1380

99th Congress
2d Session
JOINT COMMITTEE PRINT
S. PRT.
99-163

TECHNOLOGY AND TRADE: INDICATORS OF U.S. INDUSTRIAL INNOVATION

A STUDY

PREPARED FOR THE USE OF THE

JOINT ECONOMIC COMMITTEE
CONGRESS OF THE UNITED STATES

JULY 14, 1986

Printed for the use of the Joint Economic Committee

U.S. GOVERNMENT PRINTING OFFICE
60-128 O
WASHINGTON : 1986

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, DC 20402

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LETTER OF TRANSMITTAL

JULY 7, 1986.

Hon. DAVID R. OBEY,
Chairman, Joint Economic Committee,
Congress of the United States, Washington, DC.

DEAR MR. CHAIRMAN: I am pleased to transmit a study on "Technology and Trade: Indicators of U.S. Industrial Innovation." The authors are Wendy H. Schacht and Glenn J. McLoughlin, both of the Science Policy Research Division of the Congressional Research Service, Library of Congress. Dr. Kenneth M. Brown, Assistant Director of the Joint Economic Committee, coordinated the project.

The study reviews the current state of industrial innovation in the United States, comparing it with earlier performance and with the situation in other industrial economies. Tomorrow's economic growth depends upon today's climate for innovation, so the subject of this study is of great importance for our Nation's future economic well-being.

Sincerely,

JAMES ABDNOR,
Vice Chairman, Joint Economic Committee.

FOREWORD

By Representative Daniel E. Lungren

How well is the United States performing in technology and innovation? In 1980 the Ways and Means Committee published an important study of this issue *Technology and Trade: Some Indicators of the State of U.S. Industrial Innovation.* The report's findings were not encouraging. The data presented showed that our Nation's spending on research and development had slowed markedly and that our main commercial rivals were catching up rapidly. The United States was still the leader in technology, but there were several strong contenders for that important accolade.

To find out whether the situation has changed during the six intervening years, I asked the Congressional Research Service to update their 1980 report. I am happy to issue the results of that project as this Joint Economic Committee study.

Our report presents a large assemblage of data bearing on our Nation's progress in technology and our standing in relation to the rest of the world. The authors, Wendy H. Schacht and Glenn J. McLoughlin, rightly caution the reader against reaching conclusions more definitive than warranted by the ephemeral nature of the numbers. In other words, technology and innovation simply can't be measured with precision.

Nonetheless, I have sought this material as the basis for answering the central, vital questions: Have we pulled ourselves out of the doldrums of the 1970's, and are we maintaining our world leadership in technology?

If the 1980 study flashed a bright red danger signal, its successor has put up a somewhat more hopeful, yet cautioning, yellow light. We're doing better—and measurably so—in many key areas, but there is still much room for improvement. We seem to have overcome our languor, but Japan, Germany, and others are proving to be as formidable rivals as ever.

Consider the following findings:

—Total expenditures for performance of R&D as a portion of gross national product rose from 2.22 percent in 1978 to an estimated 2.70 percent in 1985—an increase of nearly 22 percent.

—For non-defense R&D spending, the increase was from 1.69 percent to 1.89 percent—a 12 percent increase.

—Industry spending on R&D (in constant dollars) rose by more than 56 percent between 1978 and 1985. This represented a healthy 6.6 percent annual rate of growth.

The last point is particularly significant, for it is industrial research and development that is most directly related to improvements in productivity and to the development of new commercial products. Government funded R&D has its place, but it is private-sector R&D that spurs the economy. In contrast to the healthy growth rate since 1978, the early to mid-1970's were years of near-stagnation in industry spending. In 1970 and 1975, for example, industry spending on R&D actually declined. Clearly, our performance has improved since then.

The Federal Government has also taken a more positive view of R&D. Spending on defense research has increased, but so has governmental support of industrial research. And the strategy has changed too. In the 1970's, the Federal Government was beguiled by the notion that it could outguess and redirect the market to more "socially desirable" goals. Hence, huge and often wasteful projects were funded to develop alternative energy sources, high-tech housing, and expensive but technologically advanced transport systems. During the Reagan Administration, however, the policy has been to concentrate upon basic research (in which industry may underinvest, since private returns are generally less than total benefits to the economy), and to leave commercial ventures to the private sector, which can assess risks and opportunities far better than government can.

Federal policy has also paid more attention to private sector R&D. The tax credit for industrial research and experimentation, enacted in 1981, has been a definite plus. (See our Joint Economic Committee study *The R&D Tax Credit: An Evaluation of Evidence on Its Effectiveness,* August 23, 1985.) The Department of Commerce has vigorously promoted joint research ventures by means of legislation, publicity, and education. The tax revisions of 1981 encouraged entrepreneurship and risk-taking. The Reagan Administration deserves much credit for the significant improvement in the business climate which has done so much to bring back a spirit of enterprise and inventiveness.

The domestic situation, then, is much improved, but there is still room for progress. A close look at the most recent figures on industrial R&D suggests the possibility of a slight slowdown. Moreover, since we do not fully understand why industrial spending on research lagged in the 1970's, we should not become complacent now. In the context of the present tax structure, we should not, for example, weaken the R&D tax credit in the belief that it is no longer needed.

The report devotes two-thirds of its length to the study of innovation worldwide. This is a vital part of the picture because it is difficult to answer the question "are we doing enough" in a vacuum. We need international comparisons. The 1980 report found that while the United States had the highest absolute levels with respect to many indicators of innovation, the other industrialized nations, particularly Japan and Germany, had growth rates ". . . higher than that of the United States, so they appear to be making gains."

This statement still appears to be correct. Of particular concern are the figures on R&D expenditures as a percent of gross national product. We lead the world in overall R&D per dollar of GNP, but when only industrial R&D is considered we trail both West Germany and Japan and are not far ahead of France. Exactly what this portends for our future prosperity is beyond the scope of our report; suffice it to say that smug satisfaction is not justified.

The aggregate numbers may, however, be somewhat misleading. When we look at R&D spending in individual industries, we see that foreign R&D resources tend to be concentrated in the traditional smokestack industries, while the United States far outstrips their spending in computers, aerospace, instruments, and other rising high-tech industries. (This is true in general, though Japan in particular has focused some of its research on certain high-tech products such as semiconductors and ceramics.) Furthermore, the service industries (which tend to spend less on R&D than do manufacturing industries) are far more prominent in the United States, and therefore tend to pull down the aggregate ratio of R&D to gross national product.

But, aside from these statistical issues, what really works in our favor is America's secret weapon—the free enterprise system. Our competitive market economy enables us to get more marketable innovation out of a dollar of R&D than does any other nation. Other nations tend to hamper their technology entrepreneurs with all sorts of regulation, tax handicaps, and competition from the public sector. These problems exist here too, but on a far smaller scale.

The report discusses the innovative advantages of small, start-up companies and their recent robust proliferation—in large measure a result of huge increases in the pool of venture capital in the 1980's. The 1978 and 1981 reduction in the tax rate on capital gains had a lot to do with this, and it is important that any tax reform preserve this low rate.

In any case, our entrepreneurial climate has magnified the results from our aggregate R&D spending. Other industrial nations, particularly those in Europe, have sought to emulate this climate by offering all manner of encouragement to their fledgling small-business innovators. I am confident that we will maintain our advantage in this area if our policies continue to recognize its importance. For more analysis of this subject, I refer the reader to the Joint Economic Committee study *Venture Capital and Innovation,* December 28, 1984.

The report reviews our performance in trade in high-technology products. Since 1965, high-technology trade has recorded large trade surpluses which have, however, declined during the 1980's. While recently Japan has posed the major threat to this leadership, the report raises the question of whether other East Asian nations fostering technological innovations similar to Japan will provide a similar economic challenge to the United States. In this regard, I am confident that with a policy framework which encourages entrepreneurship and innovation our high-tech industries can meet any such challenge. As I read the figures, they have been performing remarkably well under the handicap of a very unfavorable exchange rate. Within two years our technology exports should expand greatly. To put it simply, when a declining dollar gives customers bargain prices on superior products, sales will take off.

To be sure, the Japanese are taking the lead in a few areas. This is to be expected from their monumental efforts in technology. Furthermore, we must be ever alert to the erection of new barriers to trade in high-technology products; practically every nation seems prone to episodes of protectionism. Here too I must commend the Administration for its efforts to break down such barriers.

This report discusses the need to educate more people with advanced degrees in science and engineering, noting the growing portion of graduate students who are foreign and the growing dependence of our high-tech industries upon foreign-born scientists. This presents something of a dilemma: We don't want to drain technical people from foreign nations—particularly the developing nations—and we don't want to see Americans lose jobs to foreign nationals; yet we don't want to cut off the supply of foreign talent in a way that would handicap our technology sector. As the ranking member of the Subcommittee on Immigration, Refugees, and International Law, I have worked on an amendment to assure that foreign nationals could work in our high-tech industries (when it is in the national interest) at least until 1991, at which time we would review the situation to see if necessary steps are being taken to develop sufficient supplies of our domestic talent. In this regard, I look to cooperation between industry and universities as the basis for solving the supply-of-domestic-talent problem, and I am encouraged by progress to date.

This report takes a balanced and realistic view of the newly industrialized countries (NICs). Too often these nations have been portrayed as low-wage juggernauts, pouring cheap imports into a protesting U.S. marketplace. In fact, they display both strengths and weaknesses in their technology resources. We should look for trade opportunities with these nations; the workings of the market guarantee that nations that pursue a high-export strategy will sooner or later become hungry markets for imports.

The NICs appear to have a deep appreciation of the long-term value not only of R&D spending but also of cooperation among firms in joint ventures. Nevertheless, these nations currently seem to do best at receiving innovations and then mass-producing products based upon these innovations.

In conclusion, I find this report to be timely and deserving of careful attention by policymakers in Washington, by local officials concerned with economic growth, and by industry leaders. Technology and innovation in a free-enterprise economy are this Nation's keys to economic success. We must continue to build upon these strengths.

CONTENTS

I. INTRODUCTION

BACKGROUND

There has been continuing concern over the competitive position of the United States in the world marketplace. Various studies have been undertaken over the past several years, numerous conclusions drawn, and multiple remedies offered. In this context, this report is a look at one area which has an impact on the state of U.S. competitiveness—industrial innovation. It is an update of a report prepared by the Congressional Research Service and published by the House Committee on Ways and Means titled *Technology and Trade: Some Indicators of the State of U.S. Industrial Innovation.* The perspective maintained throughout this effort is that of technological innovation and the factors which contribute to the innovation process. This focus is taken because of innovation's contribution to economic growth, increased productivity, and enhanced international competitiveness in high technology trade (although it is acknowledged that other macroeconomic factors also affect the Nation's economic well being).

At the close of World War II, the United States was in a dominant position in terms of technological know-how and application. Other nations, with some U.S. assistance, have improved their scientific and technical competence and have emerged to challenge our technological leadership. This on-going challenge has led to a concern over the state of U.S. innovation in comparison to past domestic levels and with regard to international competition.

Technological innovation is the process by which industry provides new and improved goods, processes, and services. It is a dynamic process which involves idea origination, research, development, commercialization, and diffusion of the innovation throughout the economy. It is not necessarily a linear process. A concept can become an innovation without evolving through the entire process. An invention becomes an innovation when it has been significantly integrated into the economy such that economic growth occurs as the knowledge created is applied to the production process to increase productivity or results in a new or improved product that can be sold in the marketplace.

There are currently no direct measures of innovation. As the previous CRS report noted, while there have been case studies of individual firms, industries, or economic sectors, these studies have not necessarily been representative of the entire firm, industry, or sector, nor of the U.S. economy itself.[1] In the absence of direct

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[1] U.S. Congress. House. Committee on Ways and Means. Technology and Trade: Some Indicators of the State of U.S. Industrial Innovation. Committee Print, 96th Cong., 2d Sess., Washington, U.S. Govt. Print. Off., 1980. p. 2.

measures, it has been customary to survey various indicators of the numerous components of innovation activity. These have traditionally been classified as input or output indicators. As was stated in the previous CRS study:

> Input indicators are measures of the resources and effort devoted to generating innovations . . . Output indicators refer to the results of the innovation process . . . Output indicators reflect the ability of industry to introduce new products and processes that meet economic and social needs, that can compete successfully with other products, and make a large enough return to cover the development costs and still return a profit. Thus output indicators reflect much more than technical capability or effort. They are also influenced by economic conditions, competitive pressures, business acumen, Government policies, and much more.[2]

Input indicators are more readily available than output indicators.

The use of these indicators to measure innovation is not without problems. It appears that some information which could be helpful is not available. Inputs to the process of innovation do not necessarily translate into outputs. As noted previously, the innovation process does not necessarily follow a linear path. In some instances, it is unclear whether increases in one component activity will lead to innovation; thus it may be inaccurate to draw the conclusion that increases in input resources will result in changes in innovative capability. For example, it is extremely difficult to judge how increases in funding affect the quality of the research and its outcome. In addition, the amounts of funds invested in research and development do not, in themselves, indicate if the results will in fact be utilized and, if so, for what purpose.

Sheer numbers of new products and processes do not necessarily indicate the presence of "innovations". Some argue that much of what is considered innovation today is in fact nothing more than cosmetic changes in already existing products rather than a novel good, service, or process. The few current output indicators are thus limited in what they express since they can not measure the quality of the innovation, its contribution to the improved quality of life, and its value to economic growth.

Another form of measurement often cited by analysts is the volume of high technology trade a nation has with other nations. This trade can be an indicator of the ability of a nation to convert the innovative high technology products or processes of other nations into commercial commodities. The United States has been able to obtain the lead in world markets by developing new products and processes. Similarly, other nations have developed innovative products and processes in certain commodities to broaden their markets. However, it should be noted that there is not always a linear relationship between high technology trade and innovation. High technology trade may be based on adopting existing technology; innovation may not always result in commercialized products in world markets.

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[2] Ibid., p. 2.

Despite these caveats, experts in the field have found strong correlations between various factors in the innovation process and increased innovation leading to economic growth and productivity improvement. Thus, while it may not be possible to establish direct cause and effect relationships, the data provide a general framework (and the only one now feasible) within which to make a tentative assessment of the condition and nature of U.S. technological innovation and how that contributes to the U.S. ability to compete in international markets. The earlier CRS report found that the available information indicated ". . . there are trends in a number of both input and output indicators of industrial innovation that may be interpreted to mean declining U.S. innovation performance relative both to past levels and to foreign competition." [3] The Joint Economic Committee of the United States Congress raised the question of whether these trends (reported through 1979) are still accurate and what, if anything, are the implications of the new data. This study will look at the updated information and attempt to determine the scope of the innovation process within the United States and its impact on our competitive position in international technology development.

APPROACH

The United States is continuing to expand the resources devoted to research and development in the domestic area. However, the rates of growth in most of the inputs to the innovation process do not match the growth rates in several western industrialized nations and the East Asian newly industrializing countries (N.I.C.s). In addition, an evaluation of various output indicators of innovation seems to demonstrate that the United States is falling behind relative to other nations in these areas. Of particular concern is the issue of the U.S. share of high technology trade.

It appears that the discrepancy between the resources devoted to innovation activities within the United States and the apparent competitive problems in the areas of high technology trade and productivity might be explained, in large part, by an understanding of the source of U.S. innovation-related support and the subsequent utilization and dissemination of resources. Perhaps the most striking fact of the innovation process within the United States is the large amount and proportion of financing supplied by the Federal Government. This provides the Government with a significant role in determining the distribution of funds for the innovation endeavor. According to the National Science Foundation, in 1986, the U.S. Government funds 47 percent of the total national R&D effort and funds approximately 32 percent of the research and development performed in industry. This support generally is for mission-related work. Over 70 percent of these Federal funds are for defense-oriented activities. Thus, much of the research and development performed within the United States is reflective of Federal needs—in particular, defense—rather than those of the marketplace. While there is general support for innovation-related activities in those areas where Government and industry interests coin-

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[3] Ibid., p. 35.

cide, there has been less emphasis, to date, on the commercialization of technology and its diffusion in the civilian marketplace. This is in marked contrast to many of the other countries studied in this paper in which there are on-going efforts to promote the development and commercialization of technologies for world markets.

The following report provides data and analyzes the possible reasons for this assessment. The organization of this study is designed to provide the reader with the basic data, to develop a context for the information, to offer an analysis of the material, and to finally draw conclusions based on what has been reported. Information concerning the domestic situation is presented, followed by data on U.S. activities in the international context. Each topic is introduced by a table (or set of tables) which provides the reader with sources for the subsequent discussion. Pursuant to the presentation of the data and the identification of the trends, the issue is analyzed. This analysis incorporates the many, and often diverse measurements and concepts which have been offered throughout the preceeding text.

II. DOMESTIC INNOVATION INDICATORS *

NATIONAL RESEARCH AND DEVELOPMENT EXPENDITURES

Research and development are often important components of the innovation process. While they are not the only factors necessary for innovation, studies have shown that R&D contributes to increases in industry productivity and that productivity growth in an industry or in a firm is directly and significantly related to the amount spent previously on R&D by that industry or company.[4] Concurrently, growing industries tend to have relatively high rates of investment in research and development.[5]

However, the use of research and development figures as indicators of the state of U.S. innovation must be tempered by other considerations. There is evidence that most innovation is stimulated by the recognition of market demand or market need rather than by technological opportunity.[6] In addition, innovations often result from minor alterations in existing products and processes which do not require research and development. Thus, R&D expenditures do not necessarily reflect accurately innovation activities within the economy. Yet, because of the correlation between R&D and economic growth noted above, it is of interest to analyze trends in research and development funding.

Total R&D Funding

TABLE 1.—NATIONAL EXPENDITURES FOR R&D, BY SOURCE: 1960–86 [1]

[Million constant 1972 dollars] [2]

Year	Total	Federal Government	Industry	Universities and colleges [3]	Other non-profit institutions
1960	$19,634	$12,674	$6,573	$214	$174
1961	20,585	13,283	6,861	235	206
1962	21,749	13,988	7,255	259	247
1963	23,736	15,572	7,612	285	267
1964	25,855	17,178	8,089	320	267
1965	26,898	17,445	8,805	356	291
1966	28,441	18,180	9,546	395	320
1967	29,240	18,175	10,298	434	333

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* Note: All calculations for this study are made in constant 1972 dollars using GNP price deflators provided by the National Science Foundation. Numbers are rounded so totals may not add up uniformly. All tables are figured by fiscal year unless otherwise noted.

[4] Mansfield, Edwin. How Economists See R&D. Harvard Business Review, Nov.-Dec. 1981. p. 98. Also: Mansfield, Edwin. Seminar on Research Productivity and the National Economy. U.S. Congress. House. Committee on Science and Technology. June 18, 1980. p. 6.

[5] Atkinson, Richard C. The Role of Research and Development in Economic Progress. In: U.S. Congress. House. Committee on Science and Technology. National Science and Technology Policy Issues. Washington, U.S. Govt. Print. Off., 1979. p. 24.

[6] Fernelius, W. Conrad and W. H. Waldo. Innovations Debt to Basic Reseach. In: Chemtech, v. 13, Mar. 1983. p. 150. Also: Mansfield, Edwin, and Anthony Romeo, Mark Schwartz, David Teece, Samuel Wagner, Peter Brach. Technology Transfer, Productivity, and Economic Policy. N.Y., W. W. Norton and Company, 1982. p. 5.

TABLE 1.—NATIONAL EXPENDITURES FOR R&D, BY SOURCE: 1960–86 [1]—Continued

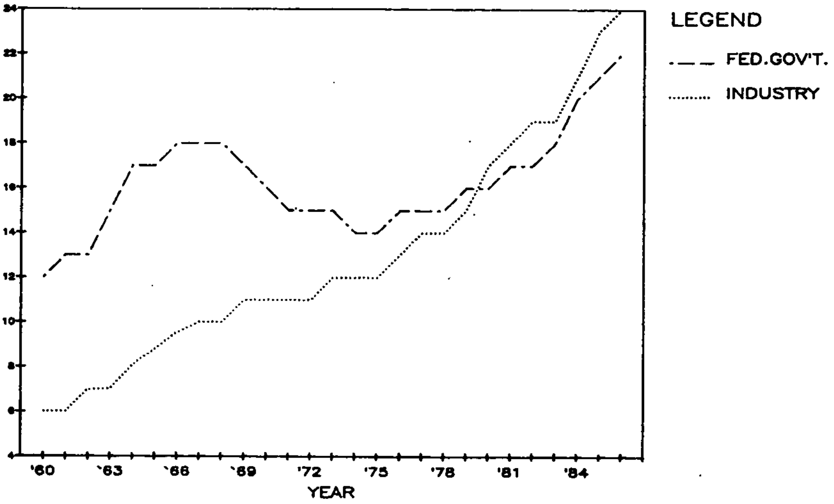
[Million constant 1972 dollars] [2]

Year	Total	Federal Government	Industry	Universities and colleges [3]	Other non-profit institutions
1968	29,831	18,105	10,910	474	342
1969	29,586	17,210	11,534	487	354
1970	28,613	16,316	11,421	506	369
1971	27,816	15,614	11,272	553	377
1972	28,477	15,808	11,710	574	385
1973	29,147	15,596	12,571	587	393
1974	28,764	14,825	12,931	604	404
1975	28,153	14,537	12,578	608	430
1976	29,511	15,072	13,370	614	454
1977	30,507	15,382	14,015	631	479
1978	32,002	15,878	14,925	690	509
1979	33,612	16,407	15,959	734	512
1980	35,122	16,542	17,325	745	510
1981	36,740	17,087	18,375	780	498
1982	38,155	17,528	19,329	804	493
1983	40,059	18,687	19,995	857	521
1984	43,059	20,030	21,611	885	533
1985 (estimate)	46,440	21,733	23,214	939	555
1986 (estimate)	48,557	22,620	24,350	1,024	563

[1] NSF Science Indicators—1985, p. 218 and unpublished data.
[2] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.
[3] Includes State and Local Government Sources.

National research and development expenditures grew through 1968, a trend which was reversed in the period of time between 1968 and 1975. Beginning in 1976, funding for research and development again began to increase. The average annual rate of increase for the years 1975 through 1980 was 4.5 percent and 5.6 percent between 1980 and 1986. The rates of increase experienced after 1980 remain above the 5.3 percent growth of the 1960s. The slow growth that the earlier CRS report found returning in the late 1970s accelerated in last six years. (See Table 1 and Figure 1.)

FIGURE 1
NATIONAL EXPENDITURES FOR R&D, BY SOURCE: 1960–1986
(Million constant 1972 dollars)



The growth in total research and development spending since 1975 has been due to increased funding for R&D by both the Federal Government and industry. However, during this time industry funding has experienced a greater average annual increase than that of the Federal Government. Between 1975 and 1980, non-Federal support expanded at an average annual rate twice that of the Government, while in the years 1980 through 1986, annual industry spending grew 5.9 percent as Federal spending increased 5.4 percent.

Sources of National R&D Funding

R&D EXPENDITURES OF THE FEDERAL GOVERNMENT

The sources of national research and development funding are of interest because they may provide some indication of the direction of the work receiving support. Expenditures by the Federal Government reflect Government priorities; funding by industry may tend to reflect private sector decisions, although they also tend to be influenced by Federal support of industrial R&D.

Until 1978 the Federal Government funded over half the national research and development endeavor; by 1986 this had declined to approximately 47 percent of the total. Prior to 1980, the amount of Government funds for R&D exceeded those of industry. Federal spending for R&D began to decline in 1968 and continued to do so through 1975. From 1975 through 1980, the Federal contribution to the research and development enterprise again began to increase at an average annual rate of 2.6 percent. In the following years (through 1986), this growth rate expanded to 5.4 percent per year.

R&D FUNDING BY INDUSTRY

Industrial funded research and development has tended to increase since 1960 and has every year since 1975. Between 1975 and 1980, the average annual rate of increase in industry support of R&D was 6.6 percent (as compared with a 2.6 percent increase in Federal support). In 1980, industry funding surpassed Government support of research and development. Between 1980 and 1986, the average annual growth rate for industrial R&D was 5.9 percent. This is 0.5 percent higher than the average annual growth rate of Federal R&D spending for this time period.

Industry funded 50 percent of the national research and development endeavor in 1986. This is an increase over the 33 percent of the total in 1960 and the 49 percent it funded in 1980, the year in which industrial support for R&D exceeded Federal support.

ADDITIONAL FUNDING FOR R&D

In 1986, NSF estimates that universities will fund two percent of the total national R&D endeavor. University funding for research and development has increased since 1960. The average annual rate of growth between 1980 and 1986 was 5.5 percent. This is higher than the average annual growth rate of 4.2 percent which occurred between 1975 and 1980.

Other not-for-profit institutions made up the additional contribution to the total R&D effort. There was a general trend of increased funding support by this sector throughout this time frame, with the exception of 1980–1982. The average annual rates of growth were higher between 1975 and 1980 than they were the following six years. In 1986, not-for-profit institutions accounted for 1.2 percent of the total R&D effort.

Ratio of R&D to Gross National Product

TABLE 2.—NATIONAL EXPENDITURES FOR PERFORMANCE OF R&D AS A PERCENT OF GROSS NATIONAL PRODUCT [GNP]: 1961–85 [1]

Year	United States
1961	2.73
1962	2.73
1963	2.87
1964	2.96
1965	2.89
1966	2.88
1967	2.89
1968	2.82
1969	2.71
1970	2.63
1971	2.48
1972	2.40
1973	2.31
1974	2.29
1975	2.27
1976	2.27
1977	2.23

TABLE 2.—NATIONAL EXPENDITURES FOR PERFORMANCE OF R&D AS A PERCENT OF GROSS NATIONAL PRODUCT [GNP]: 1961-85 [1]—Continued

Year	United States
1978	2.22
1979	2.27
1980	2.38
1981	2.43
1982	2.58
1983 (preliminary)	2.62
1984 (estimate)	2.62
1985 (estimate)	2.70

[1] NSF Science Indicators—1985, p. 187.

The ratio of national research and development funding to the gross national product can be utilized as an indicator of the portion of domestic resources which are devoted to R&D. However, it should be noted that use of this ratio may be conceptually limiting. The GNP reflects a movement of the U.S. toward a more service-oriented economy. The often low R&D component of many service sector activities may serve to dilute the actual impact of the utilization of research and development resources.

The R&D/GNP ratio reached a peak of 2.96 percent in 1964 due to Federal spending for space and defense. Once Government funding for space declined so did the ratio, hitting a low of 2.22 percent in 1978.[7] Since 1979, the ratio has increased to an estimated 2.70 percent in 1985. The average annual rate of increase during this time period was 2.9 percent.

The total increase in the ratio, however, can not be attributed solely to the increased amount of R&D funding but results, in part, ". . . from a slowing of GNP growth relative to the steady expansion of R&D expenditures." [8] Over the time period from 1976 to 1985, R&D increased at an average annual rate of 5.2 percent while the concurrent average annual growth rate of the GNP was 2.7 percent.[9]

TABLE 3.—ESTIMATED NONDEFENSE R&D EXPENDITURES AS A PERCENT OF GROSS NATIONAL PRODUCT [GNP], 1971-85 [1]

Year	United States
1971	1.68
1972	1.63
1973	1.62
1974	1.69
1975	1.68
1976	1.68
1977	1.67
1978	1.69
1979	1.75
1980	1.86
1981	1.87
1982	1.94
1983 (preliminary)	1.91

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[7] U.S. National Science Board. Science Indicators—1982. Washington, 1983. p. 42.
[8] Ibid., p. 42.
[9] U.S. National Science Board. Science Indicators—The 1985 Report. Washington, 1986. p. 31.

TABLE 3.—ESTIMATED NONDEFENSE R&D EXPENDITURES AS A PERCENT OF GROSS NATIONAL PRODUCT [GNP], 1971-85 [1]—Continued

Year	United States
1984 (estimate)	1.86
1985 (estimate)	1.89

[1] NSF Science Indicators—1985, p. 190.

If the ratio of civilian research and development (national R&D expenditures minus Federal funds for defense) to gross national product is utilized, a different picture emerges. These ratios are consistently lower than those associated with total R&D/GNP. This ratio reached a low of 1.62 percent in 1973. Since then it has vascillated in no discernable pattern. The preliminary figures show that the ratio reached a high point of 1.94 in 1982, declined through 1984, and rose again in 1985, although not to the 1982 figure. At its highest point in 1982, the ratio of civilian R&D to GNP was 75 percent of the total national R&D/GNP ratio.

Federal R&D Funding by Objective

The Federal Government is a major funding source for the research and development activities taking place within the United States. As noted previously, until 1978, the Government supported over half the national R&D endeavor; in the fiscal year 1986 budget this declined to 47 percent of the total. The way in which these funds are applied to the research and development effort impacts significantly on the type of work performed. It can influence the allocation of resources in other sectors as well as influence the direction of new innovative initiatives.

TABLE 4.—FEDERAL FUNDING OF INDUSTRIAL R&D, FOR SELECTED INDUSTRIES: 1971, 1980 AND 1983 [1]

Industry	1971	1980	1983
Total	$7,666	$14,029	$20,215
Lumber, wood products, and furniture		NA	0
Chemicals and allied products		372	448
Industrial chemicals		341	440
Petroleum refining and extraction		151	NA
Primary metals		135	391
Ferrous metals and products		105	NA
Nonferrous metals and products		30	NA
Fabricated metal products		49	66
Nonelectrical machinery		647	1,144
Electrical equipment	2,211	3,744	5,081
Radio and TV receiving equipment		210	NA
Communication equipment		1,657	2,367
Electronic components		382	346
Other electrical equipment		1,495	NA
Motor vehicles and motor vehicle equipment		655	566
Aircraft and missiles	3,864	6,628	10,300
Professional and scientific instruments		573	640
Scientific and mechanical measuring instruments		350	NA
Optical, surgical, photographic, and other instruments		223	NA
Nonmanufacturing industries		779	1,048

[1] NSF Science Indicators—1985. p. 265, and NSF, National Patterns of R&D Resources—1984. p. 51.

As shown in Table 4 above, Federal funding for research and development within industry has been, and continues to be, concentrated in a very few areas. In 1983, 25 percent of these funds went toward activities in the area of electrical equipment and 51 percent for aircraft and missile R&D. This has not changed significantly since 1971 when 29 percent of Federal funds to industry were applied to the former and 50 percent to the latter.

TABLE 5.—FEDERAL FUNDS FOR R&D, BY BUDGET FUNCTION: 1971-86 [1]

[Million constant 1972 dollars]

Function	1971	1972	1973	1974	1975	1976	1977	1978
Total	16,254.4	16,495.9	16,084.4	15,536.4	15,446.0	15,756.5	16,659.6	17,279.3
National defense	8,481.4	8,901.6	8,618.4	8,045.5	7,852.8	7,908.5	8,428.4	8,580.7
Health	1,346.8	1,546.7	1,517.5	1,846.0	1,760.7	17,821.2	1,867.4	1,974.1
Space research and technology	3,187.6	2,931.8	2,703.6	2,411.0	2,242.4	2,373.3	2,011.7	1,955.0
Energy	581.3	574.0	602.9	677.5	1,106.1	1,250.0	1,820.0	2,085.0
General science	536.0	625.3	629.6	668.7	659.8	650.4	691.8	698.6
Transportation	761.2	558.2	547.2	618.8	515.1	478.1	503.3	510.5
Natural resources and environment	434.5	478.5	530.2	460.5	506.5	517.9	535.0	601.3
Agriculture	270.9	294.4	295.0	279.4	277.3	290.0	324.5	333.5
Education, training, employment and social services	225.3	235.3	278.0	211.0	193.6	193.2	163.5	229.6
International affairs	33.4	28.6	27.1	21.2	23.5	32.2	47.1	38.0
Veterans benefits and services	65.8	69.1	71.1	75.7	76.9	74.1	76.0	73.9
Commerce and housing credit	93.6	49.7	48.1	45.3	52.7	52.1	50.1	51.0
Income security	151.5	106.3	101.8	63.3	58.3	36.6	39.2	44.8
Administration of justice	10.9	23.4	31.8	31.0	35.9	36.6	21.1	29.1
Community and regional development	67.6	65.8	75.1	73.3	75.0	82.3	71.7	61.1
General government	6.9	7.6	7.1	8.3	9.5	9.0	9.0	13.5
	1979	1980	1981	1982	1983	1984	1985	1986
Total	17,256.8	16,762.2	17,269.9	17,252.7	17,814.5	19,571.5	21,546.4	23,901.3
National defense	8,436.9	8,414.8	9,426.1	10,543.2	11,458.5	12,964.0	14,654.0	17,379.2
Health	2,080.8	2,079.9	1,981.6	1,848.3	1,975.0	2,115.4	2,308.3	2,095.7
Space research and technology	1,918.5	1,541.5	1,592.6	1,234.5	980.6	1,081.1	722.6	1,289.9
Energy	2,117.6	2,028.6	1,792.5	1,438.9	1,184.6	1,142.5	1,024.8	895.6
General science	684.6	694.0	686.0	649.2	690.2	741.9	799.5	816.4
Transportation	488.3	499.7	445.1	377.9	402.5	460.4	448.6	390.6
Natural resources and environment	617.6	562.6	542.9	461.0	437.5	426.3	440.9	371.3
Agriculture	337.5	329.5	337.1	330.9	342.3	337.3	349.6	319.2
Education, training, employment and social services	216.3	263.5	152.8	108.9	86.8	88.5	91.8	86.2
International affairs	71.5	71.1	81.9	78.8	81.3	85.0	92.6	92.3
Veterans benefits and services	75.1	70.8	73.2	66.5	72.1	96.5	82.4	76.7
Commerce and housing credit	56.7	57.5	54.0	49.6	49.1	48.7	49.5	43.5
Income security	34.7	43.5	21.8	15.1	14.7	11.5	10.7	9.8
Administration of justice	28.4	25.4	17.3	14.8	17.0	10.6	19.2	16.4
Community and regional development	77.9	67.2	53.4	29.9	20.2	20.4	18.4	11.5
General government	14.3	12.4	11.3	4.8	2.7	3.5	7.3	7.4

[1] NSF Science Indicators—1985, p. 227.

There have been major shifts in Federal funding for certain budget functions. The Federal outlay for national defense and space has far surpassed civilian research and development. In 1971, 52 percent of Government R&D funding went to defense, 20 percent to space and 28 percent to civilian activities. Ten years later in 1981, approximately 55 percent of the Federal R&D budget went for national defense, nine percent for space, and 36 percent for civilian research and development. By 1986, 73 percent went for defense, five percent for space, and 22 percent for civilian activities. Federal R&D funding in defense-related areas had increased by 105 percent from 1971 through 1986, while at the same time civilian R&D (including energy) grew only 14 percent. Between 1981 and 1986 Federal support for defense increased 84 percent while support for civilian activities decreased 16 percent.

Other dramatic shifts in Federal support are evidenced by changes in funding for energy-related and space-related R&D. Reflecting an increased interest in energy research and development resulting from the oil embargo, the Government increased its funding in this area so that at its peak in 1979 this support comprised 12 percent of the total Federal R&D outlay. In 1986 this had decreased to less than five percent of the Governmental effort. Similarly, Federal funding for space decreased from 24 percent of the budget in 1969 to 5 percent by 1986.

Type of Research and Development

TABLE 6.—NATIONAL EXPENDITURES FOR BASIC RESEARCH, BY SOURCE: 1960–86 [1]

[Million constant 1972 dollars] [2]

Year	Total	Federal Government	Industry	Universities and colleges [3]	Other nonprofit institutions
1960	$1,730	$1,031	$497	$103	$98
1961	2,003	1,246	520	121	116
1962	2,426	1,589	558	143	137
1963	2,721	1,812	593	167	150
1964	3,128	2,181	595	196	156
1965	3,417	2,417	620	219	162
1966	3,659	2,571	664	256	168
1967	3,852	2,773	622	281	177
1968	4,001	2,837	648	335	181
1969	3,986	2,930	623	346	187
1970	3,894	2,732	578	384	200
1971	3,836	2,643	570	418	205
1972	3,829	2,633	563	415	218
1973	3,766	2,589	573	391	213
1974	3,757	2,589	567	386	215
1975	3,720	2,540	562	388	230
1976	3,771	2,604	581	360	225
1977	3,939	2,718	607	374	240
1978	4,251	2,957	641	402	251
1979	4,440	3,086	668	435	251
1980	4,543	3,128	709	453	253
1981	4,698	3,178	810	465	244
1982	4,757	3,178	870	470	240
1983	5,068	3,340	946	517	264
1984	5,366	3,495	1,080	533	259
1985 (estimate)	5,688	3,690	1,172	551	275
1986 (estimate)	5,916	3,783	1,226	626	280

[1] NSF Science Indicators—1985, p. 222, and unpublished data.

[2] GNP implicit price deflators used to convert current dollars to constant price dollars.

[3] Includes State and Local Government Sources.

TABLE 7.—NATIONAL EXPENDITURES FOR APPLIED RESEARCH, BY SOURCE: 1960–86 [1]

[Million constant 1972 dollars] [2]

Year	Total	Federal Government	Industry	Universities and colleges [3]	Other nonprofit institutions
1960	$4,380	$2,442	$1,784	$95	$58
1961	4,401	2,512	1,723	98	68
1962	5,174	2,913	2,082	98	82
1963	5,202	2,948	2,069	99	86
1964	5,657	3,280	2,189	105	84
1965	5,819	3,379	2,224	117	98
1966	5,989	3,359	2,398	116	116
1967	6,036	3,399	2,389	128	120
1968	6,222	3,410	2,575	118	120
1969	6,139	3,222	2,673	122	122
1970	6,264	3,377	2,654	108	126
1971	5,986	3,141	2,598	120	127
1972	5,984	3,104	2,615	140	125
1973	6,267	3,235	2,734	165	133
1974	6,340	3,123	2,896	181	140
1975	6,297	3,173	2,796	182	146
1976	6,844	3,434	3,025	215	171
1977	6,945	3,406	3,149	215	175
1978	7,211	3,478	3,311	235	186
1979	7,570	3,591	3,545	247	186
1980	7,887	3,709	3,753	241	184
1981	8,631	3,824	4,360	263	185
1982	8,900	3,902	4,540	277	181
1983	9,353	4,249	4,642	282	181
1984	9,869	4,287	5,093	295	195
1985 (estimate)	10,201	4,245	5,432	329	196
1986 (estimate)	10,358	4,197	5,629	336	197

[1] NSF Science Indicators—1985, p. 223, and unpublished data.

[2] GNP implicit price deflators used to convert current dollars to constant price dollars.

[3] Includes State and Local Government Sources.

TABLE 8.—NATIONAL EXPENDITURES FOR DEVELOPMENT, BY SOURCE: 1960–86 [1]

[Million constant 1972 dollars] [2]

Year	Total	Federal Government	Industry	Universities and colleges [3]	Other nonprofit institutions
1960	$13,525	$9,201	$4,291	$16	$17
1961	14,181	9,526	4,617	16	23
1962	14,149	9,487	4,615	18	28
1963	15,813	10,812	4,950	19	31
1964	17,069	11,717	5,306	19	27
1965	17,662	11,649	5,962	20	31
1966	18,793	12,249	6,484	23	36
1967	19,352	12,003	7,287	25	37
1968	19,608	11,859	7,687	21	41
1969	19,461	11,159	8,238	20	44
1970	18,454	10,207	8,189	14	44
1971	17,994	9,830	8,104	15	45
1972	18,664	10,071	8,532	19	42
1973	19,114	9,772	9,264	32	46
1974	18,667	9,113	9,467	37	49
1975	18,136	8,824	9,220	38	54
1976	18,896	9,034	9,764	39	58
1977	19,623	9,258	10,260	41	63
1978	20,540	9,443	10,973	52	72
1979	21,603	9,729	11,746	52	75
1980	22,692	9,705	12,864	51	73
1981	23,410	10,086	13,204	52	69
1982	24,498	10,449	13,920	57	72

TABLE 8.—NATIONAL EXPENDITURES FOR DEVELOPMENT, BY SOURCE: 1960-86 [1]—Continued

[Million constant 1972 dollars] [2]

Year	Total	Federal Government	Industry	Universities and colleges [3]	Other nonprofit institutions
1983	25,639	11,098	14,407	58	76
1984	27,823	12,248	15,438	58	80
1985 (estimate)	30,551	13,798	16,610	60	83
1986 (estimate)	32,282	14,641	17,494	61	86

[1] NSF Science Indicators—1985, p. 224, and unpublished data.
[2] GNP implicit price deflators used to convert current dollars to constant price dollars.
[3] Includes State and Local Government Sources.

R&D is often broken down into component parts which are traditionally referred to as basic research, applied research, and development. According to the definitions utilized by the National Science Foundation, basic research is that directed to the understanding of the fundamental nature of the world without specific applications toward future development of products and processes. Applied research is that systematic study designed to ". . . gain knowledge or understanding necessary for determining the means by which a recognized and specific need be met." Development is the systematic utilization of the results of the research endeavor ". . . directed toward the production of useful materials, devices, systems, or methods, including design and development of prototypes and processes." [10]

The balance between national funding for basic research, applied research, and development has remained approximately the same over the years; 12 percent, 23 percent, and 65 percent respectively.[11] The Federal Government is the primary source of funds for basic research (64 percent in 1986), although the proportion of industrial support in this area is increasing; from 1980-1986 industry support increased from 16 percent of the total to 21 percent. While Federal expenditures grew at an average annual rate of 3.2 percent between 1980 and 1986, industry funding for basic research during the same time period increased at an average annual rate of 9.6 percent. Colleges and universities perform approximately one half of the basic research undertaken in this country and fund about 11 percent of the total work that is done in the basic research area.

Total funding for applied research has also been increasing. From 1980 through 1986, there was a 31 percent overall increase. This compares with growth of nine percent between 1970 and 1976 and with 24 percent growth between 1974 and 1980. Industry began to fund a larger proportion of the national applied research effort in 1980. Federal funding for this endeavor has declined since 1984. In 1986, industry financed 54 percent of the total in contrast to the Federal Government's 41 percent. This is a reversal of the situation in 1970 when the Government funded 54 percent of the total applied budget and industry supported 42 percent of this endeavor.

Development funding is by far the largest portion of the national R&D effort; it constitutes two-thirds of the total. Expenditures for

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[10] U.S. National Science Foundation. Federal Funds for Research and Development—1984. Washington, 1984. p. 1.

[11] Science Indicators—1982, op. cit., p. 47.

this activity by both the Federal Government and industry have expanded since 1975. There was a 42.3 percent increase in total development spending for the years 1980 through 1986. The increases in Federal funding during this time amounted to 50.9 percent due primarily to increased spending for defense-related activities. Industry expenditures for this endeavor increased 36 percent. This compares with a 6.5 percent increase in Federal support and 35.9 percent increase in industrial funding for development in the years between 1974–1980. Industry finances a larger portion of the development work (in 1986 industry funded 54.2 percent of the total; the Government funded 45 percent), although the portion declined slightly between 1980 and 1986 (from 56.7 percent to 54.2 percent) as Federal expenditures grew at a faster rate. Industry performs about 85 percent of the development work in the United States.

INDUSTRY ACTIVITIES

The performance of the industrial sector is critical to the maintenance and advancement of technological innovation. Industry is a crucial link in the innovation process for it manufactures products for sale in the marketplace or utilizes processes to increase productivity. It is this sector which provides the commercialization and diffusion activities necessary to insure that a new idea, in fact, becomes an innovation. It provides the Government with the technologies needed to secure the nation's defense, health, and welfare since the public sector has neither the mandate nor the capabilities to manufacture. In addition, industry responds to demands in the marketplace, or creates new needs, to provide the goods and services which fuel our economy.

Industrial Research and Development

TABLE 9.—NATIONAL EXPENDITURES FOR R&D, BY PERFORMER: 1960–86 [1]

[Million constant 1972 dollars] [2]

Year	All performers	Federal Government	Industry [3]	Universities and colleges [4]	FFRDC's [5]	Other nonprofit institutions
1960	$19,634	$2,481	$15,297	$929	$517	$410
1961	20,585	2,663	15,733	1,084	583	521
1962	21,749	2,940	16,236	1,267	659	649
1963	23,736	3,141	17,622	1,490	730	752
1964	25,855	3,868	18,569	1,738	857	825
1965	26,898	4,125	19,076	1,966	839	892
1966	28,441	4,184	20,255	2,228	819	955
1967	29,240	4,275	20,725	2,418	847	975
1968	29,831	4,245	21,116	2,611	874	986
1969	29,586	4,065	21,095	2,582	841	1,002
1970	28,613	4,480	19,756	2,565	810	1,002
1971	27,816	4,422	19,081	2,615	749	950
1972	28,477	4,590	19,552	2,630	753	952
1973	29,147	4,559	20,094	2,761	782	951
1974	28,764	4,382	19,888	2,698	772	1,024
1975	28,153	4,344	19,228	2,766	801	1,014
1976	29,511	4,374	20,400	2,828	870	1,040
1977	30,507	4,271	21,296	2,889	983	1,067
1978	32,002	4,531	22,141	3,077	1,142	1,112
1979	33,612	4,538	23,391	3,280	1,184	1,220
1980	35,122	4,297	24,944	3,412	1,264	1,205

TABLE 9.—NATIONAL EXPENDITURES FOR R&D, BY PERFORMER: 1960–86 [1]—Continued

[Million constant 1972 dollars] [2]

Year	All performers	Federal Government	Industry [3]	Universities and colleges[4]	FFRDC's [5]	Other nonprofit institutions
1981	36,740	4,313	26,488	3,490	1,273	1,176
1982	38,155	4,367	27,966	3,469	1,184	1,169
1983	40,059	4,863	29,135	3,575	1,258	1,242
1984	43,059	5,122	31,489	3,751	1,380	1,317
1985 (estimate)	46,440	5,613	33,934	4,055	1,451	1,387
1986 (estimate)	48,557	5,732	35,619	4,340	1,474	1,392

[1] NSF Science Indicators—1985, p. 220, and unpublished data.

[2] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

[3] Expenditures for federally funded research and development centers administered by industry and by nonprofit institutions are included in the totals of the respective sectors.

[4] Includes State and Local Governments.

[5] Federally funded research and development centers administered by universities.

TABLE 10.—EXPENDITURES FOR INDUSTRIAL R&D, BY SOURCE OF FUNDS: 1960–86 [1]

[Million constant 1972 dollars] [2]

Year	Total	Company [3]	Federal Government [4]
1960	$15,297	$6,445	$8,852
1961	15,733	6,733	9,000
1962	16,236	7,122	9,113
1963	17,622	7,479	10,114
1964	18,568	7,959	10,609
1965	19,076	8,667	10,409
1966	20,255	9,401	10,855
1967	20,725	10,144	10,581
1968	21,116	10,745	10,371
1969	21,095	11,357	9,737
1970	19,756	11,250	8,506
1971	19,081	11,097	7,985
1972	19,552	11,535	8,017
1973	20,094	12,391	7,702
1974	19,888	12,745	7,143
1975	19,228	12,387	6,981
1976	20,400	13,175	7,225
1977	21,296	13,809	7,487
1978	22,141	14,702	7,439
1979	23,391	15,731	7,660
1980	24,944	17,081	7,863
1981	26,488	18,112	8,375
1982	27,966	19,053	8,913
1983	29,171	19,783	9,388
1984	31,662	21,392	10,270
1985 (estimate)	33,810	22,990	10,280
1986 (estimate)	NA	23,995	NA

[1] NSF Science Indicators—1985, p. 252, and unpublished data.

[2] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

[3] Includes all sources other than the Federal Government.

[4] Data include federally funded R&D centers administered by industry.

The importance of industrial research and development to economic growth has been discussed previously. Research by Nadari and Terleckyj cited in the earlier CRS report points to industrially-funded R&D having a greater impact on economic growth and productivity improvement than other types of funding.[12] In 1986, ap-

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[12] Some indicators of the State of U.S. Industrial Innovation, op. cit., p. 11.

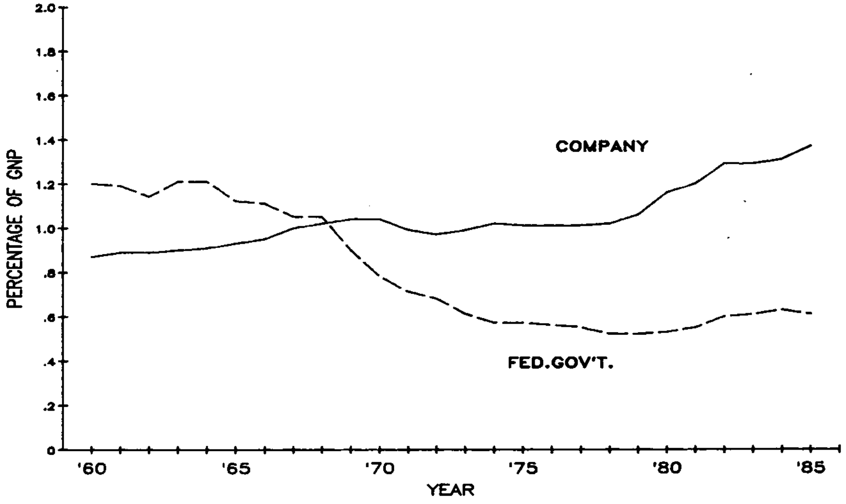
proximately 73 percent of the total national research and development expenditure was spent in industry. Funding for industrial R&D has increased every year since 1960 with the exception of 1969-1971 and 1974-1975. In the late 1960s, the Federal Government funded approximately one half of the R&D performed within industry. By the mid 1970s, this had decreased to approximately 35 percent, due in part to diminished Federal spending for space. This decline continued in the 1980s and it is expected that for the next several years the Government will continue to fund about 32 percent of the research and development performed in industry as was the case between 1980 and 1985.[13]

Funding of internal research and development by industry has increased at an average annual rate of 5.6 percent between 1980 and 1986. This is greater than the 4.1 percent yearly increases between 1975-1979. The largest growth occurred between 1983 and 1985. Industrial performance of R&D expanded 43 percent from 1980 and 1986. This was greater than the 25 percent increase between 1974 and 1980.

Figure 2 shows both Federal and company R&D funding as a fraction of gross national product. The 1970's dip and subsequent recovery are evident.

FIGURE 2

EXPENDITURES FOR INDUSTRIAL R&D
AS A PERCENTAGE OF GNP
(1972 dollars)



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[13] U.S. National Science Foundation. National Patterns of Science and Technology Resources—1984. Washington, 1984. p. 8.

Industry-University Cooperation in R&D

TABLE 11.—INDUSTRY'S EXPENDITURES FOR R&D IN UNIVERSITIES AND COLLEGES: 1960–86 [1]

[In millions of dollars]

Year	Current dollars	Constant dollars [2]
1960	$40	$58
1961	40	58
1962	40	57
1963	41	57
1964	40	55
1965	41	55
1966	42	55
1967	48	61
1968	55	67
1969	60	69
1970	61	67
1971	70	73
1972	74	74
1973	84	79
1974	96	83
1975	113	90
1976	123	93
1977	139	99
1978	170	113
1979	193	118
1980	235	132
1981	288	147
1982	326	157
1983	378	174
1984 (estimate)	457	202
1985 (estimate)	550	235
1986 (estimate)	600	246

[1] NSF Science Indicators—1985, p. 262.

[2] GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

Industry-university cooperation in research and development is an important mechanism which is intended to increase technological innovation. Traditionally, universities perform much of the basic research which is integral to certain innovations. However, these institutions do not have the commercialization capacity available in industry and necessary to translate the results of research into products and processes which can be sold in the marketplace. Universities also contribute to innovation activities within industry through the education and training of the scientists, engineers, and managers employed by companies. Thus, efforts which encourage increased collaboration between these two sectors can be expected to expand the innovative contribution of both parties.

In general, the amount of R&D performed within universities has increased with the exception of 1969, 1970, 1974, and 1982. Universities performed nine percent of the total research and development undertaken in 1986, 67 percent of which was basic research. This is below the portion of the total performed within universities in most of the 1970s but above that in most of the 1960s.

Since 1970 industry funding for research and development in universities and colleges has increased. The estimated amount of spending by companies in 1986 was over 2½ times that which it was ten years before in 1976. Between 1980 and 1986 there was an

86 percent growth in industry expenditures at universities. These figures do not include the industrial R&D funds which are involved in cooperative research agreements. In the past several years many of these often substantial industry-university joint efforts have been undertaken. According to estimates made by the National Science Foundation, if all university-industry funding mechanisms were counted, in FY81 industrial support would total $500 million (current dollars in contrast to the $288 million depicted in Table 11) which is approximately 1.5 percent of internal industrial R&D spending.[14]

SMALL BUSINESS

It has been argued that small high technology businesses tend to be highly innovative. A study by Gellman Research Associates, reported in the National Science Foundation's publication Science Indicators-1976, found that firms of less than 1000 employees were responsible for more major innovations than large firms in the years 1953–1966 and for an equal number from 1967–1973.[15] Other research has shown small companies of less than 500 employees are 2.5 times as innovative per employee as large firms.[16] Small businesses (although not all of which are high technology-oriented) have also been responsible for the creation of a major portion of new jobs.[17]

Availability of Venture Capital

TABLE 12.—CAPITAL AVAILABLE AND DISBURSED TO NEW VENTURES: 1970–84 [1]

[In millions of dollars]

Year	Net new private capital committed to venture capital firms	Total pool of capital under management	Total industry disbursements	Straight equity-acquisition disbursements [2]
1970	$97	[3] $2,500	$350	
1971	95	[3] 2,600	410	
1972	62	[3] 2,700	425	
1973	56	[3] 2,700	450	
1974	57	[3] 2,800	350	
1975	10	[3] 2,800	250	$136
1976	50	[3] 2,900	300	185
1977	39	[3] 2,900	400	207
1978	600	3,500	550	332
1979	300	3,800	1,000	665
1980	700	4,500	1,100	799
1981	1,300	5,800	1,400	1,171
1982	1,800	7,600	1,800	1,566
1983	4,500	12,100	2,800	2,457
1984	4,200	16,300	3,000	2,631

[1] NSF Science Indicators—1985, p. 260.
[2] Excludes SBIC straight debt lending and leveraged buyout financing, but includes mixed equity-debt financings.
[3] Estimated.

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[14] Science Indicators—1982, op. cit., p. 115. Reference 134.

[15] U.S. National Science Board. Science Indicators—1976. Washington, 1977. p. 116.

[16] U.S. Congress. Senate. Committee on Small Business. Innovation Development Act, P.L. 97-219. Hearings, 98th Cong., 2d Sess. Mar. 1, 1984. Washington, U.S. Govt. Print. Off., 1984. p. 8.

[17] Science Indicators—1982, op. cit., p. 103. Footnote 101.

Small businesses often are funded by venture capital. Traditional means of financing are generally unavailable for high risk undertakings by small high technology firms; thus the importance of venture capital. As Table 12 demonstrates, the availability of such funds increased dramatically in 1978. This substantial increase in venture capital has been attributed to the Steiger amendment to the 1978 Tax Act which lowered the maximum capital gains tax rate from 49 percent to 28 percent. The 1981 Economic Recovery Tax Act further reduced the maximum capital gains tax to 20 percent which had a positive affect on the availability of venture capital. Between 1980 and 1981 there was an 86 percent increase in the net new private venture capital available. Changes in the rules for investments of pension funds also contributed to the expanded availability of venture capital.

Public Stock Offerings

TABLE 13.—INITIAL PUBLIC OFFERING OF STOCK IN SMALL HIGH-TECHNOLOGY COMPANIES: 1976–83[1]

[In millions of dollars]

Year	Number of issues	Total amount
1976	4	11.7
1977	5	11.8
1978	12	10.1
1979	24	33.8
1980	33	130.8
1981	70	282.7
1982	47	182.6
1983	141	1,513.0

[1] NSF Science Indicators—1985, p. 260.

Note.—Small companies are defined as those with $500,000 or less in net income after taxes. High-technology companies are those whose primary SIC's are listed on appendix table 4-13.

Small high technology firms also may decide to sell stock on the open market as a means to secure additional funding. The number of stock offerings in small high tech companies has generally increased each year, with the exception of 1982. Substantial increases are observable between 1980–1981 and between 1982–1983. Similarly, the amount of money raised through these stock offerings has increased every year (again with the exception of 1982) including an increase of 829 percent between 1982 and 1983.

Research and Development Funding

TABLE 14.—COMPANY FUNDS FOR RESEARCH AND DEVELOPMENT BY SIZE OF COMPANY[1]

[Million constant 1972 dollars][2][3]

Size	1971	1975	1980	1981	1982	1983
Less than 1,000 employees	588	754	959	961	963	1,041
1,000 to 4,999 employees	862	900	1,265	1,322	1,458	1,570
5,000 to 9,999 employees	996	946	895	1,211	1,095	1,121
10,000 to 24,995 employees	8,650	1,798	2,728	2,831	3,091	3,245
25,000 or more employees		7,989	11,235	11,787	12,446	12,805

TABLE 14.—COMPANY FUNDS FOR RESEARCH AND DEVELOPMENT BY SIZE OF COMPANY [1]—Continued

[Million constant 1972 dollars] [2] [3]

Size	1971	1975	1980	1981	1982	1983
Total	11,097	12,387	17,081	18,112	19,053	19,783

[1] NSF, Research and Development in Industry 1982, p. 13 and unpublished data.
[2] GNP implicit price deflators used to convert current dollars to constant price dollars.
[3] Annual years.

Funding for research and development by small businesses (under 1,000 employees) increased 77 percent between 1971 and 1983. Between 1980 and 1983, there has been an increase of 8.6 percent, the major portion of this resulting from gains made from 1982 to 1983. The proportion of total company R&D funding which is financed by small business has remained fairly constant. In the years 1980–1983 this amounted to a little over five percent of the total industrial R&D enterprise.

SCIENCE AND ENGINEERING MANPOWER

Degrees Awarded

TABLE 15.—SCIENCE AND ENGINEERING DEGREES, BY LEVEL: 1960–83 [1]

Year	Total S/E degrees	Bachelor's	Master's	Doctor's
1960	147,005	120,937	20,012	6,056
1961	150,977	121,660	22,786	6,531
1962	159,864	127,469	25,146	7,249
1963	171,386	135,964	27,367	8,055
1964	192,657	153,361	30,271	9,025
1965	209,023	164,936	33,835	10,252
1966	222,852	173,471	38,083	11,298
1967	242,408	187,849	41,800	12,759
1968	271,727	212,174	45,425	14,128
1969	308,783	244,519	48,425	15,839
1970	331,079	264,122	49,318	17,639
1971	340,226	271,176	50,624	18,466
1972	353,207	281,228	53,567	18,412
1973	368,223	295,391	54,234	18,598
1974	377,102	305,062	54,175	17,865
1975	366,556	294,920	53,852	17,784
1976	364,209	292,174	54,747	17,288
1977	362,211	288,543	56,731	16,937
1978	360,600	288,167	56,237	16,196
1979	359,444	288,625	54,456	16,363
1980	362,857	291,983	54,391	16,483
1981	366,651	294,867	54,811	16,973
1982	376,062	302,118	57,025	16,919
1983	383,149	307,225	58,868	17,056

[1] NSF Science Indicators—1985, p. 267, and unpublished data.

The total number of science and engineering degrees awarded (including bachelor, master, and doctorate degrees) to U.S. citizens increased steadily between 1960 and 1974. From 1974, the number of degrees conferred declined through 1979, at which point they again began to increase. In 1983, the number of degrees awarded finally surpassed the previous high set in 1974. The figures for 1983 indicate a growth of 6.6 percent over the 1979 number. The greatest growth between 1979 and 1983 was in the area of master's degrees at 8.6 percent, followed by increases of 6.4 percent in the number of bachelor degrees awarded. Doctorates conferred in science and engineering increased 4.2 percent in this time period.

Number of Scientists and Engineers Employed

TABLE 16.—FULL-TIME EQUIVALENT [FTE] SCIENTISTS AND ENGINEERS EMPLOYED IN RESEARCH AND DEVELOPMENT BY SECTOR: SELECTED YEARS [1] [2]

[In thousands]

Sector	1954	1961	1965	1969	1971	1972	1973	1974
Total	237.1	425.7	494.5	555.2	527.1	518.3	518.4	525.4
Federal Government [3]	37.7	51.1	61.8	68.5	...	64.4	...	...
Industry [4] [5]	164.1	312.0	348.4	385.6	...	353.9	...	...
Universities and colleges total	25.0	42.4	53.4	68.3	...	66.5	...	...
Scientists and engineers	20.3	33.6	40.4	50.4	...	48.9	...	...
Graduate students [6]	4.7	8.8	13.0	17.9	...	17.6	...	...
University-associated FFRDC's, total	5.0	9.1	11.1	11.6	...	11.7	...	...
Scientists and engineers	4.9	8.8	10.7	11.1	...	11.3	...	...
Graduate students [6]	.1	.3	.4	.5	...	.4	...	...
Other nonprofit institutions	5.3	11.1	19.9	21.2	...	21.8	...	...
	1975	1977	1978	1979	1980	1981	1982 [7]	1983 [7]
Total	532.7	568.2	594.2	622.0	658.7	691.4	723.0	750.0
Federal Government [3]	63.4	62.2	64.3	64.6	65.6	66.0	66.0	66.0
Industry [4] [5]	363.8	393.6	414.2	437.2	469.2	499.7	530.6	555.9
Universities and colleges total	69.8	74.4	76.6	78.6	81.2	81.2	84.0	85.8
Scientists and engineers	51.2	54.4	56.0	56.9	57.9	58.9	59.5	60.3
Graduate students [6]	18.6	20.0	20.6	21.7	23.3	24.4	24.5	25.5
University-associated FFRDC's, total	12.7	14.0	14.1	14.1	15.2	15.4	15.4	15.3
Scientists and engineers	12.3	13.6	13.7	13.7	14.8	15.0	15.0	14.9
Graduate students [6]	.4	.4	.4	.4	.4	.4	.4	.4
Other nonprofit institutions	23.0	24.0	25.0	27.5	27.5	27.0	27.0	27.0

[1] NSF National Patterns of R&D Resources, 1984. p. 36, and National Patterns of R&D Resources 1978, table 8–10.

[2] Number of full-time employees plus the FTE of part-time employees. Excludes scientists and engineers employed in State and local government agencies. Totals may be understated by about five percent because of incomplete data on summer employment at universities and colleges.

[3] Includes both civilian and military service personnel and managers of R&D.

[4] Includes professional R&D personnel employed at FFRDC's administered by organization in the sector.

[5] Excludes social scientists.

[6] Numbers of FTE graduate students receiving stipends and engaged in R&D.

[7] Estimate.

The number of scientists and engineers employed in research and development related activities grew from 1954 through 1969, after which it declined through 1973. Since 1974, the number has continued to increase. This increase in employment of scientists and engineers is due primarily to expanded industrial hiring in these areas. As indicated in Table 16, between 1975 and 1983, the number of scientists and engineers employed in industry has increased 52.8 percent; in the Federal Government the number increased 4.1 percent; and in universities it increased 22.9 percent.

PATENTS

TABLE 17.—U.S. PATENTS GRANTED TO U.S. INVENTORS, BY TYPE OF OWNER: 1961–84 [1]

By date of application	Year				
	All patents	U.S. corporations	U.S. Government	U.S. individual [2]	Foreign [3]
1961	NA	NA	NA	NA	NA
1962	NA	NA	NA	NA	NA
1963	NA	NA	NA	NA	NA
1964	NA	NA	NA	NA	NA
1965	42,205	30,155	1,426	10,475	149
1966	45,004	23,887	1,481	10,412	224
1967	44,153	32,040	1,562	10,313	238
1968	45,334	32,980	1,714	10,362	278
1969	46,388	33,664	1,813	10,601	310
1970	45,852	33,104	1,624	10,869	255
1971	45,854	32,627	1,595	11,105	257
1972	42,434	30,551	1,520	10,143	220
1973	42,738	30,539	1,386	10,602	211
1974	44,835	30,134	1,574	9,890	237
1975	42,208	30,309	1,491	10,233	175
1976	41,576	29,087	1,337	10,934	218
1977	40,721	28,433	1,168	10,875	245
1978	39,350	27,515	1,187	10,384	264
1979	38,241	26,793	1,061	10,107	280
1980 [4]	39,600	28,100	1,100	10,000	300
1981 [4]	39,800	29,000	1,300	9,300	300
1982 [4]	40,400	29,800	1,300	9,000	300
1983 [4]	37,900	27,900	1,300	8,400	300
1984 [4]	39,500	29,100	1,300	8,800	300

	By date of grant				
	All patents	U.S. corporations	U.S. Government	U.S. individual [2]	Foreign [3]
1961	40,154	27,383	1,460	11,233	79
1962	45,579	31,377	1,276	12,817	109
1963	37,174	25,722	1,017	10,358	77
1964	38,411	26,808	1,174	10,336	93
1965	50,332	35,698	1,522	13,032	80
1966	54,634	39,891	1,512	13,050	181
1967	51,274	36,745	1,726	12,634	169
1968	45,783	33,351	1,458	10,768	206
1969	50,395	37,073	1,806	11,299	217
1970	47,077	34,978	1,760	10,096	243
1971	55,984	41,025	2,124	12,585	250
1972	51,524	37,960	1,759	11,569	236
1973	51,504	36,852	2,069	12,346	227
1974	50,650	36,118	1,715	12,556	261
1975	46,717	33,432	1,888	11,183	214
1976	44,280	32,175	1,813	10,083	209
1977	41,485	29,566	1,484	10,249	186
1978	41,254	29,421	1,233	10,399	201
1979	30,081	21,146	960	7,806	169
1980 [4]	37,356	25,967	1,232	9,940	217
1981 [4]	39,223	27,623	1,115	10,243	242
1982 [4]	33,896	24,082	1,003	8,539	272
1983 [4]	32,871	24,036	1,043	7,562	230
1984 [4]	38,364	27,972	1,224	8,888	280

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[1] NSF Science Indicators—1985, p. 259.

[2] Includes unassigned patents.

[3] Comprise patents assigned to foreign corporations, governments, and individuals.

[4] Data by date of application are estimates.

Patents serve as an indicator of the results of research and development activity. However, the use of patent data to indicate the state of industrial innovation must be tempered by various considerations. In the first place, all ideas which emanate from R&D work are not necessarily patentable. In other instances, a company or an individual might choose not to patent an invention to prevent disclosure of the idea or the scope of the work being undertaken. Some industries do not typically utilize the patent system because of the rapid pace of technological change which makes it difficult to obtain a timely patent and which limits the usefulness of the patent once granted.

Patent data has been collected two different ways; patents granted by date of the grant and patents granted by date of application. Of the years studied here, 1971 showed the highest number of patents issued measured by the date of the grant. Since that time there has been a general downward trend. The number of patents granted in 1984 was 31 percent less than the 1971 figure. However, measuring the number of patents awarded by date of application tends to provide a more accurate indication of when an invention was conceived since the amount of time necessary to process the application varies. According to the available data, the number of patents awarded by date of application peaked in 1969 and tended to decline after that. The number in 1984 was 15 percent less than the number awarded in 1969. Thus, regardless of the type of measurement utilized, it remains clear that the number of U.S. patents issued to U.S. inventors has been declining.

III. INTERNATIONAL INNOVATION INDICATORS

In the earlier report of the House Committee on Ways and Means, it was found that while the United States had the highest absolute levels with respect to many input and output indicators of innovation, the other industrialized nations, especially Japan and West Germany, had growth rates ". . . higher than that of the United States, so they appear to be making gains." [18] This section will explore what has happened with these indicators since the 1980 conclusions were made. The analysis of these data follows in Chapter V.

RESEARCH AND DEVELOPMENT EXPENDITURES

Total National Funding for R&D

TABLE 18.—NATIONAL EXPENDITURE ON RESEARCH AND DEVELOPMENT [1] BY COUNTRY AND SOURCE OF FUNDS: 1970, 1975, 1979, 1981 AND 1983 [2]

[Million constant 1972 dollars] [3]

Country and source	1970	1975	1979	1981	1983
United States	28,613	28,153	33,612	36,728	40,092
Domestic sources	28,613	28,153	33,612	36,728	40,092
Business Enterprises	11,421	12,579	15,959	18,375	20,081
Government	16,316	14,537	16,407	17,087	18,646
Nonprofit	370	429	512	498	524
Universities	506	608	734	780	841
From abroad	NA	NA	NA	NA	NA
Japan	6,127	8,348	10,658	13,174	15,457
Domestic sources	6,066	8,184	10,643	13,160	NA
Business Enterprises	3,584	4,815	6,273	8,205	NA
Government	1,772	2,478	3,134	3,549	NA
Nonprofit	22	58	38	92	NA
Universities	688	833	1,197	1,314	NA
From abroad	5	9	8	14	NA
West Germany	5,040	6,077	7,619	8,024	8,332
Domestic sources	4,985	5,975	7,480	7,947	NA
Business Enterprises	2,689	3,047	4,222	4,574	NA
Government	2,288	2,884	3,236	3,341	NA
Nonprofit	8	44	21	33	NA
Universities	0	0	0	0	NA
From abroad	55	103	140	76	NA
France	3,652	4,192	4,875	5,490	6,025
Domestic sources	3,608	4,134	4,621	5,207	NA
Business Enterprises	1,334	1,637	2,103	2,241	NA
Government	2,194	2,314	2,059	2,060	NA
Nonprofit	5	10	29	50	NA
Universities	74	173	430	857	NA
From abroad	44	57	253	282	NA
United Kingdom [4]	4,188	4,862	4,676	5,828	5,716
Domestic sources	4,003	4,621	4,390	5,436	5,405

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[18] Some indicators of the State of U.S. Industrial Innovation, op. cit., p. 34.

TABLE 18.—NATIONAL EXPENDITURE ON RESEARCH AND DEVELOPMENT [1] BY COUNTRY AND SOURCE OF FUNDS: 1970, 1975, 1979, 1981 AND 1983 [2]—Continued

[Million constant 1972 dollars] [3]

Country and source	1970	1975	1979	1981	1983
Business Enterprises	1,776	1,859	1,977	2,402	2,400
Government	2,147	2,657	2,288	2,864	2,832
Nonprofit	50	65	78	106	104
Universities	30	39	47	64	68
From abroad	184	240	286	390	312

[1] Gross expenditures for performance of R&D including associated capital expenditures, except for the United States where total capital expenditures data are not available.

[2] NSF Science Indicators—1985, p. 191.

[3] Currency conversions based on purchasing power parities. GNP implicit price deflators used to convert current dollars to constant 1972 dollars.

[4] United Kingdom data for 1970 are for fiscal year 1969/1970, and 1979 for fiscal year 1978/1979.

TABLE 19.—AVERAGE ANNUAL RATES OF INCREASE [1] IN NATIONAL R&D EXPENDITURES: 1963–79 [2]

Country	Period I	Percent	Period II	Percent	Period III	Percent	Period IV	Percent
United States	1964–70	1.7	1970–73	0.5	1973–79	2.0	1979–83	4.5
Japan	1963–69	13.9	1969–73	11.6	1973–79	5.9	1979–82	10.0
West Germany	NA	NA	1969–73	8.0	1973–79	3.9	1981–83	2.2
France	1963–69	9.9	1969–73	2.2	1973–79	3.4	1979–83	5.2
United Kingdom	1964–69	2.4	1969–72	.1	1972–78	2.9	NA	NA

[1] At 1975 prices.

[2] NSF Science Indicators—1982. p. 192, and OCED Selected Science and Technology Indicators 1979–1983. p. 13.

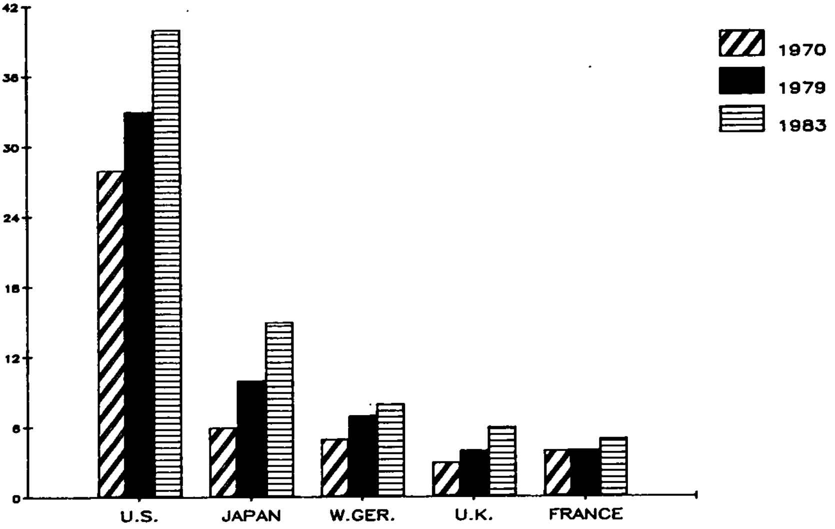
In absolute terms, the United States spends more money on research and development than any of the other western industrialized nations. In 1983, Japan's total R&D expenditure was approximately 39 percent of the U.S. total, while West Germany spent only 21 percent of the amount expended by the United States. Prior to 1979, the other western industrialized countries had larger increases in the average annual rate of growth of national R&D spending (with the exception of the United Kingdom in the period between 1969 and 1972) than the United States. Since then, the United States has demonstrated a larger average annual rate of growth than both West Germany (a reversal of the situation in the 1970s) and the United Kingdom, although this growth rate is less than half of that experienced in Japan.

The most recent figures (through 1983) show that the rate of growth of R&D expenditures in the United States has increased over that of the other time periods studied. France, Japan, and the United States all had larger rates of growth in the years since 1979 than they did between 1973 and 1979. The United Kingdom and West Germany had lower growth rates in recent years than they did during the 1970s. (See Figure 3.)

FIGURE 3

NATIONAL EXPENDITURE ON R&D

(Million constant 1972 dollars)



However, it should again be noted that increased spending for research and development does not necessarily result in parallel increases in innovation. An additional consideration in analyzing the importance of national R&D totals as an indicator of innovation is that raised by Harvey Brooks who found that because technology flows easily across borders, the commercialization of the results of R&D may only be "weakly related" to national levels of research and development.[19]

R&D/GNP Ratio

TABLE 20.—NATIONAL EXPENDITURES FOR PERFORMANCE OF R&D AS A PERCENT OF GROSS NATIONAL PRODUCT [GNP], BY COUNTRY: 1961–85 [1] [2]

Year	France [3]	West Germany	Japan	United Kingdom	United States
1961	1.37	NA	1.39	2.47	2.73
1962	1.47	1.25	1.47	NA	2.73
1963	1.55	1.41	1.44	NA	2.87
1964	1.82	1.57	1.48	2.30	2.96
1965	2.00	1.72	1.52	NA	2.89
1966	2.07	1.81	1.46	2.32	2.88
1967	2.12	1.96	1.52	2.30	2.89
1968	2.08	1.98	1.60	2.26	2.82
1969	1.93	1.82	1.64	2.27	2.71
1970	1.92	2.06	1.85	NA	2.63

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[19] Brooks, Harvey. Technology as a Factor in U.S. Competitiveness. In: Scott, Bruce R. and George Lodge, eds. U.S. Competitiveness in the World Economy. Boston, Harvard Business School Press, 1985. p. 343.

TABLE 20.—NATIONAL EXPENDITURES FOR PERFORMANCE OF R&D AS A PERCENT OF GROSS NATIONAL PRODUCT [GNP], BY COUNTRY: 1961-85 [1] [2]—Continued

Year	France [3]	West Germany	Japan	United Kingdom	United States
1971	1.90	2.18	1.85	NA	2.48
1972	1.90	2.20	1.86	2.11	2.40
1973	1.77	2.09	1.90	NA	2.31
1974	1.79	2.13	1.97	NA	2.29
1975	1.80	2.22	1.96	2.19	2.27
1976	1.78	2.15	1.95	NA	2.27
1977	1.76	2.14	1.93	NA	2.23
1978	1.76	2.24	2.00	2.24	2.22
1979	1.81	2.40	2.09	NA	2.27
1980	1.84	2.42	2.22	NA	2.38
1981	2.01	2.49	2.38	2.41	2.43
1982	2.10	2.58	2.47	NA	2.58
1983 (preliminary)	2.15	2.57	2.61	2.24	2.62
1984 (estimate)	2.22	NA	NA	NA	2.62
1985 (estimate)	2.27	NA	NA	NA	2.70

[1] NSF Science Indicators—1985, p. 187.

[2] Gross expenditures for performance of R&D including associated capital expenditures except for the United States where total capital expenditure data are not available. U.S. estimates for the period 1972-1980 show that the inclusion of capital expenditures would have an impact of less than one tenth of one percent of the R&D/GNP ratio.

[3] Gross domestic product.

Although the United States spends more for research and development in absolute dollar amounts, a comparison of R&D to the gross national product can provide insight into differences in how the western industrialized countries allocate their resources for such activities. The ratio provides a relative measure of each country's spending for R&D as a portion of the country's total expenditures. However, the potential limitations of utilizing a R&D/GNP ratio discussed previously should be acknowledged again. Because the GNP includes the service sector which is relatively large in the United States and which has tended not to be R&D intensive, it has been argued that the R&D/GNP ratio gives an inaccurate picture of the U.S. effort in research and development.

In 1961, the United States had the highest R&D/GNP ratio of all the western industrialized countries. By 1978 both West Germany and the United Kingdom had higher ratios. In 1983 the United States reestablished the largest ratio of research and development to gross national product. This is due to increased defense spending in the United States. What is interesting, however, is the rate of growth in R&D as a percent of GNP. In the years between 1978 (when the U.S. ratio was at its lowest point) and 1983, the average annual rate of growth in R&D/GNP for the United States was 3.4 percent, 5.4 percent for Japan, 4.1 for France, and 2.8 percent for West Germany. There was no growth in the ratio in the United Kingdom.

TABLE 21.—ESTIMATED NONDEFENSE R&D EXPENDITURES AS A PERCENT OF GROSS NATIONAL PRODUCT [GNP], BY COUNTRY: 1971-85 [1] [2]

Year	France [3]	West Germany	Japan	United Kingdom	United States
1971	1.46	2.03	1.84	NA	1.68
1972	1.50	2.08	1.84	1.50	1.63

TABLE 21.—ESTIMATED NONDEFENSE R&D EXPENDITURES AS A PERCENT OF GROSS NATIONAL PRODUCT [GNP], BY COUNTRY: 1971-85 [1] [2]—Continued

Year	France [3]	West Germany	Japan	United Kingdom	United States
1973	1.38	1.94	1.89	NA	1.62
1974	1.43	1.98	1.96	NA	1.69
1975	1.46	2.08	1.95	1.41	1.68
1976	1.44	2.01	1.94	NA	1.68
1977	1.44	2.01	1.92	NA	1.67
1978	1.41	2.10	1.98	1.51	1.69
1979	1.42	2.27	2.08	NA	1.75
1980	1.43	2.30	2.21	NA	1.86
1981	1.51	2.38	2.37	1.72	1.87
1982	1.63	2.48	2.46	NA	1.94
1983 (preliminary)	1.69	2.47	2.60	1.61	1.91
1984 (estimate)	1.76	NA	NA	NA	1.86
1985 (estimate)	NA	NA	NA	NA	1.89

[1] NSF Science Indicators—1985, p. 190.

[2] Gross expenditures for performance of R&D including associated capital, except for the United States, where total capital expenditure data are not available. U.S. estimates for the period 1972-1980 show that the inclusion of capital expenditures would have had an impact of less than one tenth of one percent of the R&D/GNP ratio.

[3] Gross domestic product.

If government funding for defense-related research and development is excluded from the data, the R&D/GNP ratio information is quite different. Both West Germany and Japan have higher ratios than the United States. In 1983, West Germany's ratio of civilian R&D to GNP was 29 percent higher than that of the United States, and Japan's civilian R&D/GNP ratio was 34 percent larger. Within the time frame 1978-1983 (as used above), the average annual rate of growth of the R&D/GNP ratio was 2.6 percent in the United States, 3.2 percent in West Germany, 3.7 percent in France and 5.6 percent in Japan. (There was insufficient data on the United Kingdom to determine an accurate average annual increase but it was approximately 1.3 percent.)

Research and Development by Objective

TABLE 22.—DISTRIBUTION OF GOVERNMENT SUPPORT OF R&D BY NATIONAL OBJECTIVE,[1] BY COUNTRY: 1970–83 [2]

Objective	United States				Japan [3]			West Germany				France			United Kingdom			
	1971	1975	1980	1983	1975	1980	1983	1970	1975	1980	1983	1975	1980	1983	1970	1975	1980	1983
Defense and aerospace	75.3	67.5	63.7	...	19.5	16.8	...	41.8	29.4	24.4	...	45.6	49.3	...	NA	63.2	64.8	...
Defense	52.2	50.8	47.3	64.3	4.7	4.9	2.4	29.5	19.2	15.3	9.4	32.8	40.1	33.2	72.3	52.8	59.4	50.0
Space	19.6	14.5	14.5	5.5	14.8	12.0	5.8	8.8	7.4	6.6	4.3	6.1	6.8	4.4	3.3	2.5	2.3	1.9
Civil aeronautics	3.6	2.1	1.9	...	...	...	...	3.5	2.9	2.4	...	6.8	2.4	...	NA	7.9	3.1	...
Agriculture and industry	2.5	2.5	3.0	...	41.9	37.6	...	10.9	13.2	15.3	...	13.1	12.2	...	NA	8.2	8.3	...
Agriculture	2.0	2.2	2.7	...	27.7	25.4	...	3.5	3.3	2.9	...	4.2	4.3	...	4.2	4.8	4.5	...
Industrial growth	.6	.3	.3	...	14.2	12.2	...	7.4	9.9	12.4	...	8.9	7.9	...	NA	3.4	3.8	...
Energy and Infrastructure	6.6	10.9	14.2	...	22.9	34.4	...	23.4	25.9	30.9	...	17.6	16.0	...	16.0	10.3	10.1	...
Production of energy	3.6	7.2	11.4	6.6	16.0	26.2	12.5	18.8	18.3	20.9	16.9	9.4	8.3	7.1	12.3	7.1	7.3	5.4
Transport, telecomms.	1.1	1.2	.9	...	3.9	2.9	...	...	2.5	3.2	...	3.3	3.0	...	1.4	.7	.7	...
Urban and rural planning	.4	.5	.4	...	1.2	2.3	...	.8	1.9	5.7	...	1.6	1.5	...	1.9	1.8	1.1	...
Earth and atmosphere	1.5	2.0	1.6	...	1.8	2.9	...	2.8	3.1	4.3	...	3.3	3.3	...	.5	.8	1.0	...
Health and welfare	12.2	14.8	15.2	...	12.1	11.2	...	8.6	15.9	15.3	...	6.5	7.5	...	4.1	4.1	3.9	...
Environmental protection	.9	.9	.8	...	3.2	3.4	...	.6	1.7	3.1	...	.9	1.2	...	.7	.6	.9	...
Health	8.7	11.9	12.1	11.5	6.3	6.1	2.6	3.5	5.6	9.3	4.1	4.4	4.9	4.3	2.3	2.3	1.8	1.3
Social development and services	2.6	2.1	2.3	...	2.5	1.7	...	4.5	8.5	6.0	...	1.2	1.4	...	1.1	1.2	1.2	...
Advancement of knowledge	3.3	4.3	4.3	...	3.5	4.1	...	15.3	15.7	14.2	...	17.1	15.0	...	NA	14.1	12.9	...
Total specified R&D funding	100.0	100.0	100.0	...	100.0	100.0	...	100.0	100.0	100.0	...	100.0	100.0	...	100.0	100.0	100.0	...

[1] Excluding general university funds (G.U.F.)
[2] NSF Science Indicators—1982. p. 195, and NSF International Science and Technology Update 1985. p. 8.
[3] Government intramural expenditure only.

The manner in which the Government spends its research and development funds has an impact on the type and extent of innovation as discussed previously. In the United States, the major portion of Federal R&D money is for defense-related activities—64.3 percent in 1983. The same is true in the United Kingdom where over one half of government R&D expenditures are for defense. Both Japan and West Germany have a significantly lower portion designated for military R&D. The available information shows that in Japan, government funding in this area has decreased from 4.7 percent of the total in 1975 to 2.4 percent in 1981. In West Germany the decrease has been from 29.5 percent in 1970 to 9.4 percent in 1983. Similarly, government expenditures for defense-related research and development as a percent of the total R&D funding has decreased in the United Kingdom from 72.3 percent in 1970 to 50 percent in 1983. In contrast to the declines in these countries, the United States has seen increases in government defense-related R&D as a proportion of total R&D from 52.2 percent in 1971 to 64.3 percent in 1983 (and to a larger portion through 1986). France has also shown a small increase from 32.8 percent in 1975 to 33.2 percent in 1983.

INDUSTRIAL RESEARCH AND DEVELOPMENT

Indicators of activity within the industrial sector provide information on innovation for commercial markets. As noted previously, research has shown that industry and firm R&D is closely related to productivity and economic growth in that industry or company. In addition, research has demonstrated that successful innovations are generally those which result from market demand and industry activity is typically geared to the marketplace.

Industry Financing of National R&D

TABLE 23.—PROPORTION OF NATIONAL R&D EXPENDITURES FINANCED BY INDUSTRY: 1970, 1982, AND 1983 [1]

[In percent]

Country	1970	1982	1983
Japan	59	64	64
West Germany	53	57	58
United States	38	51	50
France	37	40	42
United Kingdom	42	[2] 41	NA

[1] NSF International Science and Technology Update, 1985. p. 10.

[2] 1981.

Note.—The preponderance of the remaining non-private funding of R&D is accounted for by the Governments of these countries.

Since it has been demonstrated that industrial research and development are closely tied to economic growth and productivity at the industry and the firm level, it might then be expected that the greater the industrial involvement in the national technological enterprise, the greater the potential for expanded innovation. As shown in Table 23, in both Japan and West Germany industry plays a larger role in the national R&D endeavor than in the United States. It should be noted that in all the countries studied, with the exception of the United Kingdom, the portion of industrial involvement in R&D has increased in the years between 1970 and 1983. While Japan and West Germany have larger proportions of the national R&D effort financed by industry, the rate of growth between 1970 and 1983 for the United States was significantly higher. In the years from 1970 to 1983, there was a 31.5 percent increase in industry's contribution to the R&D activity in the United States. This compares with 8.5 percent increase in Japan, 9.4 percent in West Germany, and 13.5 percent in France. The United Kingdom showed a decrease of 2.4 percent between 1970 and 1981.

Industry R&D/GDP

TABLE 24.—GROSS DOMESTIC EXPENDITURES OF R&D PERFORMED IN THE BUSINESS ENTERPRISE SECTOR AS A PERCENTAGE OF GROSS DOMESTIC PRODUCT [1]

All fields of science	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
United States [2] [3]	1.83	1.71	1.66	1.61	1.61	1.57	1.58	1.56	1.55	1.60	1.71	1.77	1.94
Japan [4]	1.12	1.11	1.13	1.16	1.18	1.14	1.13	1.14	1.13	1.22	1.33	1.44	1.53
Germany	1.32	1.40	1.36	1.28	1.29	1.41	1.37	1.40	[5] 1.46	1.66	....	[6] 1.70	1.80
France [4]	1.06	1.07	1.08	1.03	1.06	1.08	1.07	1.06	1.05	1.08	1.11	1.18	1.21
United Kingdom	....	....	1.30	....	....	1.26	....	....	1.39	....	....	1.50	....

[1] OECD Science and Technology Indicators, Basic Statistical Series, Gross National Expenditure on R&D, GERD 1969–1982. p. 56–57.
[2] Includes depreciation.
[3] Excludes capital expenditure.
[4] Excluding SSH.
[5] Break in series.
[6] National estimate or projection.

The ratio of industrial research and development to the gross domestic product indicates the allocation of funding for R&D in terms of the total domestic expenditures of a country. Increases in the ratio demonstrate a larger expansion of the resources devoted to R&D relative to the growth of the GDP. The available data show that the United States had the highest ratio in 1982 followed by West Germany, Japan, the United Kingdom (in 1981), and France. It appears that the United States achieved the largest ratio in 1980.

After vascilation in the ratios in the early to mid 1970s, all the countries experienced growth in the industrial R&D/GDP ratio between 1978–1982. During this time span, Japan displayed the largest growth at 35.3 percent, with the United States behind with a 25.2 percent increase. The growth rate in West Germany was 23.3 percent, in France it was 15.2 percent, and in the United Kingdom it was 7.9 percent between 1978 and 1981.

Business Enterprise R&D/Domestic Product of Industry

TABLE 25.—INDUSTRIAL R&D EXPENDITURES AS A PERCENTAGE OF THE DOMESTIC PRODUCT OF INDUSTRY: 1967–83 [1]

[In percent]

Country and year	BERD [2]/DPI
United States:	
1967	2.49

TABLE 25.—INDUSTRIAL R&D EXPENDITURES AS A PERCENTAGE OF THE DOMESTIC PRODUCT OF INDUSTRY: 1967-83 [1]—Continued

[In percent]

Country and year	BERD [2]/DPI
1971	2.09
1975	1.93
1979	1.94
1980	1.97
1981	2.03
1982	2.19
1983	2.21
United Kingdom:	
1967	2.00
1971	1.73
1975	1.72
1979	1.87
1980	NA
1981	NA
1982	2.14
1983	1.93
West Germany:	
1967	1.28
1971	1.60
1975	1.65
1979	2.08
1980	NA
1981	2.15
1982	2.28
1983	2.28
France:	
1967	1.42
1971	1.34
1975	1.36
1979	1.37
1980	1.43
1981	1.53
1982	1.57
1983	1.58
Japan:	
1967	.84
1971	1.22
1975	1.28
1979	1.37
1980	1.49
1981	1.62
1982	1.72
1983	1.86

[1] NSF Science Indicators—1982. p. 201, and OECD Science and Technology Indicators Basic Statistical Series, Gross National Expenditure on R&D GERD, 1969-1982. p. 27.

Note.—Includes government funds for industry.

Because of the arguments surrounding the use of the R&D/GNP ratio, the ratio of industrial research and development to the value added may also be used to indicate how a country's resources are utilized in the industrial sector.[20] The ratio of total industrial R&D

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[20] According to the National Science Foundation, the domestic product of industry is the value added measure used by the Organization for Economic Cooperation and Development and is the sum of the value added by resident producers in industry. Source: Science Indicators 82. p. 10. Footnote 41.

expenditures (business enterprise R&D–BERD) to the domestic product of industry (DPI) measures the R&D intensity of the industrial sector within a nation. It provides data which tends to be less affected by the differences between countries regarding the constitution of the national economies and the variations in R&D intensity of the various component parts of these economies.

The 1983 data indicate that the ratio of total industrial R&D (including Government funding for industry) to value added was higher in West Germany than the United States, which in turn had a higher ratio than the United Kingdom, Japan and France. Since 1979, the R&D intensity of all the countries studied increased with the exception of the United Kingdom; 35.6 percent in Japan, 20.1 percent in the United States, 15.3 percent in France, and 9.6 percent in West Germany. However, looking at the long term, Japan and West Germany were the only countries which displayed a consistent rise in BERD/DPI since the 1970s.

Private Business Enterprise R&D

TABLE 26.—PRIVATE BERD AS A PERCENTAGE OF DPI [1]

	1979	1980	1981
France	.98	0.99	1.04
Germany	1.65		1.76
Japan	1.35	1.46	1.59
United Kingdom			1.31
United States	1.23	1.35	1.40

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[1] OECD Science and Technology Indicators, Basic Statistical Series, Recent Results, 1979–1983. p. 30.

As discussed previously, the ratio of industrial research and development expenditures (business enterprise R&D) to the domestic product of industry can be utilized as a measure of resource utilization in the industrial sector. It provides an indication of R&D intensity. The use of business enterprise R&D financed solely by the private sector (excluding Government contributions) in this ratio provides further information on how industry choses to use its own limited resources.

In 1981, West Germany had the highest ratio of private BERD to DPI, followed by Japan, the United States, the United Kingdom, and France. At that time, the ratio in the United States was approximately 80 percent of that of West Germany and 88 percent of that of Japan. The ratios of all countries have been increasing since the late 1970s through 1981. Between 1979 and 1981 the increases amounted to 17.8 percent in Japan, 13.8 percent in the United States, 6.7 percent in West Germany, and 6.1 percent in France. (There was insufficient information concerning the United Kingdom.)

Source of Funds for Industrial R&D

TABLE 27.—BUSINESS ENTERPRISE SECTOR DOMESTIC EXPENDITURES ON R&D BY SOURCE OF FUNDS (PERCENTAGES) [1]

	1970	1975	1980	1982
France:				
Business	64	64	70	71
Government	32	28	24	24
Japan:				
Business	99	98	98	98
Government	1	2	2	2
West Germany:				
Business	80	79	79	82
Government	18	18	18	17
United Kingdom:				
Business	63	62	......	[2] 61
Government	32	31	......	30
United States:				
Business	57	64	68	68
Government	43	36	32	32

[1] OCED Science and Technology Indicators, Basic Statistical Series Gross National Expenditure on R&D, GERD 1969–1982. pp. 136–137, 140–141, 174–175, 235–236, and 242–243.

[2] 1981.

The source of funds for industrial research and development activities may have some impact on what direction the work may take. If funding is predominantly generated from the private sector, the work should tend to reflect industry priorities often determined by market considerations. However, if a large portion of industry R&D is financed by the Government, the work performed may reflect government priorities which are not necessarily geared to the marketplace. For example, in 1983, 25 percent of U.S. Government funds for industry went to R&D in the area of electronics and 51 percent to aviation and missile development. This might be expected to have some influence on the scope and direction of industrial R&D activities.

In Japan, almost the entire industrial research and development budget is financed by the private sector (although the Government plays a major role in coordinating these financial resources). In West Germany, approximately 80 percent of industry funding is generated by private companies. The industrial sectors in the United States, France, and the United Kingdom are financed to a lesser extent by private funds thus resulting in a larger government share than in either Japan or West Germany. In 1982, industry funding in France and the United States comprised approximately 71 and 68 percent, respectively, of the industrial budget, up from the 1970 figures of 64 and 57 percent. The United Kingdom showed the only decline in the percent of industry contribution over the period of time studied.

PRODUCTIVITY

Productivity measurements provide an indication of the state of innovation in that research has shown that productivity growth in an industry or in a firm is directly and significantly related to the amount spent previously on R&D by that industry or company.[21] Productivity is the ratio of output to input; labor productivity is the ratio of output per man hour of labor. It is a measure of the way inputs, including labor, capital, and materials, are utilized to produce outputs of products or processes. Technological innovation is one factor which impacts on changes in productivity. Differences in productivity levels and rates of growth are not necessarily the result of technological advances. Other possible components of change include labor skills, production organization, substitution of capital for labor, and economies of scale.[22]

Levels of Productivity

TABLE 28.—GROSS DOMESTIC PRODUCT PER EMPLOYED PERSON [1] RELATIVE LEVELS: PURCHASING-POWER-PARITY EXCHANGE RATES [2]

Year	United States	Japan	France	West Germany [3]	United Kingdom
1950	100.0	16.6	41.2	37.0	57.8
1955	100.0	20.1	44.2	44.5	56.3
1960	100.0	25.6	52.3	55.7	58.3
1961	100.0	28.2	53.8	56.3	58.1
1962	100.0	28.7	55.1	56.4	56.3
1963	100.0	30.7	56.4	56.4	57.1
1964	100.0	33.3	57.6	58.4	57.5
1965	100.0	33.2	58.3	59.2	56.3
1966	100.0	35.0	59.0	61.5	55.6
1967	100.0	37.8	61.4	60.8	57.6
1968	100.0	40.9	62.0	62.9	58.9
1969	100.0	45.3	65.1	66.3	59.4
1970	100.0	49.5	69.2	69.4	61.5
1971	100.0	50.0	70.5	69.1	62.5
1972	100.0	52.9	72.4	70.4	61.7
1973	100.0	55.0	73.8	71.6	63.9
1974	100.0	56.1	77.7	74.9	64.9
1975	100.0	57.5	78.5	75.7	64.6
1976	100.0	58.8	80.3	78.9	66.3
1977	100.0	60.0	80.6	80.0	65.5
1978	100.0	61.9	82.8	81.5	67.1
1979	100.0	64.5	86.0	84.1	67.9
1980	100.0	67.5	87.6	85.4	67.6
1981	100.0	68.7	87.1	84.8	68.3
1982	100.0	71.0	90.0	86.6	71.6
1983	100.0	70.4	89.2	86.9	72.7
1984	100.0	72.0	89.0	86.9	70.8

[1] Bureau of Labor Statistics unpublished data.
[2] Relative productivity levels are sensitive to exchange rates.
[3] Data for the latest year are based on preliminary estimates.

To date, the United States has the highest levels of productivity measured by real gross domestic product per employed person. However, the other western industrialized nations are gaining on the United States. In 1965 Japan's productivity level was 33.2 percent of that of the United States, the United Kingdom was at 56.3 percent, France at 58.3 percent, and West Germany at 59.2 percent of the U.S. level. By 1984, Japan's productivity had reached 72 per-

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[21] How Economists See R&D, op. cit., p. 98.

[22] Technology Transfer, Productivity, and Economic Policy, op. cit., p. 109. Also: Some Indicators of the State of U.S. Industrial Innovation, op. cit., p. 24.

cent of the U.S. level, the United Kingdom was at 70.8 percent, France at 89 percent, and West Germany at 86.9 percent.

While all the countries studied have raised their level of productivity relative to the United States, the rates of increase slowed between 1980 and 1984. In the five years between 1975 and 1979, the average annual rate of productivity growth relative to the United States was 2.9 percent in Japan, 2.7 percent in West Germany, 2.3 percent in France, and 1.3 percent in the United Kingdom. Between 1980 and 1984, these average annual rates of growth had decreased to 1.7 percent for Japan, 0.4 percent in West Germany, 0.4 percent in France, and 1.2 percent for the United Kingdom.

Productivity Growth

TABLE 29.—PRODUCTIVITY GROWTH IN MANUFACTURING INDUSTRIES OUTPUT PER HOUR IN MANUFACTURING, TWELVE COUNTRIES: 1960–84 [1]

Year [2]	United States	Japan	France	West Germany	United Kingdom
1960	60.0	22.0	36.3	39.8	53.8
1961	61.6	24.9	38.4	41.9	54.0
1962	64.3	26.0	40.7	44.6	55.2
1963	68.9	28.1	42.7	46.7	58.1
1964	72.3	31.8	45.9	50.7	61.9
1965	74.6	33.1	49.0	53.9	63.9
1966	75.4	36.5	52.9	56.0	66.0
1967	75.3	41.9	56.1	59.5	69.2
1968	78.0	47.1	62.0	64.5	74.1
1969	79.3	54.5	65.6	68.9	75.9
1970	79.2	61.4	69.3	70.9	77.6
1971	84.0	65.3	73.1	73.5	81.4
1972	88.2	72.7	77.5	78.5	87.3
1973	93.0	80.2	82.0	83.4	93.1
1974	90.8	82.1	85.0	87.2	95.4
1975	93.4	85.3	88.4	89.8	94.5
1976	97.6	93.3	94.9	96.2	99.4
1977	100.0	100.0	100.0	100.0	100.0
1978	100.9	107.9	105.9	102.5	101.6
1979	101.6	117.4	110.6	107.4	102.1
1980	101.7	128.6	112.4	108.4	99.9
1981	104.9	135.7	116.0	110.3	106.1
1982	107.1	145.4	123.5	111.6	110.9
1983	111.6	152.8	128.8	116.8	118.3
1984	115.6	167.4	135.2	122.3	123.0

[1] U.S. Dept. of Labor, Bureau of Labor Statistics, June 1985.
[2] Preliminary estimates for latest year.

The productivity growth in manufacturing industries within the western industrialized nations is measured in Table 29. This is an index of output per man hour developed separately for each country and displays rates of change within each country. It does not permit comparisons between countries of actual productivity levels, but allows comparisons regarding rates and direction of change.[23]

In 1984, the United States had a manufacturing productivity level which was only 15.6 percent above what it was in the 1977 base year while Japan experienced growth of 67.4 percent. The increases in manufacturing productivity level in this time frame

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[23] Some Indicators of the State of U.S. Industrial Innovation, op. cit., p. 25.

were 35.2 percent in France, 23 percent in the United Kingdom, and 22.3 percent in West Germany.

TABLE 30.—MANUFACTURING PRODUCTIVITY AVERAGE ANNUAL RATES OF CHANGE: 1960–84 [1]

Country	1960–84	1960–73	1973–84	1973–81	1982	1983	1984
United States	2.6	3.0	2.0	1.7	2.1	4.3	3.5
Japan	9.0	10.7	7.3	7.3	7.1	5.1	9.5
France	5.7	6.7	4.6	4.8	6.5	4.3	5.0
West Germany	4.9	5.9	3.3	3.7	1.2	4.7	4.7
United Kingdom	3.5	4.4	2.3	1.4	4.6	6.7	3.9

[1] Bureau of Labor Statistics, 1985.

According to data provided by the Bureau of Labor Statistics, Japan had the largest average annual rate of increase in the years 1973–1984; the United States had the smallest. In 1984, Japan's 9.5 percent increase in manufacturing productivity growth led the other western industrialized countries followed by France with a five percent increase, West Germany with a 4.7 percent increase, the United Kingdom with a 3.9 percent increase, and the United States last with a 3.5 percent increase.

It is apparent that in the area of productivity the other western industrialized nations are gaining on the United States. Although in the past several years the rates of increase of the level of gross domestic product per employed person has declined from previous years, the other countries are steadily raising their level of productivity. In addition, in both 1983 and 1984, these nations have also increased their manufacturing productivity at rates greater than the United States (with the exception of France in 1983).

SCIENCE AND ENGINEERING MANPOWER

Science and Engineering Degrees Awarded

TABLE 31.—FIRST DEGREES CONFERRED BY HIGHER EDUCATIONAL INSTITUTION, 1970–82 [1]

[In thousands]

Year and country	All fields
1970	
United States	888.3
France	40.6
Japan	240.9
United Kingdom	51.2
West Germany	60.4
1975	
United States	987.9
France	NA
Japan	313.1
United Kingdom	54.1
West Germany	33.7
1980	
United States	1,010.8
France	52.2
Japan	378.7
United Kingdom	66.5
West Germany	46.3

TABLE 31.—FIRST DEGREES CONFERRED BY HIGHER EDUCATIONAL INSTITUTION, 1970-82 [1]—Continued

[In thousands]

Year and country	All fields
1981	
United States	1,019.2
France	NA
Japan	NA
United Kingdom	NA
West Germany	NA
1982	
United States	1,036.6
France	NA
Japan	382.5
United Kingdom	66.2
West Germany	50.6

[1] NSF Science Indicators—1985, p. 2.

TABLE 32.—TOTAL DOCTORAL DEGREES [1]

Year	United States	France [2]	West Germany	Japan	United Kingdom
1982	31,048	7,719	12,073	[3] 6,599	6,562
1983	[4] 31,253	7,264	13,637	7,233	[4] 6,291

[1] NSF, International Science and Technology Data Update, Jan. 22, 1985. p. 22, and unpublished data.

[2] Includes the 3'eme Cycle and Docteur Ingenieur degrees which are somewhat less than a PhD and the Docteur d'etat which is more than a PhD. France will grant one PhD level doctorate in the future.

[3] 1981.

[4] 1984.

Educational institutions in the United States granted the largest total number of first degrees awarded. However, the U.S. rate of growth experienced between 1970 and 1982 (24 percent) was less than any of the other nations with the exception of West Germany which saw a decline in the number of degrees conferred. Japan had the largest growth during this time period (59 percent). It also should be noted that in 1982, Japan had a larger number of students receiving engineering degrees (first level) than the United States.[24]

Less information is available concerning the number of doctoral degrees granted. However, as the available data in the table indicates, the numbers increased in the United States, Japan, and West Germany, with West Germany apparently experiencing the greatest gains. The number of degrees conferred in France and the United Kingdom declined. Again, institutions within the United States conferred the largest total number of degrees at the doctoral level.

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[24] Science Indicators—1985, op. cit., p. 192.

Scientists and Engineers Employed in R&D

TABLE 33.—SCIENTISTS AND ENGINEERS [1] ENGAGED IN R&D AND TOTAL LABOR FORCE POPULATION, BY COUNTRY: 1965–83 [2]

Country	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
Scientists and engineers (per 10,000 labor force population):																			
France	21.0	23.3	25.3	26.4	27.1	27.3	27.9	28.2	28.5	28.9	29.4	29.9	30.0	31.0	31.6	32.4	36.3	37.9	39.1
West Germany	22.7	22.4	24.9	26.2	28.4	30.8	33.4	35.6	37.1	37.8	38.6	39.2	41.8	NA	45.3	NA	46.8	47.8	NA
Japan	24.6	26.4	27.8	31.2	30.8	33.4	37.5	38.1	42.5	44.9	47.9	48.4	49.9	49.4	50.4	53.6	55.6	57.1	58.1
United Kingdom	19.6	NA	NA	20.8	NA	NA	NA	30.4	NA	NA	31.2	NA	NA	33.2	NA	NA	35.8	NA	NA
United States	64.7	66.9	67.2	68.0	66.9	64.4	61.0	58.3	56.8	56.1	55.8	55.8	56.4	57.2	58.4	60.7	62.7	64.6	66.2
Scientists and engineers (in thousands):																			
France	42.8	47.9	52.4	54.7	57.2	58.5	60.1	61.2	62.7	64.1	65.3	67.0	68.0	70.9	72.9	74.9	85.5	90.1	92.7
West Germany	61.0	60.0	64.5	68.0	74.9	82.5	90.2	96.0	101.0	102.5	103.7	104.5	111.0	NA	122.0	NA	128.2	131.4	NA
Japan	117.6	128.9	138.7	157.6	157.1	172.0	194.3	198.1	226.6	238.2	255.2	260.2	272.0	273.1	281.9	302.6	317.5	329.7	342.2
United Kingdom	49.9	NA	NA	52.8	NA	NA	NA	76.7	NA	NA	80.5	NA	NA	87.7	NA	NA	95.7	NA	NA
United States	494.5	521.1	534.4	550.4	555.2	546.5	526.4	518.3	518.3	525.1	532.7	546.3	568.2	594.2	622.0	658.7	691.4	723.0	750.0

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[1] Includes all scientists and engineers engaged in R&D on a full-time-equivalent basis (except for Japan, whose data include persons primarily employed in R&D excluding social scientists, and the United Kingdom, whose data include only the Government.

[2] NSF Science Indicators—1985, p. 180.

The United States continues to have the largest total number of scientists and engineers engaged in research and development. In 1983, the United States had over twice the number of scientific and engineering personnel than Japan and over eight times that of France. In 1982, the United States had almost six times the number of such employees as West Germany and almost eight times the number in the United Kingdom in 1981.

The trend in the United States has been one of growth in the total number of scientists and engineers since 1973. Between 1973 and 1983, the increase was 44.7 percent. During this time span, the Japanese have increased their number of employed scientists and engineers 51 percent and France displayed increases of 47.8 percent. The growth in skilled personnel in West Germany between 1973 and 1982 was 30 percent (compared to 39.5 percent in the United States for the comparable years).

Looking at the number of scientists and engineers in the context of the total labor force (per 10,000 work force population), the United States experienced a 20 percent decline from the high in 1968 to the low in 1976. In 1977, the number of scientists and engineers employed in R&D related work as a portion of the total work force level of the 1968 high point. The increase between 1976 and 1983 is 18 percent. This pattern differs from that of the other western industrialized countries which have shown a general trend of sustained growth in science and engineering manpower as a portion of the working population. From 1968, when the United States reached its highest concentration of R&D employment, to 1983, the United States decreased its science and engineering component of the labor force 2.6 percent. In contrast, the increase in Japan reached 86.2 percent and in France it was 48.1 percent during this time frame. Between 1968 and 1982 the number of scientists and engineers per 10,000 of the labor population employed in West Germany grew 82.4 percent and between 1968 and 1981 it increased 72.1 percent in the United Kingdom.

PATENTS

As noted previously, patents are used as an output indicator of innovation, although what they actually measure is invention. And even as an indicator of invention they are an inaccurate measure in that oftentimes inventions are not patented for a variety of reasons including timing, cost, and/or secrecy. In addition, patents do not indicate whether the idea eventually became an innovation nor do they provide any indication of the value of the idea itself.

Distribution of U.S. Patents to Foreign Nationals

TABLE 34.—U.S. PATENTS GRANTED TO INVENTORS FROM SELECTED COUNTRIES, BY DATE OF GRANT AND NATIONALITY OF INVENTOR: 1970–83 [1]

Country	1970	1971	1972	1973	1974	1975	1976
Total	64,429	78,317	74,810	74,143	76,278	72,002	70,226
United States	47,077	55,984	51,524	51,504	50,650	46,717	44,280
Foreign	17,352	22,333	23,286	22,639	25,628	25,285	25,946
West Germany	4,435	5,522	5,729	5,587	6,153	6,036	6,180

TABLE 34.—U.S. PATENTS GRANTED TO INVENTORS FROM SELECTED COUNTRIES, BY DATE OF GRANT AND NATIONALITY OF INVENTOR: 1970–83 [1]—Continued

Country	1970	1971	1972	1973	1974	1975	1976
Japan	2,625	4,029	5,151	4,939	5,891	6,352	6,543
United Kingdom	2,954	3,464	3,167	2,855	3,145	3,043	2,995
France	1,731	2,214	2,229	2,143	2,566	2,367	2,408
Switzerland	1,112	1,281	3,305	1,326	1,454	1,456	1,475
Canada	1,066	1,326	1,241	1,346	1,326	1,296	1,192
U.S.S.R.	218	333	356	382	492	421	426

Country	1977	1978	1979	1980	1981	1982	1983
Total	65,269	66,102	48,854	61,819	65,771	57,889	58,862
United States	41,485	41,254	30,081	37,356	39,223	33,896	32,872
Foreign	23,784	24,848	18,773	24,463	26,548	23,993	23,990
West Germany	5,537	5,850	4,527	5,747	6,252	5,409	5,423
Japan	6,217	6,911	5,251	7,124	8,388	8,149	8,794
United Kingdom	2,654	2,722	1,910	2,406	2,475	2,134	1,931
France	2,108	2,119	1,604	2,088	2,181	1,195	1,895
Switzerland	1,347	1,330	1,025	1,265	1,239	1,147	1,071
Canada	1,219	1,226	862	1,081	1,135	890	1,000
U.S.S.R.	394	412	354	460	373	209	222

[1] NSF International Science and Technology Update, 1985. p. 26.

Note.—U.S. patent counts for 1979 are unreliable because the Patent and Trademark Office did not have enough money in that year to print all approved patents.

The total number of U.S. patents granted declined between 1970 and 1983. While the number of U.S. patents granted to U.S. nationals declined 30 percent, the U.S. patents granted to foreigners tended to increase during most of this time span. In fact, there was a 38 percent increase between the number granted to foreigners in 1970 and those granted in 1983. The major cause of this increase was expanded U.S. patenting by Japanese nationals—an increase of 235 percent between 1970 and 1983.

Patterns of Patenting in Foreign Nations

TABLE 35.—PATENTS GRANTED IN SELECTED COUNTRIES BY NATIONALITY OF INVENTOR: 1966–81 [1]

Country	1966	1967	1968	1969	1970	1971	1972	1973
United States total	68,406	65,652	59,102	67,557	64,427	78,316	74,808	74,139
Granted to nationals	54,634	51,274	45,782	50,395	47,073	55,998	51,515	51,501
Granted to all foreigners	13,772	14,378	13,320	17,162	17,354	22,328	23,293	22,638
West Germany total	22,598	19,871	21,169	22,623	12,887	18,149	20,600	23,934
Granted to nationals	13,095	11,520	12,143	12,432	6,386	8,295	9,642	11,191
Granted to United States	3,733	3,406	3,804	4,483	2,882	4,393	4,575	4,949
Granted to all foreigners	9,503	8,351	9,026	10,191	6,501	9,854	10,958	12,743
U.S. patents as percent of foreigners	39.3	40.8	42.1	44.0	44.3	44.6	41.8	38.8
Japan total	26,315	20,773	27,972	27,657	30,878	36,447	41,454	42,328
Granted to nationals	17,373	13,877	18,576	18,787	21,403	24,795	29,101	30,937
Granted to United States	4,683	3,432	4,903	4,657	4,774	5,700	5,948	5,485
Granted to all foreigners	8,942	6,896	9,396	8,870	9,475	11,652	12,353	11,391
U.S. patents as percent of foreigners	52.4	49.8	52.2	52.5	50.4	48.9	48.2	48.2
United Kingdom total	37,272	38,999	43,038	38,790	40,995	41,554	42,794	39,844
Granted to nationals	NA	NA	NA	9,807	10,343	10,376	10,116	9,357
Granted to United States	14,117	13,676	12,588	12,678	12,728	12,682	13,001	11,717
Granted to all foreigners	NA	NA	NA	28,983	30,652	31,178	32,678	30,487
U.S. patents as percent of foreigners	NA	NA	NA	43.9	41.5	40.7	39.8	38.4

TABLE 35.—PATENTS GRANTED IN SELECTED COUNTRIES BY NATIONALITY OF INVENTOR: 1966–81 [1]—Continued

Country	1966	1967	1968	1969	1970	1971	1972	1973
France total	43,950	46,995	47,990	32,020	26,297	51,456	46,217	27,939
Granted to nationals	14,881	15,246	15,627	10,288	17,758	13,696	10,767	10,817
Granted to United States	9,807	10,911	10,794	6,943	5,664	11,973	11,206	5,047
Granted to all foreigners	29,069	31,749	32,363	21,732	8,539	37,760	35,450	17,122
U.S. patents as percent of foreigners	33.7	34.4	33.4	31.9	66.3	31.7	31.6	29.5
	1974	1975	1976	1977	1978	1979	1980	1981
United States total	76,275	71,994	70,236	65,269	66,102	48,853	61,827	65,770
Grantedto nationals	50,643	46,603	44,162	41,383	40,979	30,605	37,152	39,224
Granted to all foreigners	25,632	25,391	26,074	23,886	25,123	18,248	24,675	26,546
West Germany total	20,539	18,290	20,965	21,749	23,514	22,534	20,188	13,429
Granted to nationals	9,793	9,077	10,395	10,815	11,581	10,895	9,826	6,537
Grantedto United States	3,913	3,140	3,333	3,488	3,819	3,713	3,211	2,229
Granted to all foreigners	10,746	9,213	10,570	10,934	11,933	11,639	10,362	6,892
U.S. patents as percent of foreigners	36.4	34.1	31.5	31.9	32.0	31.9	31.0	32.3
Japan total	39,626	46,728	40,317	52,608	45,504	44,104	46,106	50,904
Granted to nationals	30,873	36,992	32,465	43,047	37,648	34,863	38,032	42,080
Granted to United States	4,432	4,918	4,029	4,884	4,014	4,625	3,968	4,371
Granted to all foreigners	8,753	9,736	7,852	9,561	7,856	9,241	8,074	8,824
U.S. patents as percent of foreigners	50.6	50.5	51.3	51.1	51.1	50.0	49.1	49.5
United Kingdom total	37,808	40,689	39,797	36,549	40,823	20,800	23,804	22,924
Granted to nationals	8,971	9,120	8,855	7,722	8,464	4,182	5,158	6,076
Granted to United States	10,976	11,497	11,024	10,420	11,690	5,951	6,726	6,234
Granted to all foreigners	28,837	31,569	30,942	28,827	32,359	16,618	18,646	16,848
U.S. patents as percent of foreigners	38.1	36.4	35.6	36.1	36.1	35.8	36.1	37.0
France total	24,725	14,320	29,754	31,045	30,530	24,618	28,060	21,477
Granted to nationals	9,282	4,962	8,420	8,361	8,083	6,846	8,438	6,855
Granted to United States	4,719	2,801	6,171	6,671	6,810	5,235	5,581	4,164
Granted to all foreigners	15,443	9,358	21,334	22,684	22,447	17,772	19,622	14,622
U.S. patents as percent of foreigners	30.6	29.9	38.9	29.4	30.3	29.5	28.4	28.5

[1] NSF Science Indicators—1982, p. 209.

Source: World Intellectual Property Organization, Industrial Property Statistics (Geneva, annual issues of 1967–1981).

Patents granted by other western industrialized countries to their nationals also have decreased with the marked exception of Japan. In West Germany, the yearly numbers have vascilated but were down 50 percent between 1966 and 1981. A similar situation existed in the United Kingdom and in France where between 1969 and 1981 the number of patents issued to nationals in the United Kingdom decreased 38 percent and between 1966 and 1981 the number declined 54 percent in France. The United States also showed a decline of 28 percent between 1966 and 1981. However, the data for Japan indicate a very different pattern. Japanese patents granted to nationals have increased 142 percent between 1966–1981, although there was not an increase in every year during this time period.

TABLE 36.—PATENT APPLICATIONS BY INVENTORS FROM SELECTED COUNTRIES

	France	West Germany	Japan	United Kingdom	United States
National Patent Applications [1] (the sum of domestic and foreign patent applications):					
1979	32,174	55,184	174,569	44,666	100,494

TABLE 36.—PATENT APPLICATIONS BY INVENTORS FROM SELECTED COUNTRIES—Continued

	France	West Germany	Japan	United Kingdom	United States
1980	27,989	51,345	191,020	41,612	104,329
1981	24,668	46,579	216,307	39,214	106,413
1982	22,242	47,826	235,324	37,093	109,625
Domestic Patent Applications [1] (applications in country A by residents of country A):					
1979	11,303	30,879	150,623	19,468	60,635
1980	11,000	30,314	165,730	19,612	62,098
1981	10,945	29,841	191,621	20,808	62,404
1982	10,681	30,668	210,897	20,530	63,316
Foreign Patent Applications [1] (applications in country A from abroad):					
1979	20,871	24,305	23,946	25,198	39,959
1980	16,989	21,031	25,290	22,000	42,231
1981	13,723	16,738	24,686	18,406	44,009
1982	11,561	17,158	24,427	16,563	46,309
External Patent Applications [2] (applications by residents of country A in other countries):					
1979	19,276	49,539	33,766	18,701	80,744
1980	18,839	48,650	35,945	17,400	79,078
1981	15,533	42,323	34,903	16,890	73,895
1982	15,498	38,985	36,901	16,144	65,335

[1] OECD Science and Technology Indicators, Basic Statistical Series, Recent Results 1979–1983. pp. 51, 52, and 53.

[2] NSF Science Indicators—1985, p. 195.

Additional information from reports of the World Intellectual Property Organization on international patent activity measured by date of application (as opposed to date of grant), while limited in their time frame (1979–1982), provide some additional insight. These data indicate that the Japanese were the most active in applying for patents. Japanese domestic patent applications were over three times that of the United States and they increased 40 percent between 1979 and 1982. During this time, the number of domestic patents applied for in France decreased 5.5 percent and 0.7 percent in West Germany. There were increased applications of 5.5 percent in the United Kingdom and 4.7 percent in the United States.

The United States had the largest increase (15.9 percent) in the number of applications for patents made by foreign nationals. While there was a two percent increase in the number of patents applied for in Japan by foreigners, all the other countries studies showed marked decreases in the number of foreign patent applications; down 44.6 percent in France, 34.3 percent in the United Kingdom, and 29.4 percent in West Germany. Most of this patenting activity can be attributed to increased activity on behalf of the Japanese. Information on external patent applications (applications made by residents in other countries) indicates that Japan was the only nation which displayed an increase in the number of patents applied for elsewhere by its own citizens.

Because patent requirements and procedures are different in each country, direct comparisons can not be made. However, it appears that the Japanese have demonstrated the greatest increases in patent activity both within a domestic context and within the United States. While this does not necessarily indicate that the Japanese are increasing their level of innovation, it does show that they are increasing the number of inventions they consider worthy of the patent protection they deem necessary if the ideas are to be developed for commercial use.

EAST ASIAN NICs AND SCIENCE AND TECHNOLOGY INNOVATION

Background

The East Asian Newly Industrialized Countries (NICs) have become a potent force in international trade and manufacturing. These East Asian NICs—South Korea, Taiwan, Singapore and Hong Kong—have been rapidly industrializing since 1965.[25] Overall, the net trade balance between the East Asian NICs and the United States doubled between 1965 and 1970; tripled between 1970 and 1975; and tripled again between 1975 and 1980.[26] Despite a recession in the early 1980s which slowed East Asian NIC exports worldwide, the East Asian NICs increased their export sales throughout the 1980s. This trade involves many basic commodities such as textiles, footwear, apparel, food, rubber, and petroleum, as well as a large segment of high technology commodities exported from the East Asian NICs to the United States.

The East Asian NICs have been able to achieve this high technology export growth over the last 25 years, generally, through selective and intelligent adaptation of new technology; through the growth of experienced and talented engineers, technicians and scientists; and through lower labor and manufacturing costs. This also includes large gains in the "low-tech" segment of high technology; those commodities which are high technology in nature but are assembled by unskilled labor. This path of growth is remarkably similar to the path taken by Japan to achieve domination in many high technology markets.[27] Yet policy and business leaders in Japan have recognized that adaptation or copying of existing technology will not continue to create new markets or increase high technology export shares. The Japanese Government has sought to create a trained and educated populace, domestic high technology transfer, economic and tax incentives, and an overall environment to foster new technological innovations. In certain fields, such as the semiconductor industry, this has become a reality.[28] In other fields, such as robotics, Japan has not only the world lead but is producing new applications. In 1983, Japan instituted the Technopolis program, in which 19 local districts and universities will be built into "mini Silicon Valleys." To date, 15 districts have applied for special status under the program, with the companies from the electronics industry prominent among the industries applying.[29] Many are asking whether other East Asian nations are fostering similar domestic high technology innovation; how far along they

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[25] South Korea is officially known as the Republic of Korea. Taiwan calls itself the Republic of China, although this is not recognized internationally.

[26] Hatter, Victoria. The Rising Trading Power of the East Asian NICs. U.S. Dept. of Commerce, 1985. p. 1.

[27] Berney, Karen. It Is No Longer Just Japan That Threatens U.S. Markets. ElectronicsWeek, Apr. 29, 1985. p. 49. An analysis of Japanese high technology trade is in chapter IV.

[28] Ibid., p. 52.

[29] Data from Mr. Ikeda Kaname, Science Counselor, Japanese Embassy. Washington, D.C. Feb. 13, 1986.

are; and whether this will pose a legitimate challenge to U.S. industrial innovation in the near future?

Education and Training

One of the barometers used among industrial nations to gauge domestic scientific and technological development is the quantity and quality of manpower training in a country. Specifically, this includes the number of university and graduate students; the fields they are entering into after graduation; and the types of journals or publications used by the scientific or technical community.

The data in this field are often incomplete and inconsistent. The United Nations UNESCO Annual Statistical Abstract contains valuable data on the level of university education attained in most countries; however, different years are used as reference points for the data, and Taiwan is not included since it is no longer recognized by the United Nations. Information from embassies is similarly inconsistent because different years are used as reference points in estimating increases in education and training. The National Science Foundation has completed some data collection on worldwide manpower and training in science and technology, but this is primarily among the industrialized nations.

Finally, the indicators for the rate of increase in the education and training of scientists and engineers; the number and quality of scientific papers they publish; and the occupations of post-graduate scientists and engineers, may demonstrate a rising level of knowledge and training for a specific nation. But there is no indication that such increases will directly result in innovative high technology products or processes. Other factors, including cultural and political factors, and economic and industrial incentives, also play a large role.

The data indicate that the number of students educated in science and engineering has greatly increased among the East Asian NICs, at the tertiary, or university, level; since the mid-1970s:

TABLE 37.—NUMBER OF UNIVERSITY LEVEL STUDENTS, FOUR EAST ASIAN NIC'S

	South Korea		Taiwan		Hong Kong		Singapore	
	1976	1982	1973	1984	1975	1982	1975	1982
Natural science	11,657	45,758	12,785	11,357	2,285	3,122	1,181	2,100
Math/computer science	3,379	19,433	NA	13,529	2,617	1,923	NA	NA
Medical science	31,748	65,824	19,851	34,340	816	2,121	841	1,102
Engineering	80,444	277,361	67,921	134,716	12,127	12,277	7,632	10,704
Total	127,228	408,376	100,557	193,942	17,845	19,443	9,654	13,906

Source: United Nations, UNESCO Annual Statistical Yearbook, 1979–1980, pp. 456–468; UNESCO Annual Statistical Yearbook, 1984, pp. 111–286, 111–304; and Republic of China Ministry on Education, Educational Statistics of the Republic of China, 1985, p. 108. and 1974, p. 114. NA—not available.

South Korea, with the largest population among the four East Asian NICs, has made the most significant increases in training university students in science and engineering, both in actual numbers and percentage increases. Of the data available among the four, Taiwan shows only a slight decrease in the number of natural science students at the university level, while Hong Kong has had a decrease in the number of math/computer science students.

Another statistical indicator of a country's development in science and technology would be an increase in the number of graduate students in science and engineering programs. These data would indicate the number of highly trained specialists in science fields to teach in universities; perform basic research and development in laboratories; or actively work in applied science in high technology industries. Unfortunately, cumulative data on the number of graduate science students in a particular country are not currently being recorded by the National Science Foundation, the United Nations, or any other United States or international organization. Some data are recorded by the specific countries; but only South Korea and Taiwan have tabulated these data in official publications. Again, both South Korea and Taiwan have shown increases in the number of domestic graduate students in science and engineering programs, although they are still significantly behind the United States.[30]

However, statistics are kept on the number of East Asian science and engineering doctoral students attending U.S. universities. The East Asian area showed the greatest increase of all regions in doctoral students going to the United States to study between 1960 and 1980. By 1980, East Asian countries represented 44 percent of all foreign doctoral students in the United States, led by engineering, biological sciences, and medical sciences.[31] It is uncertain, however, as to whether these students contribute significantly to their country's science and engineering community by returning home. The number of foreign students who apply for temporary or permanent work visas in the United States is incomplete because of the high non-response rate of foreign graduate students to this question.

Therefore, it is uncertain whether U.S. universities have created a "brain drain" of East Asian scientists and engineers, or whether they are a fertile ground for training scientists and engineers who return to East Asian NICs.[32]

Statistics on the number of scientific and engineering publications from each of the four East Asian NICs also indicate an increase in the amount of knowledge available to students in these fields. Again, these statistics do not include Taiwan; and the number of publications reflect only a quantitative count. That is, studies reflect the number of all publications, including general use textbooks, pamphlets, and journals. It does not distinguish between refereed or peer-reviewed, scientific publications and non-refereed publications. This is an important distinction because it is often in the qualitative, refereed publications that the leading-edge scientific discoveries are discussed. In terms of total scientific publications, South Korea, Singapore and Hong Kong have increased their overall production of mathematics, natural science, medical science,

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[30] Educational Statistics of the Republic of China, Taipei: Ministry of Education, 1985. pp. 114-115; and Introduction to Science and Technology in the Republic of Korea, 1984, Gwaechon: Ministry of Science and Technology, 1984. pp. 26-28.

[31] National Research Council. Summary Report 1980: Doctorate Recipients, National Academy of Science Press, 1985. pp. 9-15.

[32] Scientific Manpower Commission. The International Data Flow of Scientific Talent: Data, Policies and Issues. Washington: National Academy of Science, 1985. pp. 21-35.

and engineering publications.[33] Taiwan also has increased its total number of publications, in both scientific and technical conference papers and full papers, between 1981 and 1983.[34] More specific data on the number of qualitative scientific publications produced by the East Asian NICs would be instrumental in determining whether these nations have scientific communities and industries which are developing new and innovative ideas.

Another indicator is the number of scientific and technical personnel involved in research and development. Although teaching at the university and graduate level is crucial for developing the new generation of scientists and engineers, it is often (but not always) the laboratory scientist or engineer who performs the research which may lead to innovative new products.

TABLE 38.—NUMBER OF SCIENTISTS, ENGINEERS AND TECHNICIANS ENGAGED IN RESEARCH AND DEVELOPMENT, FOUR EAST ASIAN NIC'S

	South Korea		Taiwan		Singapore		Hong Kong	
	1977	1982	1980	1983	1975	1981	1978	1982
Scientists and engineers	12,771	28,488	13,656	18,580	635	724		
Technicians	9,315	11,663	13,483	11,313	448	535		
Total	22,086	40,111	27,139	29,893	1,083	1,259	967	

Source: United Nations, UNESCO Annual Statistical Abstract, 1978–1979, p. 732734 and UNESCO Annual Statistical Abstract, 1984, pp. V–35. For Taiwan, data are from the National Science Council, Republic of China, which follows the OECD definition of categorizing scientists and engineers as "researchers". The Taiwanese government does not include data for years before 1980. For Hong Kong, data are from the Committee for Scientific Coordination, Hong Kong; this committee was disbanded after its last report was issued in 1978.

Clearly, South Korea and Taiwan are the leading East Asian NICs developing a trained and skilled workforce, with South Korea experiencing the most rapid increase since the mid-1970s. But how do these countries fare compared to Japan, the most industrialized country in Asia, and the United States? In 1977, Japan had 407,192 scientists and engineers; by 1983, Japan had 496,145 scientists and engineers. Japanese technicians numbered 44,800 in 1977; by 1983, there were 93,326 technicians. The total in both categories for Japan are 494,975 in 1977, and 589,471 in 1983. For the United States, there were 560,000 scientists and engineers in 1977, and 707,000 in 1983. Unfortunately, neither the United Nations UNESCO Annual Abstract nor the National Science Foundation currently keep statistics on the total number of technicians currently working in the United States. The National Science Foundation does publish statistics on the number of technicians in manufacturing industries, but this does not include defense or university technicians.[35]

In summary, more quantitative and qualitative information on the education and training of scientists and engineers in the individual East Asian NICs is needed. It is particularly needed for the

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[33] United Nations, UNESCO Annual Statistical Abstract, 1978–1979. pp. 1021–1033 and UNESCO Annual Statistical Abstract, 1984. pp. VII–56—VII–66.

[34] Science and Technology Data Book 1983. Taipei: National Science Council, 1985. p. 53.

[35] The figures for scientists, engineers and technicians need to be placed into the context of the total population size for these countries, 1982: South Korea, 39.3 million; Taiwan, 19.2 million (1985); Singapore, 2.4 million; Hong Kong, 5.2 million; Japan, 118.4 million; and the United States, 232.0 million. Workforce population, which is used for statistical purposes elsewhere in this paper, are not tabulated by the United Nations UNESCO Annual Abstract.

number of domestic graduate and doctoral scientists and engineers who are trained at East Asian NIC universities; and for the number of quality, refereed science and engineering journals each country produces annually. Of the information on education and training which is available, South Korea leads all of the other East Asian NICs in training skilled scientists, engineers and technicians.

Infrastructure

In addition to the education and training of personnel, the climate of economic and industrial growth in an East Asian NIC also can contribute to the environment of innovation. Favorable tax policies, creation of industrial parks, and encouragement of joint ventures and cooperatives between domestic and foreign firms are just some of the incentives which may encourage development of innovative high technology products and processes. Among the four East Asian NICs, the approach towards establishing an innovative scientific and industrial community has varied from country to country. Yet the East Asian NICs are still classified as one region by many U.S. and international organizations.

SOUTH KOREA

Like the other East Asian NICs, South Korea has targeted several industries for development of technological innovation that will later translate into leadership in world export market shares. The South Koreans have specifically targeted the electronics industries, particularly the semiconducter, electronic components, and telecommunication components fields to develop new products and processes. The South Koreans have relied on technology transfer of 256 K semiconducter chips; component parts added to electronic goods such as VCR's to increase their total value; and telecommunications commodities, to encourage domestic industries to create new products. The South Koreans also have relied on licensing and joint ventures with other nations, stirring fears in Japan and the United States that a "boomerang" effect will occur as technology and knowledge is increasingly transferred to South Korea. The stated next step by the South Koreans is to develop a capability to create new high technology products and processes to compete internationally.[36] Patterned after the Japanese model of government and industry leaders mobilizing technology, capital, and labor, the South Koreans have initiated several major high technology projects. In 1982, the government instituted joint research projects between the private and public sector, with 31 projects singled out for subsidies, preferential credits, and other incentives. Most were in ten high technology fields, which are more fully described in chapter IV. The Korean Advanced Institute of Science and Technology (KAIST) was established in 1970 to increase the training of scientists and engineers for high technology industries.[37] Eight other national institutes and consortia have been formed since then to advance national industries, promote research and development in certain fields, and establish national standards

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[36] Ministry of Science and Technology. Introduction to Science and Technology. pp. 35–40.

[37] Ministry of Science and Technology. Introduction to Science and Technology. pp. 26–27.

in science and technology. Annual investment in national research and development projects in South Korea has grown from $24 million in 1982 to $50 million in 1985. Patent registration, both domestically and internationally, has gone from 1,251 in 1981 to an estimated 5,000 by 1986.[38] Daudek Science Town, an industrial park outside of Daejeon City, when fully completed by 1990, will contain 30 high technology institutions performing research and development.[39] Products targeted for development in South Korea during the 1990s are said to include state-of-the-art discrete memory chips, advanced fiber optic technology, and satellite components.

However, despite the recent activity in science and technology, South Korea still seriously lags behind the United States, the European Community, and Japan in competitive development of new high technology products. The push into greater research and development spending and the creation of industrial parks in the future may create a climate for innovativeness. However, the continued licensing of high technology products also may perpetuate a reliance on borrowing technology rather than innovating. Finally, cultural factors play a part in the climate of innovation. A work ethic which places emphasis on total commitment to a new technology may foster breakthroughs in that field, while in the same country, risk aversion may stifle innovativeness by inhibiting future risk-taking. It is still too early to determine which of these cultural factors will play a large role in South Korea.

TAIWAN

Taiwanese Government and business leaders are working to move Taiwan beyond the low-tech assembly of electronics, textiles, and shoes to development of new high technology products. Two recent projects have accelerated this movement.

The Hsinchu Science-Based Industrial Park outside of Taipei was established in 1980 and now houses 41 high technology companies.[40] Substantial financial incentives are provided for both domestic and foreign corporations which locate in Hsinchu Park. This includes elimination of duty import fees for machinery, raw materials, and supplies used in the Park; no commodity taxes on exports from the Park; and guaranteed full protection of patents, trademarks, and copyrights. Of the 49 companies currently in Hsinchu Park, 29 are Taiwanese companies.[41] The government hopes this demonstrates the potential for Taiwanese entrepreneurs as world-class competitors in high technology innovation, as well as alleviates the "brain drain" of trained scientists and engineers leaving for the United States and Japan.

The Industrial Technology Investment Corporation (ITIC) is another instrument for developing high technology industry and innovation. The ITIC provides funding, prototype testing and manufac-

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[38] Ministry of Science and Technology. Introduction to Science and Technology in the Republic of Korea, Gwaechon: Technical Cooperation Bureau, 1984. p. 22.

[39] Ministry of Science and Technology. Introduction to Science and Technology in the Republic of Korea. p. 34.

[40] Science-Based Industrial Park, Hsinchu: Science-based Industrial Park Administration, 1983. p. 14.

[41] Stokes, Bruce. Rising Trade Deficit, High-Tech Growth Are Threats to U.S.-Taiwan Relations, National Journal, Nov. 30, 1985. p. 2699.

turing facilities for industrial groups. The ITIC encourages and helps form joint ventures and cooperatives, and has aided in the creation of a Taiwanese industry in biocatalysis, scientific instrumentation and robotics. The ITIC, working with electronics groups like the Electronics Research and Service Organization, will select specific industries and technologies for assistance in developing new products.[42]

Taiwan, like South Korea, has more potential than actual development in creating new and innovative products and processes. Taiwan is counting on planned programs for developing innovative industries. But innovation may be an inadvertent result of basic research, end-use adaptation, or simply an accident. While Taiwan has trained people, built facilities and created economic incentives for encouraging growth of new industries, this is no guarantee of results in high technology products.

SINGAPORE AND HONG KONG

Singapore's targeted niche, as stated in the previous section, is computer software. Singapore's government is seeking to attract both foreign companies and funds by making its economic climate favorable for joint ventures and cooperatives in high technology industries. For example, the National Computer Board, a voluntary organization comprised of industry, government, and academia, has established a computer-training institute for software programmers and is creating joint ventures between Singapore software producers and U.S. and Japanese companies.[43] However, a severe shortage of domestic scientists, engineers, and trained technicians indicates that Singapore may more likely be an ally, rather than a competitor, to the United States and Japan.

Hong Kong is limited in resources to fully develop a high technology base to match the major industrialized nations. As one author noted, its political fate—the return of the colony to Chinese sovereignty in 1990—may further complicate its high technology future.[44] Its primary strength has been as a financial capital and as a source of value added and re-exported goods. Its overall spending on research and development is very small; at 0.24 percent of GNP, this is the lowest rate among all developing countries in East Asia.[45] Innovative product and process development have been left to foreign firms which locate in Hong Kong, and not planned by government policies.

Summary

In summary, South Korea and Taiwan have done the most among the East Asian NICs to develop an infrastructure for high technology innovation, particularly through the development of high technology centers. These centers are modeled after high technology centers in Japan and the United States, and are attempts to bring together industrial, government, academic and scientific re-

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[42] Industrial Technology Investment Corporation, Taipei: ITIC, 1985. pp. 1–4.

[43] Berney, Karen. The Four Dragons Rush to Play Catch-Up Game, ElectronicsWeek, May 6, 1985. p. 52.

[44] Ibid., p. 55.

[45] Ibid., p. 56.

sources in certain high technology fields. However, these developments in South Korea and Taiwan are more potential than actually realized at this point. Possible cultural factors, such as an aversion to risk, may further inhibit development of innovative high technology products or processes. It also is difficult to plan on innovation, because innovative products or processes may occur in a number of conditions; or may not occur no matter how much of a national priority is placed on innovation. Both Singapore and Hong Kong are unlikely candidates for leadership in science and technology innovation. Singapore may develop software innovations as part of its high technology niche, but currently is constrained by a lack of trained personnel. Hong Kong, because of its unique position, is more likely an ally than a competitor in worldwide high technology innovation.

IV. INTERNATIONAL TRADE

BACKGROUND

Trade between nations also is an indicator of innovation. It can demonstrate the ability of a nation to convert innovative high technology products and processes into commercial commodities and sell them on the world market. The United States had almost unparalleled success in industrial growth and world trade between 1945 and 1965, in part because of its ability to develop innovative products and to sell them all over the world. Similarly, most industrialized nations also have been able to develop new products and processes, sell these commodities abroad, and thereby enhance their balance of trade. However, a strong balance of trade is not synonymous with an innovative industrial base. There have been some nations, notably Japan in the early 1960s, which have successfully adopted existing technology (e.g., electronics or computers) and sold it at a lower price without being at the "cutting edge" of new technology. Many newly industrialized countries, currently adept at "reverse engineering" imported goods, now face the prospect of moving beyond copying technology and developing their own, indigenous and innovative products for world markets.

The U.S. dominance in world trade, unsurpassed from 1945–1965, has declined since the late 1960s. In some areas the United States has lost world market leadership; for example in automobiles, steel and clothing.[46] In other areas, such as computers, scientific instruments, drugs and pharmaceuticals, the U.S. lead has declined.[47] The U.S. trade balance among all of its leading trading partners has been affected by this change. The net trade deficit (exports minus imports) between the United States and Japan is the highest between any two countries in the world.[48] In 1984, this U.S. deficit rose to $36.8 billion, an increase of $15.1 billion from 1983.[49] Among the ten-member European Community (EC), the trade balance with the United States has changed significantly, growing from a U.S. deficit of $1.6 billion in 1983 to $13.3 billion in 1984.[50] The East Asian (South Korea, Taiwan, Singapore and Hong Kong) newly industrialized countries (NICs) are now the third leading trading partners with the United States, behind the EC. Although these four countries have a combined GNP of less than one-tenth of the European Community, U.S. imports from the East Asian NICs are almost two-thirds of EC imports, and the U.S. deficit with the

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[46] U.S. Dept. of Commerce. United States Trade: Performance in 1984 and Outlook, Washington: U.S. Dept. of Commerce, 1985. p. 14.

[47] Ibid., p. 17.

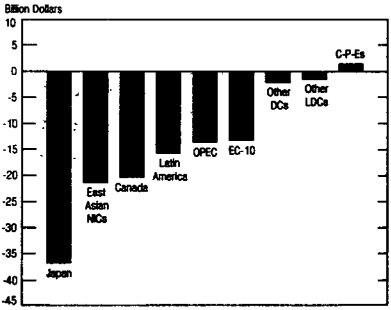
[48] See: Arlene Wilson. U.S. Trade Deficit: Data and Analysis. Congressional Research Service, Feb. 19, 1986, pp. 1-5, for an explanation of trade deficit and trade data.

[49] U.S. Dept. of Commerce. U.S. Trade: Performance in 1984 and Outlook, Washington, U.S. Dept. of Commerce, 1985. p. 20.

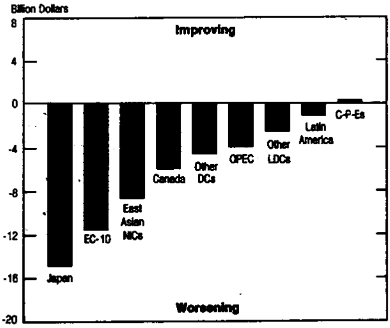
[50] U.S. Dept. of Commerce, United States Trade: Performance in 1984 and Outlook, p. 29.

East Asian NICs is two-thirds larger than with the EC.[51] The U.S. trade deficit with the East Asian NICs, as with Japan, also is worsening. As a group, the East Asian NICs doubled their 1983 trade surplus with the United States in 1984, which reached $21.4 billion.[52] Other countries also have significantly improved their trade positions with the U.S. Canada represents the United States' second most significant single trader behind Japan. The trade deficit with Canada was the second largest for the United States with any one single country in 1984, at $20.4 billion.[53] Other countries, such as Latin America, Africa, and members of the oil petroleum exporting countries (OPEC), generally represent trade to the United States of oil, petroleum products, some agricultural goods and rare minerals, while the United States exports manufactured goods and services.

U.S. TRADING-PARTNER BALANCES IN 1984



CHANGES IN U.S. TRADING-PARTNER BALANCES, 1983-84



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[51] Ibid., p. 21.
[52] Ibid., p. 23.
[53] Ibid., p. 25.

TABLE 39.—SHARE OF WORLD MAJOR INDUSTRIALIZED COUNTRIES HIGH TECHNOLOGY EXPORTS

[Percentage]

	1965	1970	1980	1981	1982 [1]
United States	28.4	28.3	24.6	27.2	26.7
Japan	7.2	11.6	15.1	18.2	17.2
Great Britain	12.2	9.9	11.3	9.5	9.8
West Germany	16.4	4.9	16.1	14.6	15.6
France	7.5	7.0	8.3	7.7	7.9

[1] Most recent year data is available.

Source: U.S. Department of Commerce, U.S. High Technology Trade and Competitiveness, 1985, p. 45.

HIGH TECHNOLOGY

Since 1965, high technology trade has ballasted the worsening U.S. trade imbalance, usually recording large enough trade surpluses to offset the growing deficits incurred in lower technology manufactures trade.[54] Generally, ten industries make up the high technology sector of manufactures:

Aircraft, engines and parts;
Communications equipment & electronic components;
Drugs and medicines;
Engines, turbines and parts;
Guided missiles, spacecraft and parts;
Industrial inorganic chemicals;
Office, computing and accounting machinery;
Ordnance and accessories;
Plastic materials; synthetic resins, rubber & fibers; and
Professional and scientific instruments

High technology commodities often represent the new frontier of scientific breakthroughs as embodied in commercial products. The United States has had the lead in high technology product development since the end of World War II, and since 1965, high technology has represented a substantial part of U.S. trade, accounting for 43 percent of exports and 25 percent of imports worldwide in 1984.[55]

The percentage of world shares for high technology exports has increased since 1965 for Japan, Great Britain and France (see Table 39). Japan has led all nations with the greatest percentage increase. However, these statistics, compiled by the U.S. Department of Commerce, do not include East Asian newly industrialized countries (NICs), which also have made large gains in recent years. Gains made by East Asian NICs are discussed later in this chapter. The U.S. high technology export shares are still the largest for any one country, higher than both Japan and West Germany.

However, U.S. high technology surpluses (exports minus imports) have begun to decline markedly in recent years, from the high of a $26.6 billion surplus in 1981 to $23.6 billion in 1982 and $18.8 billion in 1983.[56] In 1984, the surplus of U.S. high technology goods

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[54] U.S. Dept. of Commerce. U.S. High Technology Trade and Competitiveness. Washington: U.S. Department of Commerce, International Trade Administration, 1985. p. 5.

[55] U.S. Dept. of Commerce, United States Trade: Performance in 1984 and Outlook, p. 14.

[56] U.S. Dept. of Commerce, U.S. High Technology Trade and Competitiveness, p. 5. Adjusted to new 1984 SIC codes.

exported will only be $6.0 billion. For the first time, the United States ran a small deficit in high technology trade in the third quarter of 1984. Although the total U.S. share of high technology world exports has increased since 1965, a faster rising high technology import rate has offset this increase. Therefore, despite the fact that U.S. high technology exports grew by 9 percent in 1984, the value of imports in high technology products increased by 44 percent in 1984, offsetting this gain.[57] Over 65 percent of high technology exports in 1984 came from aircraft, engines and parts; communications equipment and electronic components; and office computing and accounting equipment. However, only in aircraft, engines, and parts has the United States retained a strong surplus position. In communications equipment and electronic components, the United States posted a $13.7 billion deficit in 1984, while in office computing and accounting equipment, the United States posted a $4.3 billion surplus, down from $5.3 billion in 1983 and $10 billion in 1982.[58] In other high technology areas, U.S. trade balances indicate significant drops in surplus levels from previous years.

TABLE 40.—U.S. HIGH TECHNOLOGY TRADE BALANCE

[In billions of dollars]

	Exp.	Imp.	Bal.	Exp.	Imp.	Bal.	Exp.	Imp.	Bal.	Exp.	Imp.	Bal.
		1965			1970			1980			1981	
United States	5.1	1.6 =	+3.5	10.6	4.5 =	+6.1	54.7	28.0 =	+26.7	60.4	33.8 =	+26.6
		1982			1983			1984			1985 [1]	
United States	58.1	34.5 =	+23.6	60.2	41.4 =	+18.8	65.5	59.5 =	+6.0	57.4	53.7 =	+3.7

[1] January–October.

Note: Exp. = Exports Imp. = Imports Bal. = Balance.

Source: U.S. Dept. of Commerce, International Trade Administration.

Japan

The United States imported a total of $60.3 billion in goods from Japan in 1984, of which $15.8 billion were high technology goods; this represented the third highest total of goods Japan exported after automobiles and telecommunications equipment.[59] Although the United States has retained the lead in exporting technology goods worldwide, Japan has been increasing its world share since displacing West Germany in 1981 as the number two exporter of high technology goods. Japan's overall share increase is due to three major high technology groups which have accounted for 80 percent of Japan's total high technology exports: communications and electronic equipment; professional and scientific instruments; and office and accounting machines.[60]

In communications equipment, Japan accounted for almost 47 percent of the total U.S. imports of radio and television communications equipment, including radio parts, television cameras and parts, sound and signalling apparatus, and cable television equip-

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[57] U.S. Dept. of Commerce, United States Trade: Performance in 1984 and Outlook, p. 15.

[58] U.S. Dept. of Commerce, United States Trade: Performance in 1984 and Outlook, p. 16; and U.S. Department of Commerce, U.S. High Technology Trade and Competitiveness, p. 16.

[59] U.S. Dept. of Commerce, United States Trade: Performance in 1984 and Outlook, p. 58.

[60] U.S. Dept. of Commerce, U.S. High Technology Trade and Competitiveness, p. 28.

ment. Although the United States retains its lead in newer product developments such as fiber optics, it is currently losing or has lost trade advantage with Japan in producing lower cost communication items, such as digital telephones and receivers.[61]

Electronic components consist of a wide variety of electronic parts, including semiconducters used in computers. The semiconducter is the basic component of all computers, in which memory is stored and in which electronic impulses are relayed as information. State-of-the-art technology includes the Dynamic Random Access Memory (DRAM) and the 32-bit memory microprocessor. Both of these technological developments have broadened the use of semiconducters in a variety of products, and the Japanese have continued to research and develop the DRAM and microprocessor while increasing their share of world and U.S. markets in semiconducter products. In 1984 alone the U.S.-Japanese semiconducter trade imbalance resulted in a $1.5 billion deficit for the United States. Japan accounted for 12 percent of the U.S. domestic use of semiconductors in 1984; the United States share of the Japanese market was negligible.[62] In addition, since 1980, sales of Japanese semiconducters have doubled in European markets, traditionally an important market for both U.S. and European producers.

Professional and scientific instruments include a wide variety of products such as industrial process and monitoring instruments, optical equipment, and medical testing instruments. From 1965–1982, the United States growth in exports of professional and scientific equipment grew at an average rate of 14.4 percent per year; from 1965–1982, Japanese growth was 21.8 percent, the highest among U.S. industrial competitors.[63] In 1984, U.S. imports of Japanese scientific equipment, which accounted for one-third of all imported instruments rose 44 percent over 1983. Overall the United States has maintained a surplus of exports of scientific equipment, although Japanese imports have reduced this surplus from $3.7 billion in 1980 to $2.9 billion in 1984.[64] The trend toward integration of computer technology and instrumentation has allowed many foreign competitors to carve out market niches; the Japanese success in semiconducter test equipment is a notable example.[65]

In office, computing, and accounting machines, Japan recorded the highest growth rate among major U.S. competitors. Japanese exports grew at an average rate of 31 percent from 1965–1982, with exports in office, computing and accounting machines growing from $48 million per year in 1965 to $4.8 billion in 1982.[66] Computers, their parts and related equipment accounted for three-quarters of the exports in this commodity grouping. The United States has historically enjoyed a trade surplus in computer products. However, the emphasis the Japanese government has placed on the computer industry is expected to make it increasingly difficult for the United States to gain further entry into Japanese markets for com-

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[61] U.S. Dept. of Commerce. 1985 U.S. Industrial Outlook, Washington: U.S. Dept. of Commerce, 1985. pp. 29-2 & 30-4.

[62] U.S. Dept. of Commerce, 1985 U.S. Industrial Outlook, p. 32-3.

[63] U.S. Dept. of Commerce, U.S. High Technology Trade and Competitiveness, p. 18.

[64] U.S. Dept. of Commerce, 1985 U.S. Industrial Outlook, p. 33-2.

[65] Ibid., p. 33-2.

[66] U.S. Dept. of Commerce, U.S. High Technology Trade and Competitiveness, p. 16.

puter sales.[67] The United States has been able to maintain its lead in this field in part by developing new products which integrate office automation with information systems. Japanese competition in duplicating machines, dictaphones, typewriters and other office machinery at the lower end of the technology scale in this commodity grouping continues to erode the U.S. global market share.[68]

Japan also has maintained large high technology market shares in other regions. It leads all industrial countries in high technology exports to European countries, Canada, and East Asia. Japan's exports in high technology, led by communications equipment and electronic components and office and computing machinery, have risen from 15.4 percent of all of its total exports in pressure internationally to 1965 to 29.2 percent in 1983.[69] Despite domestic markets which are increasingly opened to foreign imports, Japanese imports in the near future will probably continue to be raw materials, food, and petroleum, therefore keeping its high technology balance of trade surplus high.

European Community Countries

The development and export of high technology in the EC is led by three nations: West Germany, Great Britain and France.[70] Overall, the relative position of the EC has remained constant or has declined in many areas of high technology trade with the United States. West Germany, Great Britain and France lead the EC in world market shares of high technology exports.

WEST GERMANY

West Germany has generally ranked second or third worldwide in most high technology exports in the last twenty years. Communications equipment and electronic components are the leading high technology export commodities for West Germany with 1982 exports at $5.6 billion, third behind Japan and the United States.[71] West Germany has remained the world leader since 1965 in the development of plastic materials and synthetic resins, rubber and fibers. This includes various products of condensation, polymers and polymer by-products; synthetic resins; and some textile yards and threads. In 1982 West Germany had a 23.5 percent share of the world market in this commodity, or exports of $4.5 billion.[72] The U.S. share of plastics, synthetics and fibers was 12.5 percent in 1982, at $2.4 billion.[73]

In other high technology goods, West Germany's position has moved erratically. Since 1980, West Germany's share of world office computing and accounting machines has dropped sharply, due primarily to the entry and expansion of Japan into world and

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[67] Ibid., p. 16.

[68] U.S. Dept. of Commerce, U.S. High Technology Trade and Competitiveness, p. 16.

[69] U.S. Dept. of Commerce, United States Trade: Performance in 1984 and Outlook, p. 58.

[70] The other EC member countries are: Belgium, Denmark, Greece, Ireland, Italy, Luxembourg and the Netherlands.

[71] U.S. Dept. of Commerce, U.S. High Technology Trade and Competitiveness, p. 29.

[72] U.S. Dept. of Commerce, U.S. High Technology Trade and Competitiveness, p. 29.

[73] In relation to other high technology commodities, plastics, synthetics and resins was the seventh largest of the ten high technology export groups in 1982. U.S. Dept. of Commerce, U.S. High Technology Trade and Competitiveness, p. 21.

European markets. However, in exports of aircraft and parts group, it has raised its market share sharply since 1965, rising from a 3.5 percent of the world market to 16 percent of the world market.[74] West Germany retains strong world market shares in professional and scientific equipment; engines, turbines and parts; industrial inorganic chemistry (nitrogen, rare gases, nonmetallic oxygen compounds, radioactive isotopes, etc.); and ordnance and accessories (non-military arms, hunting and sporting ammunition and percussion caps).[75] Most of this trade is conducted with other European countries and the United States. West Germany continues to have a strong technological and industrial base for high technology commodities; however, its overall high technology trade position has declined relative to Japan since 1981.[76]

GREAT BRITAIN

The British have had a long and varied history in research and development in aircraft, electronics, communications, and synthetics. However, they have seen both their equivalent dollar share and world market share either declining or failing to improve over the last twenty years in eight of ten high technology fields. Only in guided missiles and spacecraft; and aircraft, engines and parts, has Great Britain maintained its competitive edge in world markets. Great Britain is the second largest supplier of guided missiles and spacecraft in the industrial world, and the third leading supplier of aircraft and parts.[77] Due to the classified nature of much of the guided missiles and spacecraft, and because the procedure used to estimate the exports of a specific country is "especially problematic",[78] analysis of this commodity group is difficult. However, Great Britain's participation in the North Atlantic Treaty Organization and the European Space Agency accounts for almost all of the sales within the European community.[79] In the field of aircraft and engine parts, Great Britain's participation in the European consortium of Airbus Industrie has accounted for greatly increased sales in Europe. The United States is still the leading exporter of aircraft engines and parts; however, its world market share has declined as both Great Britain's and France's have risen. Between 1965 and 1975, the United States aircraft engines and parts and exports climbed at an annual average rate of 18.2 percent. Since 1975, however, U.S. exports have risen by only 10.3 percent per year while competitors grew at a rate of 21.2 percent.[80] This competition was led by Great Britain followed by France and West Germany. In other high technology areas, Great Britain has remained fairly static or has lost market shares, including declines in drugs and medicines, plastic materials and synthetic, and industrial inorganic chemicals.

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[74] U.S. Dept. of Commerce, U.S. High Technology Trade and Competitiveness, p. 29.

[75] Ibid., pp. 16–29.

[76] U.S. Dept. of Commerce, United States Trade: Performance in 1984 and Outlook, p. 61.

[77] U.S. Dept. of Commerce, U.S. High Technology Trade and Competitiveness, p. 24.

[78] Ibid., p. 24.

[79] U.S. Dept. of Commerce, 1985 U.S. Industrial Outlook, p. 37–8.

[80] U.S. Dept. of Commerce, U.S. High Technology Trade and Competitiveness, p. 15.

FRANCE

French high technology exports totalled $15.9 billion in 1982, the most recent year the U.S. Department of Commerce has analyzed statistics on world high technology trade patterns. This accounted for 8.0 percent of its high technology industrial exports. This trade primarily has been with Western European nations and in European consortiums. Although French high technology trade has increased in all ten commodity fields since 1965, it remains a small percentage of total world trade; it reached a total dollar high of $16.7 billion in 1980, and in 1979 a percentage share high of 9.2 percent of all worldwide high technology trade in 1979.[81] From 1965–1982, French high technology sales as a share of the world market were strongest in plastics, synthetics, rubber and fibers; and industrial inorganic chemicals. However, French sales of these two commodities in 1982 totalled $1.8 billion in plastics, synthetics, rubber and fiber; and $2.0 billion in inorganic chemicals; each less than ten percent of France's 1982 sales.[82]

Other EC nations produced and exported high technology commodities, but they tended to be traded within EC members. The total percentage of world sales of these remaining EC nations is small, and the dollar value of these sales fall far below the world high technology leaders. The importance of the EC nations as a market for the leading high technology commodity producers is important, however. A reduction in U.S. sales in EC markets due to Japanese growth has hurt the United States in these markets. The growing interdependence of the EC nations in building consortiums in aerospace, defense, and transportation also may erode U.S. high technology sales there in the future.

East Asian Newly Industrialized Countries

The East Asian newly industrialized countries (NICs)—South Korea, Taiwan, Singapore and Hong Kong—have moved rapidly into head-to-head competition with the United States and other industrialized countries in manufactured goods. In particular, these NIC's have opened new markets in high technology and knowledge-intensive capital goods.[83] Increasingly, the United States has become an important export market for East Asian NIC high technology goods, although Japan has retained its role as chief exporter of manufactured commodities to the United States. High technology trade between the East Asian NICs and the United States have grown by nearly 25 percent every year since 1980, compared to gains of nearly 30 percent per year for Japan, but a 14 percent per year average with the rest of the world.[84] The trade impact from these four countries on the United States has been rapid and dramatic: U.S. high technology imports from the East Asian NICs grew three times as fast as U.S. exports to them during the 1980s.[85] Three high technology trade groups have dominated East

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[81] Ibid., pp. 31, 45 and 56.

[82] U.S. Dept. of Commerce, U.S. High Technology Trade and Competitiveness, p. 63 and 66.

[83] U.S. Dept. of Commerce, United States Trade: Performance in 1984 and Outlook, p. 63.

[84] Hatter, Vicky. East Asian Countries Play Key Role In Eroding U.S. High-Tech Trade Surplus. Business America, Sept. 2, 1985. p. 6.

[85] Ibid., p. 6.

Asian NIC trade with the United States: communications equipment and electronic components; office, computing and accounting machines; and professional and scientific instruments. These three product groups accounted for 98 percent of all U.S. high technology imports from the East Asian NICs in 1984.[86]

Although all of these countries have developed manufactured goods for export through low-cost, labor-intensive, and low technology assembly and site testing for high technology products, the East Asian NICs are not identical. U.S. high technology trade with Taiwan is the highest of the four, at $3.6 billion in 1984; imports between South Korea, Singapore and Hong Kong ranged between $2.4 and $2.6 billion each.[87] South Korea is looked upon as Japan's most serious competitor in semiconductors, while the Singapore and Hong Kong governments see themselves as collaborators rather than competitors with the industrial nations. Yet despite differences in economic strength, population sizes, education, government involvement in industrial planning and high technology market shares, U.S. Federal agencies have tended to regard these East Asian NICs, often along with Japan, as a regional market. Analysis of individual East Asian NICs high technology market shares has been scarce in recent U.S. Federal agency publications. [88]

SOUTH KOREA

South Korea is following the same high technology strategy which Japan followed to become a superpower—buying foreign technology, protecting technology latecomers, and creating joint ventures with leading world technology producers focusing particularly on electronic parts and components. This strategy has paid off as South Korea has expanded its exports of total electronic goods from $2.2 billion in 1981 to $4.2 billion in 1984, with $5.2 billion estimated for 1985.[89] Other high technology goods, such as communications equipment and drugs and medicines, also have grown since the early 1970s.

The government of South Korea has directly fostered the growth of the domestic semiconducter industry through its Semiconducter Industry Promotion Plan in 1982 and the Semiconducter Industry Fostering Plan of 1984 which has provided direct and indirect incentives for South Korean companies to enter this field. In 1968, semiconducter production in South Korea was $14.9 million; by 1983 this production was $860 million, growing at an average yearly rate of 31 percent.[90] Although most of this was in the labor-

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[86] Hatter, East Asian Countries Play Key Role in Eroding U.S. High-Tech Trade Surplus, p. 7.

[87] Ibid., p. 6.

[88] See Hatter, Victoria L. The Rising Trading Power of East Asian NICs. Washington, U.S. Dept. of Commerce, Oct., 1985. This study covers the overall trading patterns of the U.S. and East Asian NICs, which is dominated by many low technology goods such as textiles. For the purpose of this report, information on the East Asian NICs was obtained from Victoria Hatter, Office of Trade Investment Analysis, International Trade Administration, U.S. Dept. of Commerce (including Vicky Hatter, "East Asian Countries Play Key Role In Eroding U.S. High-Tech Trade Surplus, Business America, Sept. 2, 1985); Karen Berney, It Is No Longer Just Japan That Threatens U.S. Markets, ElectronicsWeek, Apr. 29, 1985 and Karen Berney, The Four Dragons Rush To Play Catch-Up Game, ElectronicsWeek, May 6, 1985.

[89] Korean Development Bank. Industry in Korea, 1984. Seoul: Korean Development Bank, 1985, p. 221, and Electronic Industries Association of Korea, Seoul, Korea.

[90] Ibid., p. 220.

intensive integrated circuit production, the government has placed new emphasis on discrete circuit production, which is more technology-oriented. Several of the largest semiconducter companies also have established licensing agreements to obtain "second-source" information on advanced semiconducter technology, as well as establishing corporate branches in Silicon Valley to further obtain U.S. technology. In addition, South Korean semiconducter companies have joined with Japanese firms in exchanging semiconducter technology through joint ventures.

South Korea also has accelerated its exports of electronic components, growing from $88 million in 1971 to $2.9 billion by 1983, at a rate of 36 percent and comprising 12 percent of the total export trade for South Korea.[91] Among these electronic components, consumer goods such as color televisions, black/white televisions, video recorders, sound recorders, and stereo equipment accounted for $1.2 billion in South Korean exports in 1983. Of component parts IC's, transistors, magnetic heads, cassette tapes, fixed capacitors and VTR tapes amounted to exports of $943 million in 1983. Other exports included telephones, telephone exchangers, and transceivers, slightly under $100 million during 1983. South Korea also has begun to develop a joint venture program with a U.S. company to develop fiber optics for both domestic and international markets. In office, computing, and accounting machinery, South Korean exports of computers, negligible as recently as 1979, were worth $35 million to South Korea in 1983.[92]

The United States is the leading recipient of high technology trade from South Korea. As its largest customer, it received 36.1 percent of South Korean high technology exports in electronic parts and components in 1983.[93] In communications equipment and office, computing and accounting machines, South Korea ranks second to Taiwan among East Asian NICs providing imports for the United States. Rapid increases in the world high technology markets have been achieved primarily through cutting labor and manufacturing costs in producing goods. Joint ventures and licensing with other countries, primarily the United States and Japan, may create a situation where the most innovative technology starts to flow into South Korea for domestic high technology production.

TAIWAN

Taiwan's high technology trade policy has focused on developing a post-industrial society in which lower-end technology goods are replaced by high technology commodities. This means moving beyond exports in shoes, textiles, wine, beer and cigarettes into high technology electronic goods parts and components. Taiwan has now become the leading high technology trader among the East Asian NICs and the United States, particularly through the use of trading by U.S. subsidiaries and affiliates. Taiwan also has attempted to establish domestic centers to advance from lower technology assembly and manufacture of goods to the provision of services and information in high technology.

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[91] Ibid., p. 190.

[92] Ibid., pp. 191-192.

[93] Korean Development Bank, Industry in Korea, 1984, p. 192.

One of the major thrusts in this effort was the establishment five years ago of the 5,000 acre Hsinchu Science-Based Industrial Park, which houses 49 companies, including eleven U.S. firms. It is the aim of the Taiwanese government that this "Silicon Plateau" will conduct research and development, train domestic talent, employ them, and develop commercial technology for export.[94]

Three high technology categories dominate Taiwanese exports: communication equipment and electronic components; office, computing and accounting machinery; and professional and scientific instruments. Taiwan's primary market for exports is the United States; however, its market shares in both the communication equipment and electronic components, and in professional and scientific instrumentation to the United States, declined between 1980 and 1984. In part, this reflected the entrance of new East Asian NICs such as Indonesia and Malaysia, with cheaper labor costs, into these fields. In communications equipment and electronic components, Taiwan exported $2.3 billion in 1984, the largest of all of the East Asian NICs.[95] Among the individual product groups within the communications equipment and electronic components groups, Taiwan was the leading East Asian NIC exporter to the United States of consumer electronics and communications equipment, although U.S. imports from South Korea and Hong Kong have grown at a more rapid pace than those from Taiwan.[96] These exports to the United States included discrete 64K memory semiconductors among the electronic components exported, and low-end communications equipment such as telephones, switchboards and walkie-talkies.[97] In office, computing and accounting machinery, the United States imported over $791 million worth of goods in 1984. Taiwanese goods in this commodity group include microprocessing designs for microcomputers, and production of floppy disk drives, printers, and terminals.[98] The Taiwanese government also is encouraging production of software for world markets. In scientific and professional instrumentation, Taiwanese exports to the United States rose to $330 million in 1984, although this amount represented only 4.2 percent of the total U.S. market in scientific and professional equipment. This group is comprised primarily of optical disks, navigational and medical instruments, watches and clocks.[99]

Of all of the East Asian NICs, Taiwan has captured both the largest share and dollar volume of the U.S. high technology market. However, other countries have begun to produce goods at lower costs and export them to the United States, which may force Taiwan to develop new high technology commodities to sell on the world market.

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[94] Stokes, Bruce. Rising Trade Deficit, High-Tech Growth Are Threats to U.S.-Taiwan Relations, p. 2699.

[95] Berney Karen. The Four Dragons Rush to Play Catch-Up Game. Electronics Week, May 6, 1985, p. 54.

[96] Hatter, East Asian Countries Play Key Role In Eroding U.S. High-Tech Trade Surplus, p. 8.

[97] Berney, Four Dragons Rush to Play Catch-Up Game, p. 54.

[98] Ibid., p. 54.

[99] Hatter, East Asian Countries Play Key Role In Eroding U.S. High-Tech Trade Surplus, p. 9.

SINGAPORE

Despite a steady flow of investment by the United States and other industrial nations, it is unlikely that Singapore will develop, in the near-term, a flourishing and competitive domestic electronics, communications, computer hardware, scientific and professional instrumentation industries, or any of the other major high technology commodities. Although U.S. imports of Singaporean high technology goods in three major commodity groups have risen since 1980, Singapore only holds shares of 5 percent and .8 percent, respectively, of the U.S. market in communications equipment and electronics, and professional and scientific instrumentation.[100] Yet in office, computing and accounting machinery, Singapore leads all of the East Asian NICs in U.S. imports, at over $1 billion in 1984.[101] This lead has developed through the encouragement of relocation of foreign industries into Singapore, led by the top computer manufacturers. Exports to the United States were led by disk drives, disk cartridges, computer keyboards, and printers.[102] Industry and business leaders, aware that Singapore cannot soon match the hardware-intensive production and trade of other East Asian NICS, have shifted both emphasis and resources to other, "knowledge-intensive" services. These services, which are hoped will lead Singapore as a leading technological power into the 21st century, are being pushed by development of domestic software technology in Singapore. This development is being encouraged by the Japanese, who see the Singapore software industry as a gateway into the East Asian regional market in goods and services.[103]

HONG KONG

High technology trade from Hong Kong to the United States continued to expand in communications and electronic components; office, computing and accounting equipment; and scientific and professional equipment, in 1984. Much of this trade resulted from U.S. and other foreign companies locating "off-shore" facilities in Hong Kong; U.S. companies' branches or joint ventures composed 80 percent of the electronic goods, parts and components exported in 1984.[104] The total value of electronics exported amounted to $1.46 billion in 1984. This production fell into two categories: production of radio equipment, its biggest worldwide export, and "fad" products, such as electronic games and cordless telephones.[105] Hong Kong's largest share of the U.S. high technology market is in the export of watches and clocks; Hong Kong had 29 percent of the entire U.S. market in 1984.[106] Yet a lack of support facilities and service industries may be depriving Hong Kong of some of the higher technology, value added exports market. Further complicat-

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[100] Hatter, East Asian Countries Play Key Role In Eroding U.S. High-Tech Trade Surplus, p. 7.

[101] Berney, The Four Dragons Rush to PLay Catch-Up Game, p. 53.

[102] Ministry of Trade and Industry. Economic Survey of Singapore, 1984. Singapore: Government of the Republic of Singapore, 1984. p. 3.

[103] Berney, The Four Dragons Rush To Play Catch-Up Game, p. 52.

[104] Ibid., p. 56.

[105] Ibid., p. 56.

[106] Hatter, East Asian Countries Play Key Role In Eroding U.S. High-Tech Trade Surplus, p. 9.

ing Hong Kong's high technology trade is the treaty which will return Hong Kong to Chinese sovereignty in 1997. So far, this treaty has facilitated greater trade between the U.S. and the People's Republic of China, as Hong Kong serves as a point of re-export of high technology goods for the two countries. U.S. electronic goods re-exported from Hong Kong grew 42 percent in 1984 from 1983; Chinese goods re-exported to the United States through Hong Kong grew 54 percent from 1983 to 1984.[107]

The East Asian NICs have increased their export volume in high technology commodities with the United States since 1980. The East Asian NICs also have been a growing market for U.S. high technology exports, taking nearly 10 percent of the U.S. high technology export total in 1984, more than that of Japan.[108] The East Asian NICs are now the third largest export market for U.S. high technology goods, with Singapore the leading importer of U.S. high technology goods, followed by Korea, Taiwan and Hong Kong.[109] This is reflected by a growing need of U.S. components for value added commodities assembled in the East Asian NICs (for example, integrated circuits for semiconducters); the growing importance of re-exporting U.S. goods; and the growth of these countries as consuming nations. However, this has not offset U.S. high technology trade surplus with these nations; only Japan and the four East Asian NICs have high technology trade deficits with the United States. The growth of Malaysia and Indonesia in the high technology, low-assembly cost field may exacerbate this deficit.

Other Nations

High technology trade between the United States and the rest of the world lags far behind U.S. high technology trade with Japan, the EC nations, and the East Asian NICs. The United States does have a substantial trade balance with Canada other than high technology, but this trade is comprised primarily of automotive parts and energy products. Some of the automotive parts produced in recent years in Canada have been high technology components used in U.S. autos, but this dollar figure is relatively small.

South American, African and Middle Eastern high technology trade with the United States is relatively small and one-sided, with most of the goods flowing from the United States to these countries. There are few U.S. high technology subsidiaries, off-shore assembly or domestic production of high technology goods for U.S. importation in these three areas. Most of the countries in South America, Africa, and the Middle East have not developed into serious markets for U.S. high technology exports, although some nations are markets for high technology strategic and tactical military weapons.

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[107] Berney, The Four Dragons Rush to Play Catch-Up Game, p. 56.

[108] Hatter, East Asian Countries Play Key Role In Eroding U.S. High-Tech Trade Surplus, p. 6.

[109] Ibid, p. 6.

V. ANALYSIS *

In the domestic context, the indicators studied seem to demonstrate an improving situation with regard to the state of U.S. innovation compared to this country's performance in the 1970s. As noted previously, there currently are no direct measures of innovation, thus the available data only provide information on several factors in the innovation endeavor. It is clear from data presented in the previous chapters and discussed below that there are increased resources being utilized in the innovation arena.

Research and development are only two components of the innovation process. Increased funding for R&D does not necessarily result in increased innovation. In fact, research and development are not always necessary for innovation to occur; innovations may be the result of incremental changes in a product or process. Sumner Myers and Don Marquis found that many innovations were not directly based on R&D and ". . . that technological innovations are more often stimulated by perceived production and marketing problems and needs than by technological opportunities." However, they also found that ". . . it is quite likely that innovations based on technological opportunities—and on R&D—are the more important ones." [110] It is for this reason that changes in R&D funding are of interest in the study of innovation.

The amount of money spent for research and development within the United States has been increasing in the 1980s. This is true in both the Government and industrial sectors. The average annual rate of growth in the total national R&D expenditure was higher between 1980 and 1986 than it was from 1960–1969 and 1971–1979. However, the declines experienced in earlier years might have future impacts on innovation in the United States. There has tended to be a time lag of 10 to 15 years between the conceptualization of an idea and the commercialization of a product or process. Thus the reduction of funding for R&D several years ago might be manifest in results, or lack thereof, occurring through this decade.

Increases in the ratio of research and development to gross national product also have been established. This ratio provides an indication of the changes in resource allocation for R&D compared to other economic activities. Since hitting the low in 1978, the ratio has increased but has yet to match the 1964 peak which was due primarily to government funding for space and defense. Current growth of Federal funding for defense-related R&D has helped increase the R&D/GNP ratio. However, a different scenario emerges when only civilian R&D is compared to GNP. This number is substantially lower and has not displayed the growth since 1978 of the

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* Note: All calculations are made in constant 1972 dollars.

[110] Technology Transfer, Productivity, and Economic Policy, op. cit., p. 5.

former measure. At its highest, the civilian R&D/GNP ratio was only 75 percent of that of total R&D/GNP.

It should be noted that there are problems inherent in utilizing the R&D/GNP ratio as a measure. The gross national product calculates, in part, the increasing contributions of the service sector which has tended not to be R&D intensive and therefore does not reflect the contribution of research and development to this sector of the economy. Recently, the service sector has become increasingly dependent on high technology (especially the financial, information, and insurance industries). There are inadequate measures to quantify the impact of these changes on the economy, and they are generally not reflected in the R&D/GNP ratio. In addition, it has been argued that the rise in the R&D/GNP ratio is more reflective of the slower growth of the gross national product than a large increase in research and development.

The source of research and development funding is important because it provides insight into the type of innovation that might be anticipated in the long term. The Federal Government generally funds R&D to meet the mission responsibilities of the Federal departments and agencies. It also supports work in areas where the Government is the primary user of the results or where there is an identified need for R&D not be performed in the private sector. On the other hand, industry makes the new products sold in the marketplace which generate profits or develops the new processes which can be applied to make manufacturing more productive. Increases in R&D spending on behalf of industry tend to be directed toward the development of commercial goods and services to meet or create market demand.

There have been commercial successes resulting from government-financed research and development. The computer and commercial aviation industries are but two examples of this phenomenon. Other "spin-offs" have occurred when technologies or techniques developed within Federal laboratories (or otherwise funded with Federal money) have been applied to create commercial products or processes. However, research has indicated that innovations are most successful, when the R&D processes are tied to market demand [111] and it is industry activities which would be expected to be oriented toward the marketplace.

Since 1975 the Federal Government has increased its R&D funding, with the growth rate increasing in the 1980s. Prior to 1978, the Government funded over half the national research and technology endeavor; in fiscal 1986 this has decreased to 47 percent of the total amount spent on R&D. However, of major significance in determining the potential scope and direction of future innovation is the Government's allocation of these funds between various objectives. The previous CRS study noted the argument by Herbert Hollomon, the former Assistant Secretary of Commerce for Science and Technology, that "how" R&D funds are spent is the basic issue in innovation, not how much is expended.[112]

The Federal support for research and development in defense and space has far surpassed funding for civilian activities. While

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[111] Innovation's Debt to Basic Research, op. cit., p. 150.

[112] Some Indicators of the State of U.S. Industrial Innovation, op. cit., p. 13.

today the amount spent for space has decreased significantly from the 1960s and 1970s, defense-related R&D has increased and currently accounts for approximately 73 percent of the Federal effort in this area. This compares to 22 percent of the Federal R&D budget which is directed toward civilian activities. Between 1981 and 1986 Federal funding for defense grew 84 percent while civilian R&D expenditure declined 16 percent. In addition, government funding for industrial R&D is concentrated in two areas, aircraft and missile R&D and electrical equipment.

Given the growth of government spending for defense-related research and development, concern has been expressed over potential negative effects on the civilian R&D endeavor. The United States spends a smaller portion of its R&D funds on civilian activities than the other western industrialized nations. While it is clear that innovations in the civilian arena have resulted from defense and space research and development, critics argue that such technology is becoming increasingly complex and that the highly specialized R&D activities now undertaken cannot be easily transferred to the civilian sector and translated into innovations in the marketplace. The classified nature of much of the current work also serves to lessen the opportunities for spin-off to the civilian sector. Research has indicated that civilian R&D is more directly related to economic growth and other social goals than defense and space-related R&D.[113]

The extensive involvement of the Federal Government in the funding of the national R&D endeavor has created an environment in which government priorities can impact on industrial development. Certain industries, in part, create capabilities and pursue avenues of research to reflect government needs for the provision of goods and services. Federal support for mission-related research and development can have a significant impact on the scope and direction of industrial activities in a manner different from that of Federal support for general industrial competitiveness. Changes in government priorities in the defense arena have the potential for generating changes in private sector R&D to meet the new and different mission-related requirements.

Another potential problem with the concentration on military research and development is the potential for the diversion of scientists and engineers from market-oriented activities. Given shortages in the supply of trained personnel in certain areas and the ability of defense-related contractors to pay high salaries, it might be expected that the best talent will be attracted to these areas thereby ". . . gradually starving innovative capacity in the civilian economy, something many believed happened during the previous defense/space buildup of the immediate post-Sputnik era."[114]

Perhaps the most significant indicators of the potential vitality of the national innovation effort might be those which relate to increased support of various facets of research and development by the industrial sector. While increases in total R&D spending since 1975 were a result of increases in funding on behalf of both the Federal Government and industry, industry support of R&D has

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[113] Science Indicators—1982, op. cit., p. 7.
[114] Technology as a Factor in U.S. Competitiveness, op. cit., p. 349.

grown faster than that of the Government. Between 1975 and 1986 the Federal contribution increased 56 percent while industrial funding for R&D grew 94 percent. Since 1980 industry has funded more research and development than the public sector.

Performance of R&D by industry is also expanding. Industry now undertakes approximately 73 percent of the work funded. In addition, private sector support for industrial R&D is growing at a greater rate than it did in the 1970s. While in the late 1960s to the mid-1970s, the Government funded half of the research and development performed in industry, this portion has declined to 32 percent. However, it should again be noted that this government support for industrial R&D is concentrated in defense-related areas.

The increases in industial research and development are significant in that it is the private sector which makes the new products and develops new processes which can be sold in the marketplace to generate income or can be applied in manufacturing to improve productivity. Development of new technologies and techniques is the contribution of innovation to economic growth. While R&D spending does not guarantee innovation, nor does increased R&D spending guarantee increased innovation, R&D is a major component of the innovation process. Research has shown that industrially-funded R&D tends to have a greater impact on economic growth and productivity improvement than other types of funding.[115] Additional work in this area has demonstrated that ". . . there is a strong relationship between firm production and the level of its R&D investments."[116]

Industrial support for basic research is increasing along with industry-university cooperation in the innovation arena. Between 1980 and 1986 industry funding for basic research increased at an average annual rate of 9.6 percent; three times the increase in Federal funding for such activities. This support for basic research has importance for long-term innovation in that basic research activities attempt to identify the fundamental scientific principles on which to develop new technologies and techniques. Improved ties between universities, which generally, perform basic research, and industry, which develops and markets products and processes oftentimes generated from the results of the basic research endeavor, can assist in moving the results of scientific inquiry from ideas to tangible goods and services. As argued by Donald Langenberg:

> Inventions of ultimate technological and economic significance once could be made by intelligent, persistent thinkers with little formal higher education . . . Modern technological advance, however, is a different story . . . You don't find these associated with tinkering in a basement or garage . . . Thus, the modern R&D enterprise is inextricably linked with the research university.[117]

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[115] Mansfield, Edwin. R&D and Innovation: Some Empirical Findings. In Griliches, Zvi, ed. R&D, Patents, and Productivity. Chicago, University of Chicago Press, 1984. p. 133.

[116] Griliches, Zvi and Jacques Mairesse. Productivity and R&D at the Firm Level. In: Ibid., p. 368.

[117] U.S. Congress. Joint Economic Committee. The U.S. Climate for Entrepreneurship and Innovation, Dec. 1984, p. 28.

In recognition of the potential benefits to be derived from university research, industry financing for R&D in the academic sector has more than doubled in the last ten years.

The data indicate that there also have been increases in research and development spending by small businesses, although the proportion of small firm funding to total industry funding has remained fairly constant. These increases have been accompanied by large growth in the amount of venture capital available for the development of new, high technology companies, as well as an overall increase in the number of stock offerings in such firms. The expanded activity by these small high-tech businesses is important in that studies have shown these companies, in general, to be highly innovative.

As there is increasing recognition of the contribution of innovation and technological development to economic growth, the availability of scientific and engineering manpower to meet the expanded technical demands of the economy has become a concern. While there are some shortages in several specialists, the number of degrees awarded and the number of scientists and engineers employed have been increasing in the 1980s. Since 1974 the number of science and engineering personnel grew primarily due to industrial hiring. The number of degrees awarded to American students at U.S. universities began to increase in 1980, after a decline through the 1970s, although it was not until 1983 that the previous high set in 1974 was surpassed.

Despite these increases, concern has been expressed in regard to several issues surrounding the state of science and engineering education in the United States. An increasing number of students in American universities are foreign nationals who are utilizing the resources of the U.S. system to meet their educational needs. The National Science Foundation reports that in 1983, 24 percent of the recipients of science and engineering doctoral degrees awarded by U.S. universities were not U.S. citizens.[118] A new study issued by the Scientific Manpower Commission found that 50 percent of doctoral degrees in engineering go to foreign nationals, 62 percent of whom stay to work in the United States, comprising 36 percent of new Ph.D. entrants to the workforce.[119]

The knowledge gained by foreign nationals in U.S. universities can also be applied in competitive activities with American companies in the international marketplace. One of the reasons that there is room for foreign students in American universities is that U.S. students often do not take advanced degrees in math, science, or engineering if they consider themselves employable with undergraduate degrees. It can be in the best interests of industry to hire undergraduates and train them on the job. High salaries and inhouse instruction can act as a deterrent to continuing university education.

A similar situation is occurring in the ranks of professors of science and engineering. Because industry salaries, facilities, and ben-

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[118] U.S. Library of Congress. Congressional Research Service. Supply of and Demand for U.S. Scientists and Engineers: A Brief Overview of the Current Situation and Future Outlook. Rept. No. 85-674 SPR, by Edith Cooper, Feb. 15, 1985. p. 11.

[119] Foreign Students and Professionals Play Increasing Role in U.S. Technology. R&DM Digest, Oct. 1985. pp. 7-8.

efits are so attractive, universities are having trouble recruiting and keeping skilled professors to train new students and have had to use foreign nationals to fill positions. This inability to fill professorships may have an impact on the quality of the forthcoming generations of skilled scientific and technical personnel.

There are few output indicators of innovation. Patents are used as one measure but they serve more as an indicator of inventive activity. They do not provide information as to which inventions will become innovations. In addition, because of the rapid pace of technological change, or the desire to keep inventions secret, often ideas are not patented. With this in mind it is interesting to note a decline in the number of patents issued to U.S. citizens by the U.S. Patent Office calculated by both date of the grant and by date of application. This situation is particularly relevant in an international context which will be discussed later in this report. However it should be acknowledged that this major output indicator (in addition to trade data) shows a decline in the U.S. patent position from earlier years.

It appears that, in the domestic arena, increasing amounts of resources are going into the component parts of the innovation process. However, there are currently no accurate measures to determine whether these expanded resources are resulting in commercially viable products or processes. The last study on the number of "innovations" used data gathered through 1973. Work is presently being undertaken by the National Science Foundation to develop improved measures of the output of the innovation process in industry. Still, it is useful to look at U.S. performance in an international context in order to get an idea of how the inputs into the innovation process are being translated into products and processes that can be applied to increase production efficiency or sold in the marketplace to generate income.

In an earlier study, the Congressional Research Service found that

> With respect to absolute levels, the United States still ranks first in some indicators, second or third in others. However, the growth rates of foreign countries, especially Japan and West Germany, are higher than that of the United States, so they appear to be making gains.[120]

The updated data gathered in this report indicate that some changes have occurred since this assessment was made, but in general the pattern remains consistent with the earlier findings. In assessing the position of the United States with regard to various innovation-related indicators, it should be noted that, in most cases, the United States has the highest absolute totals (R&D funding, scientists and engineers, patents granted, productivity levels). However, the growth rates of several other western industrialized countries, primarily Japan, are larger than that of the United States.

Increased spending for research and development does not necessarily insure increases in innovation. As noted previously, technological innovations are more often the result of perceived production and marketing problems and needs than the result of techno-

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[120] Some Indicators of the State of U.S. Industrial Innovation, op. cit., p. 34.

logical opportunity. However, the commitment of financial resources to the R&D endeavor is one contribution to the pursuit of technological development which can be compared between countries. The data show that the United States spends the highest absolute total amount of funds for R&D. However, Japan has the highest growth rate for increased funding in this area; over twice that of the United States since 1979.

Within the United States, funding for the R&D enterprise is almost split half and half between government and the business sector. In all the other countries studied here, with the exception of the United Kingdom where government funds make up more than half the total, the business sector provides a greater proportion of the total funding than the respective governments (although these governments tend to be more active in non-financial support for commercial development). However, it should be noted that the major portion of Federal R&D funding in the United States is for defense-related activities (64.3 percent in 1983). This is in marked contrast to Japan and West Germany where government support for defense R&D is only 2.4 percent (in 1981) and 9.4 percent (in 1983) respectively.

The ratio of research and development to gross national product provides an indication of how the nations allocate their resources and the extent of the support provided to R&D in the context of the countries' total expenditures. While in recent years the United States has had the largest R&D/GNP ratio, this can be attributed to government spending for defense. When the ratio of civilian R&D to gross national product is calculated, the United States falls below both Japan and West Germany. In both cases, Japan has had the highest average annual rate of growth (1978–1983) which indicates that Japan has experienced a larger expansion of the resources devoted to R&D relative to the growth of the GNP.

Some governments, particularly the U.S. Government, tend to fund R&D which meets the government's needs (typically defense, space, and/or health) and needs which are not being met in the private sector in part because they are not perceived as commercially viable. Where these government funds are placed may be more important than the amount of the financial contribution as was noted previously. The combination of the relatively large U.S. Government contribution to the total research and development endeavor (greater than the portion of any other country with the exception of the United Kingdom) and the fact that a major segment of the U.S. Government's funds for R&D are for defense-related work (in contrast to Japan and West Germany where these portions are comparatively small), creates the possibility that decisions affecting the scope of direction of R&D in the United States might be deflected from commercially-oriented pursuits toward additional government-related activities.

The argument has been made that many commercial successes have been "spun-off" from government-oriented work. However, the increasing specialization and technological sophistication of much of the current efforts may make spin-offs less likely. As was discussed previously, successful innovations tend to result from market incentives, yet spin-offs oftentimes result from "technological push" where the technology is commercialized because it exists, rather than because it is needed, thus potentially lessening its marketability. The President's Commission on Industrial Competitiveness found that ". . . Government-funded mission-oriented R&D is not a major contributor to industry's ability to innovate and produce." While after World War II, Federal support of certain programs resulted in commercial products, and processes, industry now is the primary innovation source and ". . . Government has increasingly become a net user, not a provider, of industrial technology."[121]

The areas where the United States enjoys a favorable balance of trade in international markets are those which reflect Federal support for mission-oriented research and development—primarily defense and aerospace. In the commercially-oriented, high technology arena other countries are either leading in trade or quickly catching up. This is particularly true with Japan and the four east Asian Newly Industralized Countries (NICs-South Korea, Taiwan, Singapore and Hong Kong). Japan and the East Asian NICs have had the fastest growth rate of high technology exports to industrialized nations in the last decade, although statistics kept by the U.S. Department of Commerce on East Asian-U.S. trade lag several years behind current trade balance.[122] It also appears that the East Asian NICs are taking steps to develop a high technology infrastructure which will allow these nations to become less dependent on Japan, the United States, and other industrialized nations. Although comprehensive data on this trend also are incomplete, several of these steps are described earlier in this report.

Industry is the major player in technological innovation. The industrial sector makes and/or utilizes products and processes. New or created market demands are most often the driving force in innovation and industry is traditionally geared to the marketplace. Ideas and inventions become innovations generating economic benefits when they are made available to be sold commercially or used to improve productivity.

The available data show that in both Japan and West Germany, industry plays a larger role in national R&D funding than in the United States based on the fact that a larger portion of the national research and development endeavor is financed by industry. At the same time, the Governments of these countries, especially Japan, provide extensive non-financial support to organize and channel private sector resources and promote industrial innovation. This may mean that R&D decision-making is geared more toward the marketplace than in the United States where industry and government fund almost equal amounts of the R&D effort, but the Federal Government tends not to participate in commerical R&D endeavors. However, it should be noted that the United States has had the greatest growth rate in the portion of national R&D activities financed by industry (1970–1983). In addition, in the last several years for which data are available, the United States had the highest ratio of industrial R&D to gross domestic product

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[121] President's Commission on Industrial Competitiveness. Global Competition, the New Reality, vol. II. Washignton, U.S. Govt. Print. Off., 1985. p. 82.

[122] See U.S. Dept. of Commerce. United States Trade: Performance in 1984 and Outlook, Washington: U.S. Dept. of Commerce, 1985; and U.S. Dept. Commerce. the Rising Trading Power of the East Asian NICs. Washington, U.S. Dept. of Commerce, 1985.

indicating that a larger portion of U.S. industrial resources is allocated to research and development than in any other country. The ratio of industrial R&D (including government and industry funding) to the domestic product of industry (value added) shows that while U.S. industry was less R&D-intensive than West Germany, it was more R&D-intensive than Japan.

While various indicators make it appear that industrial R&D participation in the United States may be increasing in light of international competition, it must be acknowledged that much of the gains in relative position and/or growth is a consequence of U.S. Government spending primarily for defense rather than for commerical technology development. In Japan, 98 percent of funding for industrial activity is generated by industry; in West Germany 82 percent of industrial financing comes from the private sector (1982). In contrast, only 68 percent (1982) of U.S. industrial R&D funding is generated by industry sources, thus creating the potential for non-industrial influences on decision-making within the industrial sector. Extrapolating from information that shows what percent of total industrial R&D funding is from industry,[123] it can be estimated that the ratio of private sector funding to gross domestic product would be higher in both West Germany and Japan than in the United States. When only industrial financing for R&D is figured as a percent of the domestic product of industry (or value added), the United States again exhibits a lower ratio than either West Germany or Japan. Thus, while U.S. industry is more R&D-intensive than Japan when government funds are included, it is less R&D-intensive when only industry generated R&D resources are considered. In all these cases (with the exception of the rate of growth of the portion of total national R&D financed by industry), the United States had displayed slower rates of growth than Japan.

The preceding data indicate that in the United States the Federal Government plays a much greater direct role in the funding of R&D than in any other nation with the exception of the United Kingdom. This is true in terms of the national R&D endeavor and in terms of financial support for industrial research and development. It may be argued that the governments of the other western industrialized countries studied here also have been involved in R&D; however, this involvement takes a different approach than the direct funding activities of the U.S. Government. While the United States has recently instituted several efforts to promote technological development (including tax credits for R&D and donations of equipment to universities for use in research, mandating technology transfer, a small business innovation research program, changes in the antitrust laws to encourage joint research activities, and patent law changes to foster commercialization, [124] the governments of the other nations have been more supportive of technological development and cooperation among firms in the generation of new products and processes. They have also tended to work coop-

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[123] Organization for Economic Co-operation and Development. Science and Technology Indicators, Basic Statistical Series—Recent Results 1979–1983. Paris, 1984. P. 28.

[124] For additional information see: U.S. Congress. Congressional Research Service. Industrial Innovation: The Debate Over Government Policy. Issue Brief No. IB84004, by Wendy H. Schacht, Dec. 30, 1985 (continually updated). Washington, 1985.

eratively with industry in the areas of trade, capital formation, and investment in R&D. According to Harvey Brooks:

> . . . until recently foreign managements and governments have assigned a considerable higher importance to technology as the critical factor affecting future competitiveness and have, therefore, incorporated informed estimates of future world technological trends more intimately into their strategic planning and management philosophy.[125]

Corresponding, the U.S. Government fosters military and aerospace technology and we excel in these areas; the Japanese government encourages development of commercial products and processes and they are dominant in the development, production, and marketing of many of these technologies.

The United States continues to maintain the highest absolute levels of manufacturing productivity. Although the other western industrialized nations, led by Japan, are moving up toward the U.S. level, the rate of gain has slowed (1980-1984) relative to earlier years. Despite this, the Japanese have displayed the largest growth in productivity over the 1977 base year while the United States has had the smallest growth. Particularly disturbing to considerations of U.S. competitiveness in innovation is the situation where, as Brooks points out, productivity levels in Japan are higher than in the United States in certain critical industries. An industry by industry analysis indicates that Japanese productivity is higher in steel, electrical machinery (computers and telecommunications), general machinery, transportation equipment (including cars), and precision equipment. "Not surprisingly, the industries in which the Japanese have been most successful in penetrating the U.S. domestic market are precisely those that enjoy a productivity advantage over their U.S. counterparts."[126] This also holds true for the East Asian NICs. The high technology fields of communications equipment, electronics and components, office automation equipment and "low technology" watches and precision instruments are the same commodities which these countries can produce at a very low cost in their country with the resources which are available.

An analysis of productivity measures must be viewed within certain constraints. Technological change is only one of the many factors which have an impact upon the rate of growth of productivity. Brooks notes that productivity measures only manufacturing process technologies and thereby tends to underestimate the U.S. contribution to innovation which generally focuses on product innovation.[127] He concludes that the lag in productivity growth in the United States as compared to certain other countries is not "primarily a symptom" of decreased innovation, but rather results from managerial and broader economic and cultural factors.[128]

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[125] Technology as a Factor in U.S. Competitiveness, op. cit., p. 353.

[126] Ibid., p. 339

[127] Ibid., p. 340.

[128] Ibid., p. 341.

Similarly Mansfield et al. argue that the decrease in the rate of productivity growth in the United States is not necessarily due to decreased innovation; other factors, including increased oil prices, regulation impacts, and declines in the rate of increase in the capital-labor ratio may also be contributing factors.[129]

The degree of technical competence and the availability of a trained science and engineering work force is important to the pursuit of technological innovation. Any slowdown in the training of scientists and engineers will have an import in the future if there are insufficient numbers of skilled personnel to replace those now working. U.S. institutions grant significantly more first level and doctoral degrees in science and engineering (total) than any of the other nations. However, the rate of growth in first level degrees conferred in Japan was twice that in the United States (1970–1982). In addition, the number of first level engineering degrees awarded by Japanese institutions in 1982 was greater than those granted by U.S. universities.

The United States has by far the largest total science and engineering labor force, over twice that of Japan its nearest competitor. In the ten years between 1973 and 1983, growth in the total technical work force lagged slightly behind Japan and France (behind 6 and 3 percentage points respectively). However, when examining the number of scientists and engineers as a portion of the total work force, the United States has seen a slight decline since reaching a peak in 1968. All the other western industrialized countries studied have displayed significant growth in the portion of the employed population involved in scientific and engineering pursuits led by Japan with an 86.2 percent increase. Yet this situation must be analyzed in perspective. The U.S. enconomy has become increasingly service oriented (at a faster rate than the other western industrialized nations) and by virtue of this fact there have probably been corresponding now account for owner-related personnel in the workforce. Services now account for over 70 percent of employment and almost two-thirds if the nation's output.[130] Thus, the science and engineering component is bound to decrease as a percent of the total labor force which has been expanded by the addition of service industry personnel. As the service sector continue to use more technology, it might be expected that the ratio of scientists and engineers to the total number of employed persons will increase.

Patents provide a measure of invention, although they do not provide any indication of which inventions will eventually become innovations. Differences between countries regarding patent policies make comparisons difficult. However, it appears clear that the Japanese are by far the most active in applying for patents both at home and abroad, and that the United States is the nation where foreign nationals are most interested in patenting. The number of patients granted by all the countries to their own citizens has declined with the exception of Japan. In addition, while the number of patents granted by the United States to U.S. nationals has de-

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[129] Technology Transfer, Productivity, and Economic Policy, op. cit., p. 218.

[130] U.S. Office of the U.S. Trade Representative. International Trade in Services: Data Improvements. Washington, July 1985. p. 4.

creased, there has been an increase in the number granted to foreigners, primarily the Japanese. This is significant given research that shows that:

> the propensity to patent in another country is thought to be related to the perceived market potential of that country [and that] high correlations have also been found between export shares of ten OECD countries and their patenting activity in the United States, particularly in chemicals, capital goods, and durable consumer goods.[131]

If this is correct, the increase in foreign nationals patenting in the United States might have future implications for the U.S. trade balance in high technology products and processes.

Any study of technological innovation is limited by the fact that there are currently no direct measures of innovation. Utilizing the existing data requires much interpretation and decision-making with regard to what a figure means, what are the relationships between the data, what can cause the results, and what caveats are necessary. In additional, the data must be placed in context. It is necessary to distinguish between what is in actuality a slowdown in U.S. innovation and what are the consequences of other nations catching up to a comparable level of technological capability. After World War II the United States had a large technological lead; however, a concerted effort was made by the United States to restore the science and technology base in both Japan and Western Europe. These efforts have been relatively successful if we look at the indicators of the R&D endeavor in these countries. Yet the U.S. innovation effort continues to be compared with the U.S. position held in the 1950s and 1960s when it was the undisputed leader in technology. The differences from that time period to the present are used as evidence for the argument that the United States has a declining innovative capability. However, it can be argued persuasively that the situation depicted by the data is actually one in which the United States is not losing its technological leadership, but one in which other nations are meeting their potential in developing innovative products:

> Given the fact that our populations have comparable educational levels and similar political and economic systems, and that an increasingly open world trading system permits free movement of capital and knowledge as well as access to raw materials and energy, it is hard to imagine if anything could have preserved a dominant U.S. advantage over time.[132]

The rise in the importance of international trade in transferring innovative technology between nations indicates that greater emphasis must be placed on obtaining and maintaining current trade statistics between nations. It also is important to obtain reliable data so that accurate distinction can be made between the overall trade a nation has with other nations, as well as what aspects of that trade are due to innovations in industrial products ans proc-

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[131] Science Indicators—1982, op. cit., p. 13.
[132] Technology as a Factor in U.S. Competitiveness, op. cit., p. 332.

esses. These distinctions are important; being ahead in world market shares in a particular segment of trade may not correlate to innovations in that nation. Other factors play a part in the overall trade position of a nation: the rate of commercialization of new products; the value of a nation's currency *vis a vis* other nations' currencies; trade barriers or lack of barriers; and other factors. All of these factors may or may not have an effect on the innovative process.

Although U.S. Federal agencies (notably the Commerce Department) keep data for most of the industrialized countries in the West, there still is a notable absence of data on the East Asian countries, particularly the four major NICs (South Korea, Taiwan, Singapore, and Hong Kong). This includes an absence of data on current East Asian NIC world market shares in high technology trade, current commodities traded by these nations, the importance of reexportation, new commodities and goods being exported, the number of domestic patents applied for and received, and other pertinent trade data. Overall trade statistics indicate that Japan and the four East Asian NICs represent the fastest growing exporters of high technology goods in the world. This may have a serious impact on U.S. industrial innovation by affecting U.S. trade deficits, the growing inability to sell U.S. goods abroad, and domestic sales of U.S. goods.

Similarly, there is a lack of comprehensive data to demonstrate what the East Asia NICs are doing to create an environment of innovation within their countries. The thoroughness of information on the number of graduate students in science fields graduating from universities in the Far East, and the number of scientists and engineers engaged in R&D is inconsistent from country to country. Some Federal agencies in the United States have no statistics on science and technology development in the Far East, while others classify the four East Asian nations within a region and do not address each country individually. Other areas, such as East Asian tax policy, economic development, and the targeting of industries, have not been fully addressed in either Federal or academic literature.

From the information available, it is evident that the countries of East Asia are making great strides in gaining world market shares in exports, particularly in high technology goods. Some countries in East Asia also are developing science parks and are pushing to develop their own innovative products and processes, rather than just adopting foreign products. However, how quickly or successfully many of these newly industrialized countries are developing innovative products of their own has not been fully determined because of incomplete data.

The tendency to view innovation as a composite of research and development activities also has clouded evaluation of the situation. As noted previously, research and development are just two components of the multifaceted innovation process which also involves idea generation, commercialization, and diffusion of technology into the economy. Focusing on the increase or decrease in levels of funding for R&D within and between countries ignores other very important issues which have been raised throughout this paper. In terms of the ability of the United States to compete in the technological arena, the commercialization and diffusion of products and processes stand out as significant problems. Basic research and the pursuit of science are done rather successfully in the United States as evidenced, in part, by the number of Nobel prizes awarded to Americans. However, several other countries, primarily Japan and the East Asian NICs, have been more successful in commercializing the results of R&D. They have created an environment in which the adoption and/or adaptation of new ideas to commercial interests is facilitated. As the President's Commission on Industrial Competitiveness found, "foreign firms have increased the speed with which they adopt and commercialize technology developed in the United States, and they have also improved their ability to develop technology on their own." [133] The inability, unwillingness, and/or slowness to commercialize by U.S. companies is a serious problem since, as John Marcum argues, ". . . it is at this stage of applications where technology has its greatest economic impacts in terms of productivity, growth, and competitiveness." [134]

As has been noted throughout this paper, innovations do not necessarily emerge from technological imperative, but more often from an unmet market need, whether new or existing. Portions of the innovation process within the United States are not tied to the marketplace, but are rather reflective of government priorities and needs. Thus, while there is general support for R&D in those areas where industry and government interests coincide, there is less emphasis, to date, on commercializing technology for and diffusing technology in the civilian marketplace. In addition, several U.S. industries have had a dedicated buyer in the form of the U.S. Government. Other U.S. industries have focused on the large domestic market. Lacking such favorable conditions for both these outlets, the industries in many of the other countries, the Western industrialized nations and the newly industrializing countries, have had to identify outside possibilities and develop products and processes to meet international marketplace demands. This concentration on behalf of other nations, and the lack of experience by many U.S. firms, has hampered the ability of many U.S. industries to compete on a global scale. For example, the East Asian market has been a source of many of the goods imported into the United States: automobiles, electronic goods and components, textiles, and other high volume commodities. Yet often these very markets are restricted to U.S. manufacturers, either because they cannot enter these markets or do not know how to enter these markets.

The data appear to indicate that in many areas American industry has failed to compete successfully in the commercialization and diffusion activities associated with industrial innovation. Research has shown that the primary objective of R&D funding in most industries is to improve existing products, not to develop new and different technologies.[135] Decisions tend to be made on a fi-

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[133] Global Competition, op. cit., p. 22.

[134] Marcum, John M. Technology Leadership: Co-operation, Competition and Interdependency. In Science and Public Policy, v. 12, Dec. 1985. p. 319.

[135] Mansfield, Edwin, John Rapport, Anthony Romeo, Edmond Vallani,a Samuel Wagner, and Frank Husic. The Production and Application of New Industrial Technology. New York, W.W. Norton [1977] p. 3.

nancial basis to meet profit demands of shareholders, often with limited regard to the long-term nature of much of the innovation endeavor. Government funding for defense-related activities is increasing with added potential for diverting resources away from the development of civilian technology (however, some argue that the R&D activities of the Department of Defense have provided industry with many opportunities to develop commercially viable technology). Other countries are increasingly willing and able to identify and/or develop markets as they generate new products and processes.

Despite this, there are several trends which indicate that changes are being implemented in the United States. The increased involvement of U.S. industry in funding research and development—and thereby in setting priorities—may help to alter the direction of industry activities toward more commercially viable technological development. The closer university-industry ties have the potential for augmenting opportunities to tie research to commercialization. There may be a need to incorporate greater efforts to commercialize and diffuse the results of the inventive capabilities of U.S. industry in order for American firms to compete more successfully in world markets.

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