 3, 1989, pp. 28-29). The ultimate feasibility or benefit of such a European-American alliance, however, are uncertain.
7. A recent front-page story in the *New York Times* discussed the growing concern that "the trends that hamper major commercial enterprises—lagging productivity, competition from imports, foreign ownership of American companies and inadequate long-term research—are damaging producers of weapons. In response, the Pentagon is beginning to argue for broad industrial policies that would benefit high-technology industries as a whole, hoping that the rewards would reach sectors of the economy that directly serve the military." (p. D22) The story describes a report by the Defense Science Board that recommended the "formation of an 'Industrial Policy Council' that would be headed by the President's National Security Advisor and would recommend policies to bolster industries that support the military. At the same time, the report said, the Defense Secretary should be made a permanent member of the Economic Policy Council, the Cabinet's group for making economic policy." (p. D22). See J.H. Cushman, "Bigger Role Urged for Defense Dept. in Economic Policy," *New York Times*, October 19, 1988, pp. A1 and D22.
8. See D.C. Mowery and N. Rosenberg, "The Commercial Aircraft Industry," and R. Levin, "The Semiconductor Industry," in R.R. Nelson, ed., *Government and Technical Progress: A Cross-Industry Comparison* (New York, NY: Pergamon, 1983), as well as K. Flamm, *Targeting the Computer* (Washington, D.C.: Brookings Institution, 1988).
9. The recent Congressional criticism of the commercial consequences of U.S.-Japanese collaboration in the development of the FSX fighter aircraft seemingly belies this assessment of military-civilian technology spillovers. Opponents of the FSX agreement, however, appear to have considerably overstated the likely applications of military fighter airframe technologies in large commercial transports. See D.C. Mowery, "The Japanese Commercial Aircraft Industry: Deja Vu All Over Again?" presented at the meetings of the International Studies Association, London, England, March 29, 1989.
10. See B. Davis, "Pentagon Seeks to Spur U.S. Effort to Develop 'High-Definition' TV," *Wall Street Journal*, January 4, 1989, p. 29.
11. P. Waldman, "Sixteen U.S. Companies to Form Groups to Develop Advanced-TV Technology," *Wall Street Journal*, January 13, 1988, p. 2. Waldman quoted Pat Hill Hubbard of the American Electronics Association, the trade association that announced formation of a loose consortium of 16 U.S. firms to develop HDTV technology, as stating that "it's too early to tell whether the collective will allow foreign-owned companies [many of which are members of the AEA] to participate in any consortiums that emerge . . . 'The main purpose of this is to ensure the U.S. gains and retains HDTV research and development capacity, engineering design capability and product manufacturing expertise.' " According to a later account of the DARPA research program, "European companies are expressing fears that their American subsidiaries will be shut out of a U.S. government [DARPA] research project on high-definition television." J. Wolf, "Europeans Fear Obstacles by U.S. on Advanced TV," *Wall Street Journal*, May 31, 1989, p. A16.

12. This article does not pursue the intrinsic merits of either Sematech or the NCMS, although both have some potentially serious problems. As Nelson and others have pointed out, the efforts of other nations, such as France and Great Britain, to merge military and commercial technology development have not been successful in the aircraft and electronics industries, nor has a similar effort in the U.S. nuclear power industry yielded major commercial technological benefits. In addition, the focus of Sematech on high-volume DRAM production technologies rather than custom application-specific chip designs, the consortium's unproven ability to transfer technological developments to member firms, and the political feasibility of using general revenues to subsidize the technological development of a group of U.S. firms at the expense of their nonmember U.S. competitors, all raise questions. The recent *Report on the Semiconductor Industry* by an interagency federal committee (Washington, D.C.: National Science Foundation, 1987) provides some basis for skepticism about the appropriateness of Sematech to meet current competitive challenges to the U.S. semiconductor industry.
13. Although U.S. opposition thus far has not eliminated Airbus subsidies, it has reduced them. If the aggressive pursuit of Sematech and similar initiatives were to produce a trans-Atlantic subsidies war, the federal government might find it financially and politically difficult to match other governments' production and development subsidies in the commercial aircraft and other industries. Nor is it likely that U.S. firms in these industries would accept large-scale U.S. government involvement in their operations. Policies that undercut U.S. pressure on Airbus member governments therefore could impose serious costs on the U.S. commercial aircraft and other successful export industries.
14. According to one account, " 'Sematech is for manufacturing knowledge and expertise,' said Stan Victor, a spokesman for Texas Instruments in Dallas. He added that the purpose of the agreement with Hitachi was different, because it was a 'technology development' program meant to create the most effective designs for the 16-megabit [microprocessor] chip." T.C. Hayes, "Developing a Computer Chip for the 90's," *New York Times*, December 23, 1988, p. C6.
15. For additional discussion, see P. Krugman, "Technology-Intensive Goods," in J.M. Finger and A. Olechowski, eds., *The Uruguay Round: A Handbook* (Washington, D.C.: World Bank, 1987); *idem*, "Is Free Trade Passé?" *Economic Perspectives*, 1 (1987); and C.M. Aho, "Technology, Structural Change, and Trade," in R.M. Cyert and D.C. Mowery, eds., *The Impacts of Technology on Employment and Economic Growth* (Cambridge, MA: Ballinger, 1988).
16. Although efficient capital markets should be capable of providing the support for these industries in their infancy, faith in the perfection of capital markets is not widely shared.
17. Foreign government research subsidies need not create difficulties comparable to those raised by development or production subsidies. To the extent that U.S. firms and other institutions invest in monitoring of the advances made in foreign research facilities, they are able to reap the benefits of this research without incurring the full costs—monitoring and purchase of licenses for the results of foreign research and development, after all, was a key factor in the development of Japanese commercial technologies. Both the monitoring of offshore research and the conversion of scientific research results into commercial technologies, however, require a robust domestic public and private research system.
18. Krugman, "Is Free Trade Passé?" op. cit.
19. See A.W. Pollack, "Chip Makers Will Seek U.S. Aid to Spur Output," *New York Times*, September 10, 1988, p. D4. Another account noted that "U.S. computer manufacturers have been seriously affected by high prices and the shortage of supplies of Japanese-made Drams. These problems are, however, 'nothing compared to the problems they will have in the future if we don't have a plan to free the hostages—our U.S. customers,'

Mr. W.J. Sanders, chairman of Advanced Micro Devices, a Silicon Valley chip maker, told industry analysts recently.

"Mr. Sanders's emotive language is a measure of the frustration felt within the U.S. electronics industry. This frustration has led to plans for drastic action, including jointly funded Dram plants." L. Kehoe, "U.S. Chip Makers Plan to Open Second Front," *Financial Times,* September 27, 1988, p. 28. Sanders' firm is one of the participants in U.S. Memories, Inc., a recently announced consortium dedicated to the production of DRAMs. Currently, U.S. Memories expects to obtain financing entirely from private sources.

20. Allegations of dumping (predatory pricing of exports below average cost), for example, often compare export prices with some constructed average cost of production. Producers of goods characterized by average costs that decline over time, however, may find it profitable to price below average cost in the early generations of a product so as to increase production volume rapidly and reap the cost reductions from learning, thus allowing reductions in price.

    Alternatively, restrictions on access to the domestic market of a foreign firm or government subsidies to that firm in the early stages of production may enable it to penetrate export markets with low-cost, high-quality products after the cessation of such government assistance. Allegations of unfair trade or subsidies, however, may not be supported by the behavior and costs of the foreign firm by the time the firm has become a successful exporter.
21. These nontariff barriers to trade are by no means the exclusive province of foreign governments. During the 1980s, the U.S. government imposed nontariff import restrictions in the steel, automobile, machine tool, semiconductor, and other industries. Tyson estimated that 35% of U.S. imports in 1983 were subject to nontariff restrictions, an increase from an estimated 20% in 1980. L. Tyson, "Making Policy for National Competitiveness in a Changing World," in A. Furino, ed., *Cooperation and Competitiveness in the Global Economy* (Cambridge, MA: Ballinger Publishers, 1988).
22. International coordination and harmonization of national macroeconomic policies has progressed considerably, albeit haltingly, in the wake of the Plaza Agreement of 1985. Similar coordination of sectoral policies, however essential, is likely to be far more difficult, since the range of policy instruments is much greater and their effects are more difficult to trace and monitor.
23. A. Olechowski, "Nontariff Barriers to Trade," in J.M. Finger and A. Olechowski, eds., *The Uruguay Round: A Handbook for Negotiators* (Washington, DC: World Bank, 1987) estimated that 17-19% of the imports of developed nations (by value) were covered by nontariff barriers. Olechowski also concluded that the use of nontariff barriers increased significantly during 1981–85 (p. 125).
24. Nontariff trade barriers received considerable attention in the "Tokyo Round" of multilateral trade negotiations that concluded in 1979. Although disciplines covering some of these policies were agreed upon in the Tokyo Round Codes, the coverage and enforcement of the disciplines contained in several of these Codes, such as those covering government procurement and subsidies, has not always been effective. See G. Winham, *International Trade and the Tokyo Round Negotiation* (Princeton, NJ: Princeton University Press, 1986); D.K. Tarullo, "The MTN Subsidies Code: Agreement without Consensus," in S.J. Rubin and G.C. Hufbauer, eds., *Emerging Standards of International Trade and Investment* (Totowa, NJ: Rowman and Allanheld, 1984).
25. The allegation has been made in C. Prestowitz, *Trading Places* (New York, NY: Basic Books, 1988), and in a number of journalistic descriptions of this Agreement.
26. Prestowitz (op. cit.) noted that the Semiconductor Agreement "amounted to getting the Japanese government to force its companies to make a profit and even to impose controls to avoid excess production—in short, a government-led cartel. For the free-traders

of the United States to be asking Japan to cartelize its industry was the supreme irony. Yet it was logical." (p. 62).

27. According to estimates in A. Pine, "Computer Chip Pact Backfires on U.S. Industry," *Los Angeles Times*, June 6, 1988, the price of 256K DRAMs has risen within the U.S. from roughly $2.60 at the time the Agreement was signed to more than $3.60 in June 1988. The price of 64K DRAMs rose from $.90 to nearly $1.40 during the same period. Prices in Japan for DRAMs remained constant or declined slightly during this period. A more favorable view of the effects of the Agreement can be found in D. Yoffie, "Chip Shortage: Don't Blame the Pact," *Wall Street Journal*, June 21, 1988, p. 36.
28. W.E. Steinmueller, "International Joint Ventures in the Integrated Circuit Industry," in D.C. Mowery, *International Collaborative Ventures in U.S. Manufacturing* (Cambridge, MA: Ballinger, 1988).
29. For an insightful review of this debate, see J.A. Hart and L. Tyson, "Responding to the Challenge of HDTV," *California Management Review* (Summer 1989).
30. Reciprocal access is a concept that is more easily stated than implemented in national R&D systems that differ as sharply as do those of the U.S., where publicly funded research accounts for nearly 50% of all national R&D and where relatively open institutions like universities play a very important role in basic research, and Japan, in which corporate funding of R&D is far more significant. U.S. firms almost certainly would reject a policy that required assurances of equal access to the research facilities of U.S. and Japanese corporations.
31. The recent proposal by the Massachusetts Institute of Technology to purchase a supercomputer from the U.S.-based joint venture involving Honeywell and Nippon Electric Company of Japan illustrates the use by U.S. government officials of trade policy sanctions as instruments of technology policy (the treatment by U.S. policymakers of the products of this U.S.-based joint venture as Japanese in origin also points out the complexity of determining national origin in a technologically interdependent world). Threatened by the Department of Commerce with an investigation of dumping in supercomputers, MIT elected to postpone the procurement, instead seeking financial support from the National Science Foundation for a supercomputer research center that would involve U.S. firms and U.S.-based technology.

    MIT Provost John Deutch stated that "it became clear important elements of the federal government would prefer to see MIT acquire a supercomputer based on U.S. technology. Since the federal government would ultimately bear nearly all the costs of the machine through research grants to MIT, the preferences of the U.S. government must be seriously addressed." "MIT Exploring Linked Supercomputer Center," News Office, Massachusetts Institute of Technology, November 5, 1987, p. 2; see also G. Putka, "MIT Cancels Supercomputer Plan, Citing U.S. Pressure to Reject Japanese Bids," *Wall Street Journal*, November 6, 1987; and D.E. Sanger, "M.I.T., Pressed by U.S., Won't Buy Computer," *New York Times*, November 6, 1987.
32. In addition to the U.S.-Japan Semiconductor Agreement discussed earlier, the informal discouragement by senior officials of the U.S. Commerce and Defense Departments of Fujitsu's proposed acquisition of Fairchild Semiconductor in 1984 also illustrates the growing interdependence of trade and technology policies in this industry. Official opposition to this acquisition was apparently based largely on the perceived need to prevent acquisition of the U.S. firm's technological assets by Japan, rather than opposition to acquisition of the U.S. firm by a foreign firm. At the time of the proposed acquisition, Fairchild Semiconductor was owned by a French firm, Schlumberger.
33. The Act calls for a series of reports on U.S. firms' access to foreign markets for telecommunications equipment; creates a new provision (Sec. 1315) for dealing with subsidized international consortia, widely viewed as a provision directed at Airbus; and creates new provisions for "fast-track" antidumping investigations in industries (such as microelectronics) with short product life cycles.

34. A recent survey of R & D executives by Levin et al. (1988) found that "For new processes . . . , patents were generally rated the least effective of the mechanisms of appropriation: only 20 percent of the lines of business surveyed rated process patent effectiveness in excess of 4.0 [on a 7-point Likert scale, for which 7 was the highest rating]. Eighty percent scored the effectiveness of lead time and learning curve advantages on new processes in excess of 4.3. Secrecy, though not considered as effective as lead time and learning advantages, was still considered more effective than patents in protecting processes. Patents for products were typically considered more effective than those for processes, and secrecy was considered less effective in protecting products than processes. Generally, lead time, learning curves, and sales or service efforts were regarded as substantially more effective than patents in protecting products. Eighty percent of the sample businesses rated the effectiveness of sales and service efforts above 5.0, but only 20 percent considered product patents this effective." R.C. Levin, A.K. Klevorick, R.R. Nelson, and S.G. Winter, "Appropriating the Returns from Industrial Research and Development," *Brookings Papers on Economic Activity,* 1987, 783-820, pp. 794-795.
35. See D.C. Mowery and N. Rosenberg, *Technology and the Pursuit of Economic Growth* (New York, NY: Cambridge University Press, forthcoming); OECD, *Science and Technology Policy Outlook: 1988* (Paris: OECD, 1988); P. David, "Technology Diffusion, Public Policy, and Industrial Competitiveness," in N. Rosenberg and R. Landau, eds., *The Positive Sum Strategy* (Washington, D.C.: National Academy Press, 1986); H. Ergas, "Does Technology Policy Matter?" in B. Guile and H. Brooks, eds., *Technology in the Global Economy* (Washington, D.C.: National Academy Press, 1987); D. Mowery, "The Diffusion of New Manufacturing Technologies," in R.M. Cyert and D.C. Mowery, eds., *The Impact of Technological Change on Employment and Economic Growth* (Cambridge, MA: Ballinger, 1988); M.J. Peck and A. Goto, "Technology and Economic Growth: The Case of Japan," *Research Policy,* 10 (1981): 222-243.
36. A central motive for many international collaborative ventures is the need to surmount nontariff barriers to market access. In many cases, as was noted earlier, these trade barriers are erected by national governments to retain the benefits of publicly funded commercial technology development programs within their boundaries. See D.C. Mowery, "International Collaborative Ventures in U.S. Manufacturing," *Research Policy* (1989); *idem,* ed., *International Collaborative Ventures in U.S. Manufacturing* (Cambridge, MA: Ballinger, 1988).
37. As Nelson (*High-Technology Policies: A Five-Nation Comparison*) points out, the ability of nations to transform "leading" technologies into "strategic" technologies is declining as a result of these developments.
38. There now exists a large prescriptive literature on this issue. See P. Osterman, *Employment Futures* (New York, NY: Oxford University Press, 1988); R.M. Cyert and D.C. Mowery, eds., *Technology and Employment: Innovation and Growth in the U.S. Economy* (Washington, D.C.: National Academy Press, 1987); and the Council on Competitiveness, *Picking Up the Pace: Commercial Innovation in the U.S. Economy* (Washington, D.C.: Council on Competitiveness, 1988) for recent contributions.
39. See G.N. Hatsopoulos, P.R. Krugman, and L.H. Summers, "U.S. Competitiveness: Beyond the Trade Deficit," *Science,* 241 (1988): 299-307.