The Global Context for U.S. Technology Policy

OFFICE OF TECHNOLOGY POLICY

OTP

UNITED STATES DEPARTMENT OF COMMERCE
The Assistant Secretary for Technology Policy
Washington, D.C. 20230

Summer 1997

Dear Colleague:

I am pleased to send you this report, "The Global Context for U.S. Technology Policy." Though brief, the report pulls together several of the principal themes of our work at the Office of Technology Policy (OTP) in recent years. The context for U.S. technology policy has changed profoundly from that prevailing during much of the last 50 years when most of our current technology policies were developed.

The new environment is driven by changes outside the direct view or control of the U.S. government, and perhaps for this reason, they figure less prominently than they should in the current debate. These trends include: the evolution of the global market; the worldwide impact of new technology; changes in U.S. industrial competitiveness; technology policies of other nations; and the recent transformation of U.S. industrial R&D.

Advances in technology have been the single most important factor in creating economic growth in the United States over the last 50 years. In the private sector, much of the success of U.S. corporations has come as a result of the very deliberate effort in the last 15-20 years to increasingly couple technology and business strategy, and to integrate technology management with the overall management of the business. These same pervasive technological changes are impacting government, and we here in the Department of Commerce are witnessing an ever closer integration of technology policy, economic policy and trade policy.

It is hoped that some of the notions in this report will play a role in moving the debate on U.S. technology policy beyond the well worn internally focused rhetoric of recent years toward a more pragmatic embrace of the global context as we enter the 21st century.

Sincerely,

Graham R. Mitchell

THE GLOBAL CONTEXT FOR U.S. TECHNOLOGY POLICY

Table of Contents

The Global Context for U.S. Technology Policy

Graham R. Mitchell
Assistant Secretary of Commerce for Technology Policy
U.S. Department of Commerce

Policy Context

In the 25 years following World War II, the United States enjoyed global competitive and technological dominance. Many of the most important technical breakthroughs occurred in the United States. U.S. companies, lacking strong competitive challenges from abroad, had both the time and resources to follow many of these scientific and technological advances from fundamental discoveries to commercialization.

During this post-war period, the Federal government's technology policy and its investments in science and technology were largely in support of basic research and various government missions. The government made especially large investments in defense and space-related research and development in response to the Cold War and Race in Space against the Soviet Union.

With respect to commercial technology, the Federal government's relationship with the private sector was one of spin-off; that is, technology first developed for government missions eventually made its way to the private sector for commercial application. The slow pace and uncertainty of the spin-off process was of little concern, since U.S. firms were uniquely positioned to take advantage of the technology and research results flowing from the Federal government's laboratories and from university-based research.

From this base of government research and development arose America's global leadership in computers and electronics, satellite communications, aerospace, and later in pharmaceuticals.[1]

The competitive challenges of the 1970s and 1980s transformed the global technology landscape [Figure 1]. Sole U.S. dominance gave way to competitive leadership shared by a triad consisting of the United States, Europe, and Japan. The Europeans and Japanese had developed significant technological capabilities, and their companies were capable of exploiting not only their own domestic science and technology resources, but those of the United States as well. This raised significant concerns when the Japanese came to dominate markets for technologies that had been pioneered in the United States, including televisions, stereos, the video cassette recorder, machine tools, and robots.

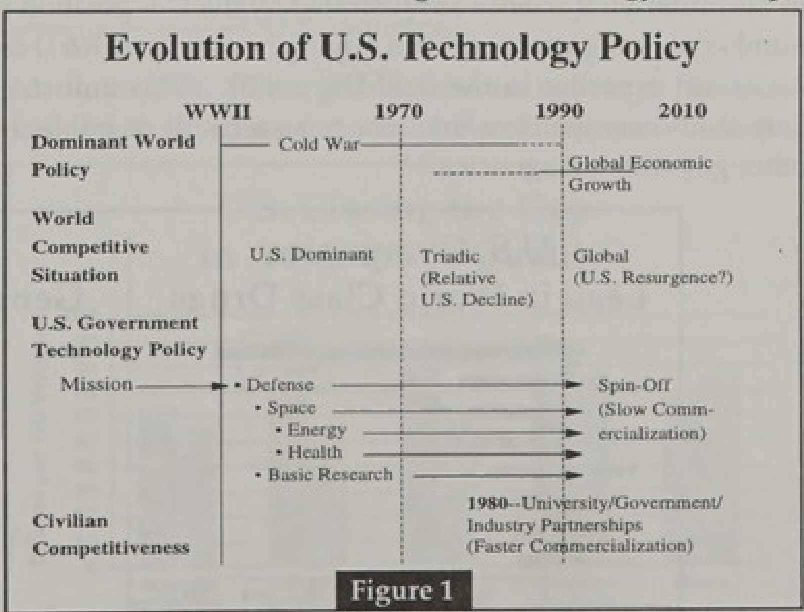


Figure 1

Moreover, other countries had learned to commercialize technology quickly, with a number of foreign companies adopting time-based competitive strategies and more flexible manufacturing systems to thrive in an era of ever shortening technology development and product life cycles. For example, during the 1980s, Ford took nearly ten years to redesign the Escort; Honda redesigned the comparable Civic four times in the same period. In another example, Xerox found that its Japanese competitors could develop a new copier in half the time it took Xerox to do it.

Many foreign companies had also implemented new quality improvement and production management methods that enabled them to compete against U.S. producers with products of superior quality at lower cost. As a result, several U.S. industries lost significant global market shares.

In a response to these competitive challenges to the United States, particularly in high-technology markets, Federal technology policies were established to encourage a fuller and faster exploitation of publicly-supported R&D by American firms. This involved efforts to create partnerships between government-funded creators of technology, principally government laboratories and universities, and U.S. industry to speed the development and commercialization of new technology. We fully expect that the need for such partnerships will continue as competitive pressures increase and further accelerate technology and product life cycles. [2]

By the mid-1990s, this triadic portrayal has given way to an increasingly global economy with a range of rapidly growing nations that are powerful new competitors and, at the same time, represent the prospect of large emerging markets. Many of these countries seek to join the ranks of the world's technological leaders, and several are rapidly developing world-class technical and manufacturing capabilities. [3]

Nevertheless, studies show that the competitive position of several U.S. industries is stronger than generally assumed in the 1980s and is improving with the introduction of new technology and the continued expansion and evolution of the global market.

The role that Federal technology programs and policy initiatives have played in promoting U.S. competitiveness varies significantly by sector. For example, in biotechnology, U.S. industry is competitively dominant. This position is illustrated not only by market data, but by U.S. commercial leadership in the production of world class drugs [Figure 2]. This, in turn, is based on U.S. dominance in the underlying science as illustrated by the U.S. position in genetic engineering patents, and by the number of foreign corporations buying or setting up R&D capacity in the United States in order to tap American expertise in the field [Figure 3]. This industry provides the clearest example of direct benefit and competitive dominance as a result of public investment in research through NIH and other government agencies. [1,4]

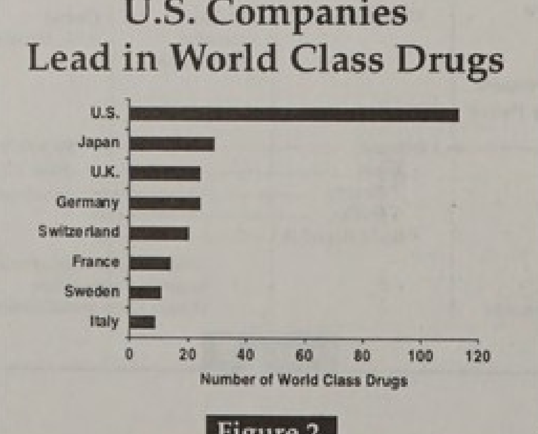


Figure 2

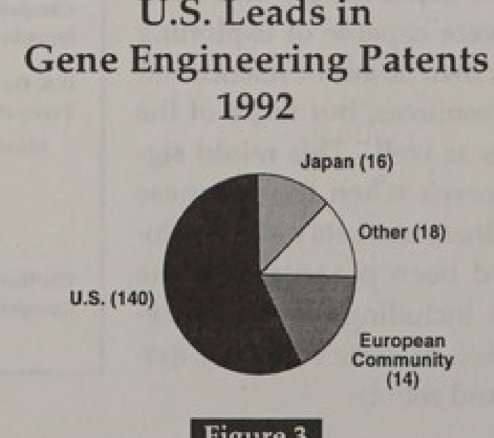


Figure 3

The U.S. chemical industry is globally competitive [Figure 4]. In contrast to the biotechnology sector, it has gained little from direct R&D programs with government agencies. However, it has benefitted enormously from public investments that have fostered a strong academic research base from which the industry draws qualified personnel. As much of the industry's future growth is expected to occur in the world's big emerging markets, U.S. policies to promote access to foreign markets and to protect intellectual property will be important to its continued success.[5]

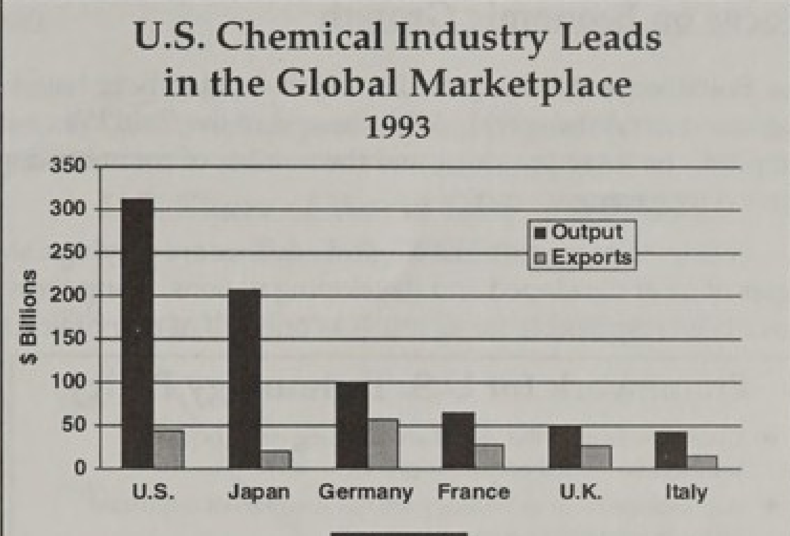


Figure 4

In autos, there has been a remarkable recovery and improvement in the competitive position of U.S. manufacturers. The U.S. auto industry has adopted new technologies—both product and process—and new management technologies—both workforce and production—and, as a result, productivity and quality are closing or have closed the gap with the Japanese, and the United States now manufactures more autos than Japan [Figures 5 and 6].[6] Government policies have had little to do with this turn around. Rather it has been the press of foreign competition that drove significant changes in the industry. However the challenging longer range industry goal of a three-fold improvement in fuel efficiency is unlikely to be achieved without a collaborative effort between the Federal government and U.S. industry.[7]

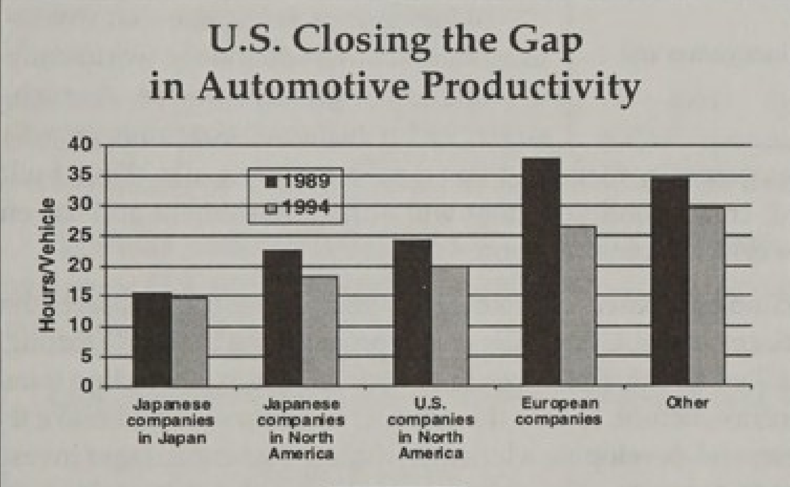


Figure 5

The U.S. also enjoys a dominant position in the $400 billion global software industry. Here, too, sustained government investments in support of defense, space and other Federal missions—including the Internet—have been critical to the strength of the industry. However a long term threat is posed by the current shortage of American computer and software professionals. The size of American universities' current graduating classes in computer science and this large number of unfilled jobs suggest that it is unlikely that the demand for computer professionals could be met anytime soon. Considering the growing importance of information technology in the American economy, this shortage of skilled workers could develop into a serious problem.[8]

Figure 6

Focus on Economic Growth

Sustained economic growth and job creation have long been high on the list of priorities for many nations around the world. With the end of the Cold War, nations have been able to place even greater emphasis on these priorities, and the number of countries implementing policies to achieve these objectives is increasing.

Policies to promote technological advance are playing a significant role in the economic growth strategies of most developed and developing nations. Long-term studies show that advances in technology have been responsible for as much as one half of economic growth in the United States over the past 50 years, through improvements in capital and labor productivity, and the creation of new products, services, and systems. In other countries, the contribution of technology to economic growth has been even greater. For France, technology is estimated to have accounted for 76 percent of economic growth; for West Germany, 78 percent; for the U.K., 73 percent; and for Japan, 55 percent.[9]

Framework for U.S. Technology Policy

- Countries around the world are focusing on policies to promote sustained economic growth
- Advancements in technology are the single most important factor in promoting economic growth
- World capital circulates in search of the highest return
- U.S. Government policy seeks to attract engines of growth to the United States and promotes domestic industries by:
  - *Investing in people*
  - *Investing in infrastructure*
  - *Developing a conducive business climate*
- To make the United States a preferred area for innovation and growth and the creation of real value

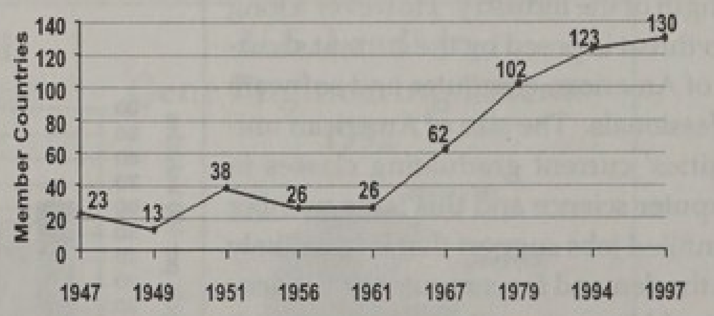
Figure 7

Today nations recognize that investment capital flows around the world daily in search of the greatest returns. As such, strategies for sustained economic growth for both developed and developing countries generally focus on two complementary goals. First, build competitive domestic industries and, second, create conditions that will attract investment and the engines of economic growth from around the world to a nation's shores.

Countries are attempting to promote technology-based economic growth by investing in assets that remain relatively fixed within their borders. For example, U.S. policies focus on investing in people through education and training to develop a highly-skilled workforce; investing in infrastructure, including transportation and the 21st century information infrastructure, to ease the conduct of commerce and make the United States an attractive place to do business; and developing a business climate that encourages investment and fosters the private sector's ability to compete. The objective of these policies is making the United States a preferred area for innovation and business activity which, in turn, will stimulate growth and the creation of high quality jobs [Figure 7].

As the economies of formerly communist countries are transformed into free markets, and poor countries look to global opportunities as a way out of their economic despair, we are seeing a political convergence—both east and west, and north and south—around the principles of open markets and free trade. The United States has been the leader in promoting these principles worldwide and our success is reflected in the three decades of growth in the number of countries that are members of GATT, and in the growing number of poor and formerly communist countries that are seeking admission to the World Trade Organization [Figure 8].

GATT/WTO Membership on the Rise



29 Countries Currently Applying for Admission to the WTO:

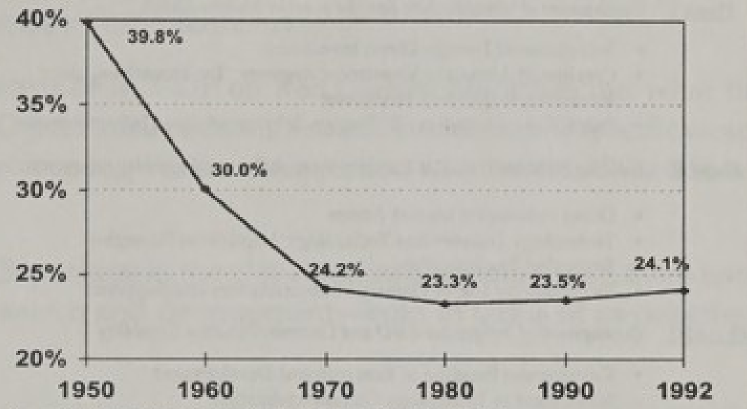
Albania	PR China	Jordan	Former Yugoslav Rep. of Macedonia	Russia	Tonga
Algeria	Chinese Taipei	Kazakhstan		Saudi Arabia	Ukraine
Armenia	Croatia	Kirgyz Republic	Moldova	Seychelles	Uzbekistan
Belarus	Estonia	Latvia	Nepal	Sudan	Vanuatu
Cambodia	Georgia	Lithuania	Panama	Oman	Vietnam

Figure 8

Changes in Relative U.S. Position

The globalization of the economy and the relative growth of nations around the world are reflected in the decline of the U.S. share of world GDP over the past 40 years [Figure 9]. In 1950, the United States was generating approximately 40 percent of the world's GDP. As the European and Japanese economies recovered from the war, the U.S. share of world GDP began to decline. In the early 1980s, at the height of the triadic period, the U.S. share of world GDP had dropped to 23 percent. Perhaps reflecting the competitive improvements in U.S. industry, the U.S. share had increased slightly by 1992.

U.S. Share of World GDP, 1950-1992
Based on 1985 Prices



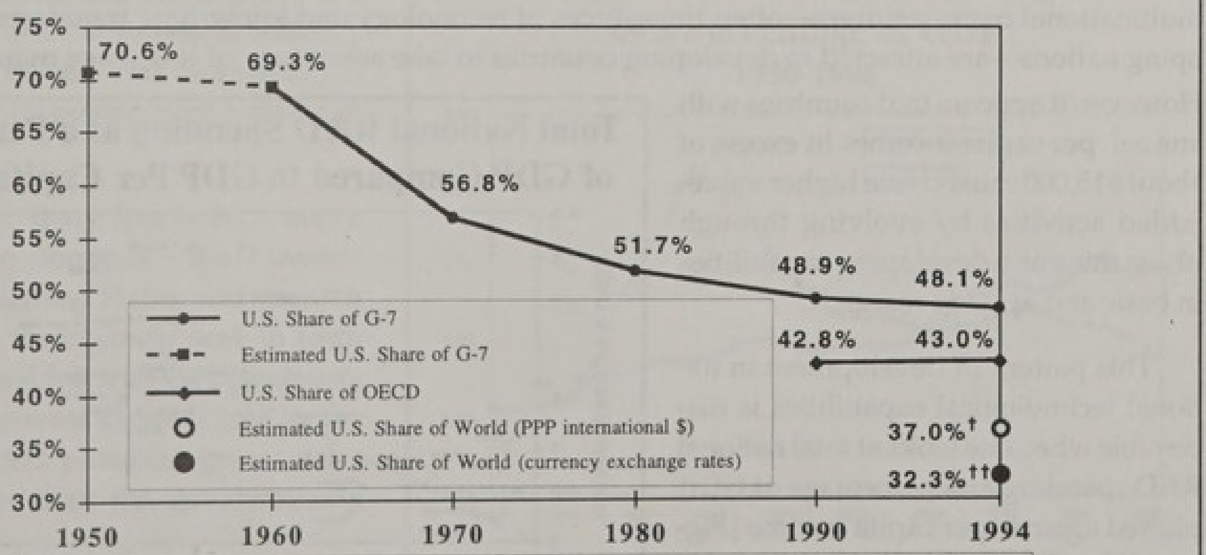
Source: Penn World Table 5.6, National Bureau for Economic Research, March 1997 (http://www.nber.org/pwt56.doc.html).

Figure 9

The shifting balance of power between the United States and the rest of the world has been more dramatic with respect to research and development [Figure 10]. In 1950, the United States performed more than 70 percent of the world's R&D. By the mid-1980s, the rest of the world had caught up with the United States in terms of R&D spending and, by 1994, the rest of the world was performing approximately twice as much R&D as the United States.

The very wide variation in R&D growth by industry sector in reent years clearly suggests that aggregate U.S. industry R&D growth trends are a questionable metric of the effectiveness of public policy initiatives.

U.S. Share of G-7, OECD, and World R&D Funding as a Percentage of GDP



NOTE: 1994 U.S. share of G-7 percentage is estimated. U.S. share of world R&D is an estimate based on most countries that report total R&D. † in purchasing power parity dollars †† in current values currency exchange rates
SOURCES: OECD *Main S&T Indicators*, 1996. OECD *Science, Economic Growth & Government Policy*, 1963. NSF *Science and Engineering Indicators*, 1991 and 1995. NSF *National Patterns of Research and Development Resources*- 1996. Penn World Table 5.6, National Bureau for Economic Research, March 1997. *Global Competitiveness Report-1996*, World Economic Gorum, Geneva, Switzerland, 1996.

Figure 10

Evolution of Global Technology Policy

Looking across the rapidly developing world, a pattern of technology policy emerges in which developing nations pass through several phases en route to full industrialization [Figure 11].[10]

Technology Policies in Developing Nations

Examples of Policies and Strategies

Phase I *Development of Infrastructure Base for Foreign Multinationals*

- Solicitation of Foreign Direct Investment
- Creation of Attractive Investment Regimes: Tax Incentives, Labor Incentives, Regulatory Incentives
- Public Expenditures on IT, Energy, & Transportation Infrastructures

Phase II *Building National Domestic Economy through Foreign Technology Acquisition*

- Offset Policies for Market Access
- Technology Transfer and Technology Acquisition Strategies
- Expanded Tax Incentives
- Incentives for Use of Domestic Subcontractors and Suppliers

Phase III *Development of Indigenous R&D and Commercialization Capability*

- Government Funding of Research and Development
- Investment in Technology Commercialization
- Investment in Higher Education and Human Resource Development
- Funding of R&D in Specific High Technology Sectors

Figure 11

An early phase focuses on the development of an infrastructure that will help attract the investment and business activities of multinational firms, and provide a base for their marketing and manufacturing. This includes measures such as investment incentives and the development of infrastructure such as transportation, energy, and communications.

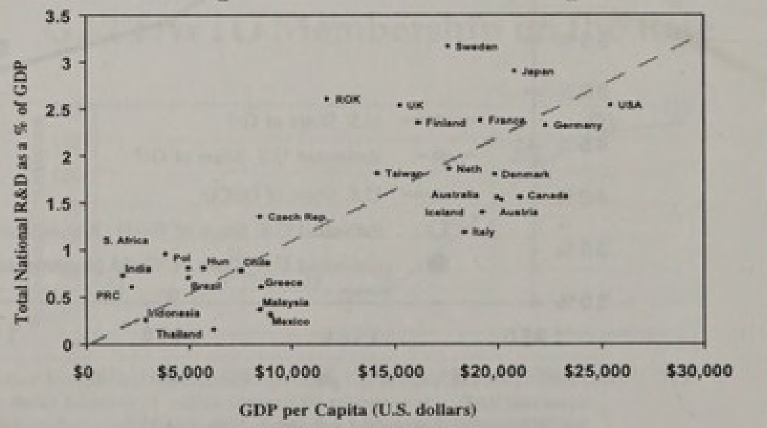
This is usually complemented by the development of a domestic science and technology capability through the acquisition of technology and know-how from advanced nations. Foreign technology acquisition strategies may include offset policies for market access, personnel exchanges, and technology transfers from multinational corporations to domestic subcontractors and suppliers.

A later phase involves the development of indigenous R&D and commercialization capability, strongly linked to leading-edge technical advances throughout the world. It includes substantial government and private sector investments in R&D, a significant focus on higher education and workforce development, and the creation of a business climate to strongly promote technological innovation.

It appears that phases one and two are viable strategies for low wage economies. For example, multinational manufacturers—often the sources of technology and know-how transferred to developing nations—are attracted to developing countries to take advantage of low wage manufacturing. However, it appears that countries with annual per capita incomes in excess of about $15,000 must create higher value-added activities by evolving through phase three and developing capabilities in basic and applied research.

This pattern of development in national technological capabilities is discernible when one looks at total national R&D spending as a percentage of GDP, plotted against per capita income [Figure 12]. Generally speaking, as per capita income rises, so does national R&D spending as a percentage of GDP. Thus we see a group of lower wage developing countries at one end of the

Total National R&D Spending as a Percentage of GDP Compared to GDP Per Capita—1996



Source: The Global Competitiveness Report, 1996, World Economic Forum, Geneva, Switzerland
WORLD BANK, From Plan to Market: World Development Report 1996, NSF, Science and Engineering Indicators, 1996

Figure 12

spectrum, spending one percent of GDP or less on R&D; and we see a number of high wage developed countries at the other end of the spectrum, spending about two percent of GDP or more on R&D. This suggests that the higher the standard of living, the higher the fraction of GDP needed for R&D to create new jobs.

One country in particular, however, departs from this pattern. Korea, with GDP per capita at about $10,000, is spending more than 2.6 percent of its GDP on research and development. This high rate of spending suggests that Korea is implementing aggressive technology policies for purposes of moving rapidly toward an advanced, technology-based economy.[11]

While the United States spends 2.5 percent of its GDP on R&D, when one takes out what the United States spends on defense-related R&D (and most of that is test and evaluation of specific weapons systems of marginal value to the civilian economy) one must question whether the United States spends enough on civilian R&D.

In addition to a relative decline in the U.S. position in the global technology enterprise, there have been major shifts in the character of U.S. research and development—both in terms of its objectives and sources of R&D investment.

U.S. R&D investment as a percentage of GDP has exceeded 2 percent since 1957, peaking at 2.8 percent in 1966. Between 1956 and 1979, the Federal government provided the bulk of R&D funding and, in 1964, at the height of the Cold War and Race in Space, government investment in R&D peaked at 2.2 percent of GDP [Figure 13].

Government investment in R&D as a percentage of GDP began to decline significantly in the late 1960s and, following a slight rise during the Reagan era defense build-up, investment in R&D as a percentage of GDP has declined steadily every year since to 0.9 percent in 1995.

By contrast, industry investment in R&D as a percentage of GDP has increased gradually over the entire post-World War II period, rising from 0.55 percent in 1950 to 1.5 percent of GDP in 1995. Industry's investment drew ahead of government funding in 1980, and rose rapidly as a percentage of GDP to where industry investment in R&D was more than 150 percent of total government funding in 1995.

As such, there has been a major shift in who dominates R&D investment in the United States, and research universities increasingly seek to form R&D partnerships with the private sector, as the private sector's role in the Nation's R&D portfolio grows relatively larger than the government's role.

U.S. Sources of R&D Funding as a Percentage of GDP 1950-1996

Source: National Patterns of R&D Resources: 1996, Early release tables, National Science Foundation.

Figure 13

Shifting Focus of U.S. Industrial R&D[12]

In addition to the growing level of private sector R&D investment, the intensity and composition of industry R&D is changing [Figure 14]. In the past 15 years, the R&D intensity of U.S. industry in aggregate (measured by R&D spending as a percentage of sales of publicly traded companies that conduct at least $1,000 of R&D) has doubled. There are two complementary processes at work: first—the larger effect—the R&D intensity of several large industrial sectors has been increasing, and second, R&D intensive industries are growing faster than others and, over time, account for an increasing proportion of the U.S. economy.

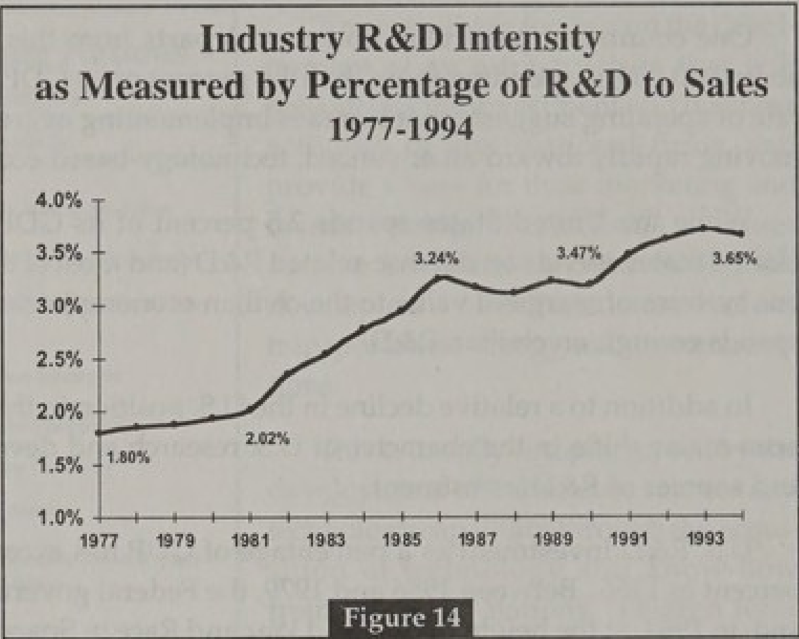


Figure 14

There has been wide variation in R&D investment from industry to industry [Figure 15]. For example, two industries—the electronics/information technology sector and the pharmaceutical/biotechnology sector—have dramatically increased their share of industry R&D investment, and account for a large portion of the increase in overall industry R&D intensity. The electronics/ information technology sector's share of total industry R&D investment has grown from 32 percent in 1981 to 44 percent in 1995; in the same period, the drugs/medicine industry's share grew from 7 percent to 16 percent.

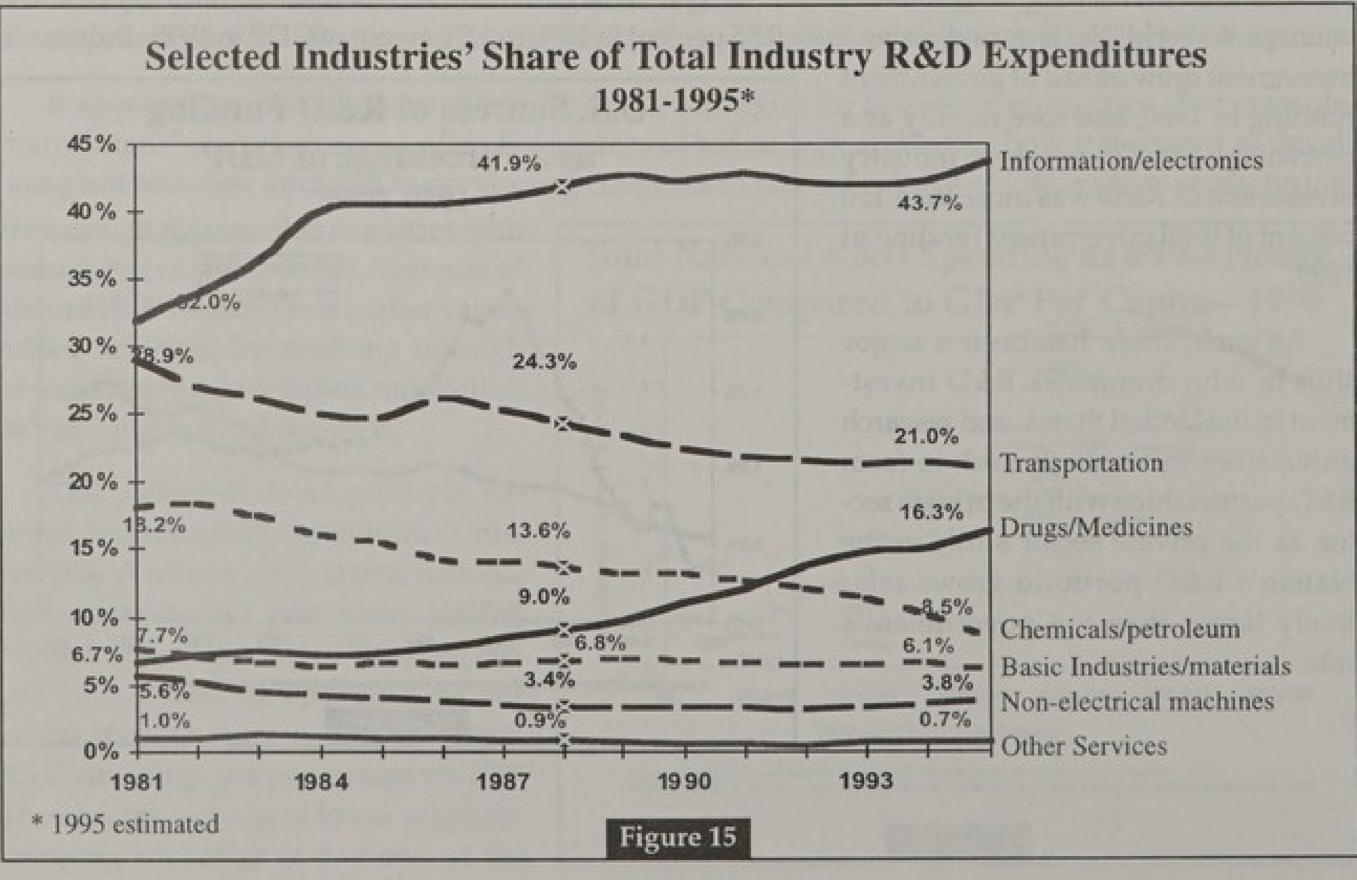


Figure 15

As a result, these two industries dominate industry-funded R&D growth in the United States, account for some 60 percent of all U.S. industry research and development, and promise to drive future technology and innovation [Figure 16].

It should be noted that these two industries have benefitted enormously from large Federal R&D investments made on behalf of government missions in defense, space, and health.

Shifts in industries' shares of net sales also show the growing role of high-technology industries in the United States, especially the role of the information technology/electronics sector. For example, in 1981, the information technology/electronics industries accounted for 17.8 percent of U.S. industry's net sales [Figure 17]. By 1995, that sector accounted for 28 percent of industry net sales.

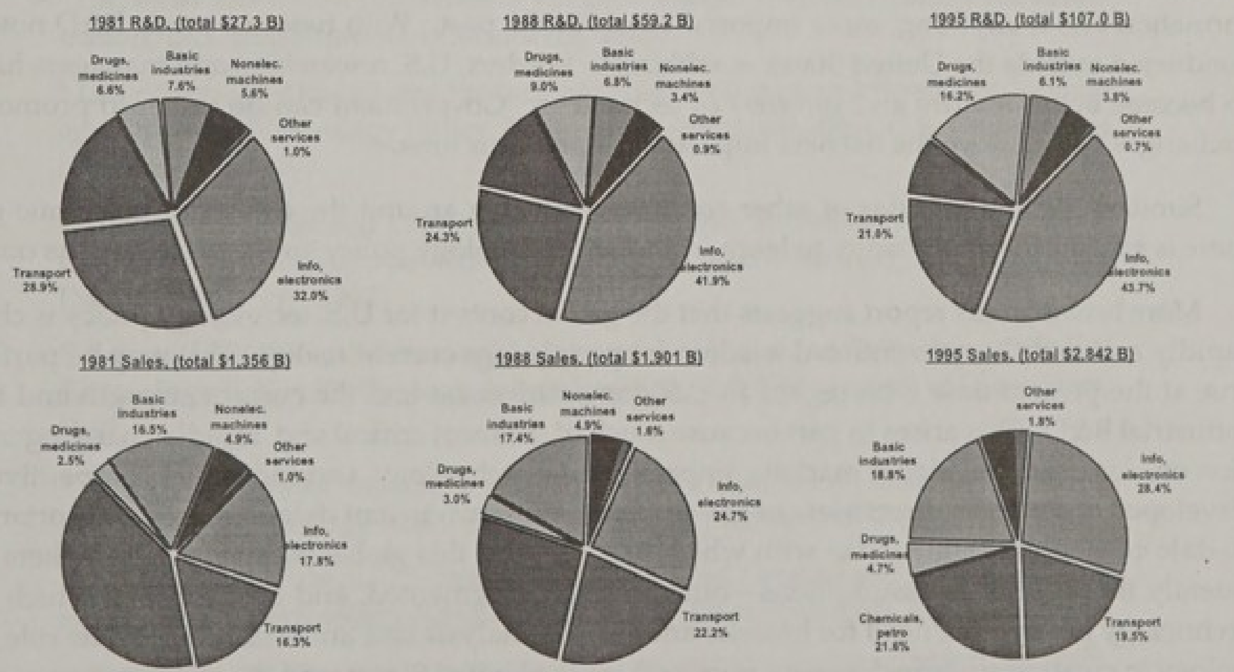
Information/Electronics, Drugs/Medicines Approximate Share of Total U.S. Industry R&D

	1981	1988	1995
Information/Electronics R&D	32%	42%	44%
Drugs/Medicines	7%	9%	16%
Combined Share of Total U.S. R&D	39%	51%	60%

Figure 16

Sectors' Percentage Shares of Total Industry R&D Spending and Net Sales, 1981, 1988 & 1995*

Publicly-Traded R&D-Conducting Firms, Billions of Current Dollars



*1995 is estimated. Data Source: Standard & Poor's Compustat, Oct. 1996. All listed U.S. publicly-traded companies that conduct at least $1,000 R&D.

Figure 17

Conclusions

Today's global competitive and technology landscape is profoundly different from the situation during much of the post-World War II period, when most of our current technology policies were developed. The U.S. share of world GDP and world R&D has declined. And there has been a large shift in the relative roles the Federal government and the U.S. private sector play in R&D.

Despite a more dynamic and competitive global environment, the United States is competing at world class levels in a number of key industries, having recovered strongly from the foreign competitive challenges of the 1980s. In information technology and biotechnology, where the U.S. performance is especially strong, sustained public investment in R&D has contributed significantly to U.S. technological leadership.

Throughout, we have seen the complex set of relationships between government and industry continue to evolve, with more partnerships between industry, academia, and government being formed to speed the development and commercialization of technology. As technology and product life cycles continue to shorten, such partnerships will be needed increasingly.

Nevertheless, the government's primary role is to focus investments on building assets that remain largely within the country—the people, the infrastructure, and the business climate—freeing the private sector to develop new technology whenever necessary to grow and compete. In doing so, all partners in the economic enterprise must be alert to new policies and models that are appropriate to today's competitive and technology environment.

For example, policies that promote vigorous exchange of S&T and technology management information are, if anything, more important than in the past. With twice as much R&D now being conducted outside the United States as within our borders, U.S. researchers and managers have had to become better *hunters* and *gatherers* of technology. Government can do much to promote such exchanges and remove the barriers imposed in a previous time.

Similarly, as the agendas of other countries converge around the desire for economic growth, there is significant opportunity to learn from their technology policy successes as well as our own.

More broadly, this report suggests that the global context for U.S. technology policy is changing rapidly and that the conventional wisdom frequently lags current reality. This may be particularly true at the present time with regard to U.S. competitiveness and the current strength and focus of industrial R&D. This arises in part because much of the most critical and rapidly changing information on, for example, global markets, impact of new technology, and industrial competitiveness is developed outside the direct view of government. Without current data and, more importantly, up-to-date conceptual frameworks with which to synthesize this global picture, policy makers are frequently thrust back to assumptions—often implicit, fragmented, and obsolete—on which to base technology policy. The need for broader and deeper analysis and understanding of the role of technology in creating sustained economic growth for the United States, and the effectiveness of technology policy alternatives has never been greater. As globalization speeds up, the gap between today's perceptions and current reality will grow.

REFERENCES

[1] *Technology in the National Interest*, National Science and Technology Council, The White House, 1996.

[2] *Effective Partnering: A Report to Congress on Federal Technology Partnerships*, Office of Technology Policy, Technology Administration, U.S. Department of Commerce, 1996.

[3] *Globalizing Industrial Research and Development*, Office of Technology Policy, Technology Administration, U.S. Department of Commerce, 1995.

[4] *Meeting the Challenge: U.S. Industry Faces the 21st Century: The Biotechnology Industry*, Office of Technology Policy, Technology Administration, U.S. Department of Commerce, 1997.

[5] *Meeting the Challenge: U.S. Industry Faces the 21st Century: The Chemical Industry*, Office of Technology Policy, Technology Administration, U.S. Department of Commerce, 1996.

[6] *Meeting the Challenge: U.S. Industry Faces the 21st Century: The U.S. Automobile Manufacturing Industry*, Office of Technology Policy, Technology Administration, U.S. Department of Commerce, 1996.

[7] *Partnership for a New Generation of Vehicles Program Plan*, Technology Administration, U.S. Department of Commerce, 1995.

[8] *Labor Shortage, Quality, and Productivity Issues in American Information Technology*, Office of Technology Policy, Technology Administration, U.S. Department of Commerce, 1997.

[9] Michael J. Boskin and Lawrence J. Lau, "Capital, Technology and Economic Growth," *Technology and the Wealth of Nations*, Nathan Rosenberg, Ralph Landau, David C. Mowery, 1992.

[10] *International Plans, Policies, and Investments in Science and Technology*, Office of Technology Policy, Technology Administration, U.S. Department of Commerce, 1997.

[11] *Korea's Strategy for Leadership in Research and Development*, Office of Technology Policy, Technology Administration, U.S. Department of Commerce, 1997.

[12] *The Transformation of U.S. Industrial Research and Development*, Office of Technology Policy, Technology Administration, U.S. Department of Commerce, 1997.

Graham R. Mitchell
Assistant Secretary for Technology Policy
(202) 482-1581

Kelly H. Carnes, Esq.
Deputy Assistant Secretary
(202) 482-1403

Cheryl Mendonsa
Office of Public Affairs
(202) 482-8321

OTP Publications Request Line
(202) 482-3037

U.S. Department of Commerce
Office of Technology Policy
14th Street & Constitution Avenue, NW
Washington, DC 20230
Phone: (202) 482-5687
Fax: (202) 482-4817