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RESEARCH and DEVELOPMENT

A Foundation for Innovation and Economic Growth

AEROSPACE INDUSTRIES ASSOCIATION OF AMERICA, INC.

RESEARCH and DEVELOPMENT

A Foundation for Innovation

and

Economic Growth

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The mission of the Aerospace Research Center is to engage in research, analyses and advanced studies designed to bring perspective to the issues, problems and policies which affect the industry and, due to its broad involvement in our society, affect the nation itself. The objectives of the Center's studies are to improve understanding of complex subject matter, to contribute to the search for more effective government-industry relationships and to expand knowledge of aerospace capabilities that contribute to the social, technological and economic well being of the nation.

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"Technology innovation is the key to conquering our present calamities and discovering future treasures. Without it, we are forever consigned to carving up the same old pie in smaller and smaller slivers. With it, we can expand the real wealth of the pie to provide larger portions for all."

National Strategy for Technological Innovation
Report of the Committee on Commerce, Science, and Transportation, U.S. Senate

"Fundamental changes have taken place in the American and world economies in recent decades. With cheap labor, cheap fuels, cheap money and cheap raw materials all gone and competition growing for the world's markets and supplies, the most promising sources of growth, real wealth and enhanced productivity are through technological advances and industrial innovation."

Senator Adlai Stevenson
Committee on Commerce, Science and Technology, U.S. Senate

"Our industrial policymaking to date has been largely reactive in nature. We seek to solve immediate problems without analyzing the long-term consequences . . . Often, we fail to consider the repercussions of these actions on other sectors of the economy . . . I do not think this Nation can afford a muddling relationship between government and industry. We must make a choice, and that choice must be to define a new relationship in the form of an industrial policy based on cooperative arrangements between business and government."

Jerry J. Jasinowski
Assistant Secretary for Policy
U.S. Department of Commerce

INTRODUCTION

The last one hundred years or so might well have been called the American Century, a recent magazine article pointed out, if only for the amazing number of American-born innovations that changed the world and the way people live. The import of the article, however, was not glowing; instead, it was bleak. The American Century will not be repeated, the author prophesied, for, clearly, innovation in the United States is on the decline.

The evidence presented is by now familiar to those in industry, and is becoming so even to the general public, thanks to a spate of articles on the demise of "Yankee" ingenuity. Capital investment in technological progress is down; U.S. funding of R&D is lower than a decade ago with no substantial growth in sight; the number of scientists and engineers as a proportion of the population is down; so, too, are the number of patents issued to U.S. citizens. Other important indicators confirm the trend: A drop in the productivity growth rate, an overall negative balance of trade. Even the one bright spot in the U.S. trade picture is dimming. High-technology industries have consistently made positive contributions to the balance of trade but, even in technology intensive products, the U.S. now has an overall negative trade balance with Japan, primarily because of Japanese commercial success in the consumer electronics field. At the same time, the nation is lacking technological solutions to pressing energy, environmental, transportation, and other social problems.

While the U.S. falls behind in areas in which it has always been out in front, other countries are consistently moving ahead. From the beginning of the Industrial Revolution, the U.S. made tremendous strides in industrial innovation. Today, locked in, in some instances, to older investments in plant and technology, the U.S. makes relatively small, incremental steps in technological advance while other countries—starting from ground zero after World War II with new facilities and new technology—leap-frog ahead. While the United States has led in some new technologies such as aircraft, electronics and computers, the national commitment to innovation has not been sufficient to forestall enormous market inroads by other nations.

Abroad, many countries are making substantial capital investments in innovation. R&D investment as a proportion of gross domestic product has been increasing in many nations—not declining as in the U.S.—and so has the number of patents issued: Japan and West Germany have outstripped the U.S. in this respect. Foreign governments have put considerable financial muscle behind industrial development in order to be competitive in world markets, with considerable success. The British and France, for example, have achieved significant technological advances in aerospace which have been reflected in overseas market success. The Japanese have penetrated certain high-technology markets—electrical machinery products, professional and scientific instruments and non-electrical machinery—in which the U.S. has excelled. The faltering American steel industry has been surpassed in inventiveness by Belgium and Austria and the Germans and Swiss are ahead in textiles.

And other nations are committing themselves to future advances in high-technology fields. Roy Jenkins, president of the European Economic Community Commission, has called on the Common Market to "accelerate and coordinate" activities in high technology, especially by promoting R&D programs through the European community. The West Germans have streamlined their patent systems to encourage small-scale innovation. For years, the Japanese have awarded research subsidies to companies in selected industries, such as the computer industry in the 1970s. Smaller nations are making their own commitments to innovation. As 1979 came to a close, Israel discussed plans for government infusions of risk capital and a transfer of scientists from academia to the private sector. As exports of R&D-based industrial products move ahead of agricultural exports, Israel sees its economic future in "exporting sophisticated industry."

Concern over the American lag in innovation is more than a matter of national pride. In 1971, the U.S. experienced the first negative balance of trade since 1888 and has had a negative balance since then except in 1973 and 1975. A pernicious cycle has been established: The balance of payments deficit and the weak American dollar are fueling an inflation that, in turn, discourages new innovation, and new jobs. The high-technology industries that, along with agriculture, make positive contributions to our trade balance depend on an increasing U.S. commitment to innovation—or they, too, may see their export balances move into the red.

As foreign competition strengthens, the U.S. must look even more to its own large domestic market. Frank Press, science advisor to President Carter and director of the Office of Science and Technology, believes "There are a number of reasons why we must be innovation leaders... there is substantial evidence to support the argument that the health of the U.S. economy is essential to a sound global economy... Because of the character of our consumer-oriented society and our advanced technological state, any products and services that are going to create major new markets here must now be fundamentally different. It is such innovation that will stimulate substantial new investments and open up new economic opportunity here. The effects will not only ripple throughout our domestic economy, but will be felt around the world."

Surely, there will be yet another American Century of technological achievement. Other countries are making enormous strides, however, and it may be that the best any nation can hope for, in the long run, is technological parity, not superiority.

At any rate, it is clear the United States can no longer take its competitive success for granted. It is also clear the well-being of the nation depends on a resurgence of technological initiative and leadership. If the nation can focus on that goal, there is no reason it cannot be accomplished.

EXECUTIVE SUMMARY

Innovation underlies the health and future development of the American economy and the nation's ability to attain important national goals. It is important in efforts to turn inflation around, improve the United States' world and domestic market situation and create jobs; it plays a central role in building economic strength. The current decline in innovation, then, has serious implications.

Is the decline in innovation inevitable? Can the trend be reversed? A search for answers leads, of course, to the source of the problem—and the reasons for the U.S. technological slump are not hard to pin down.

Today's high rate of inflation works against the long-term, high-risk investment associated with innovation. Venture capital is no longer readily available due to a persistent low rate of capital formation. The lack of capital has also affected U.S. investment in manufacturing—now falling behind that of most other industrial nations as a proportion of gross domestic product of manufacturing companies. The U.S. rate of investment has averaged about one-half the rate for France and West Germany and about one-third the rate for Japan. This decline seriously affects employment opportunities as well as investment in innovation. In recent years, government regulations have also slowed down the innovative process and, increasingly, corporate R&D is "defensive"—geared to compliance with regulations or toward avoiding future regulatory problems. Regulation has lengthened, too, the time required for product development and approval. Regulation-caused uncertainty, combined with tight and insufficient capital, has resulted in corporate reliance on investment with short-term, conservative payoff rather than long-term, high-risk reward.

Robert Anderson, Chairman and Chief Executive Officer of Rockwell International, has said that: "Total U.S. spending for R&D in 1979 is estimated at $52 billion—and we're spending almost twice that amount to comply with government regulations."

"A large share of the money that is being spent on R&D," Anderson said, "is for research to meet new Federal regulations, not for better products or technical innovations . . . today's manufacturer must keep in mind the possible punishments, as well as the potential rewards, that may be reaped from a product innovation."

There are other factors creating barriers to industrial innovation: lack of support for basic and applied research and development; an inflexible and deficient federal patent policy plus federal ownership and nonexclusive licensing of patents arising from government-funded R&D; tax policies and accounting practices that increase immediate risks of R&D losses or prevent spreading risks over many years; over-specification of federal procurements; and antitrust actions that may affect joint R&D ventures or punish innovative firms that succeed in capturing a large share of the market.

The lack of capital for innovative ventures is particularly serious and the outlook for both large and small businesses seeking to finance long-term and risky investments is not promising. The current lack of tax incentives for innovation and the failure to permit depreciation at replacement costs rather than original purchase costs inhibits financing, as do investment regulations that hinder backing of risky, new ventures. Inflation, and a serious lack of saving—as the national debt climbs—compound the situation.

While the decline in innovation is frequently charged to corporate short-sightedness, the general economic climate certainly offers some rationale for defensive planning. In an uncertain domestic economic and political environment and an unstable world situation, a prudent businessman is forced to invest cautiously; that undoubtedly means a trend toward short-term investments for greater low-risk profits—and a de-emphasis on basic and exploratory research.

If the root causes of the lack of inventiveness and innovation are known, what is holding the U.S. back?

Unfortunately, the nation has no long-range policy for R&D, innovation and technology and such a policy is critical. The nation *must* define a strategy to create a healthy and vigorous economy capable of generating sufficient capital and market demand for U.S. products, both domestically and internationally. There is a need to provide guidance and coordination for innovative policies and programs. Any such policy must embrace national goals and the concept of a partnership between government and industry. It must also call for and encourage consistent and adequate levels of private sector R&D.

Innovation, R&D and Economic Progress

The effects of technological innovation on the U.S. economy have long been recognized. Some economists credit innovation with as much as 45 percent of the Nation's economic growth from 1929 to 1969. They point out, moreover, that when high- and low-technology industries are compared, high-technology firms have had productivity rates twice as high and real growth rates three times as great as low-technology firms. Price increases of high-technology products have been only one-sixth those of low-technology products; employment in high-technology industries has seen nine times the growth during that 40-year period.

Nonetheless, innovation is a complex process and precisely how and to what extent it increases productivity and economic growth is not always clear. Even more uncertain is the relationship between R&D and economic growth for, although innovation is rooted in the basic advances in knowledge that come about through R&D, it is true that not *all* R&D leads to innovation. The economic impact of R&D is so difficult to measure and so easily arguable that R&D is one of the first things sacrificed in a time of economic uncertainty and restraint.

Much discussion and disagreement on the appropriate level of R&D funding is rooted in the complexity of the relationships between economic growth, innovation, and R&D. Economic growth can be traced most easily to product improvement, to spinoffs, to technology transfer. The link with R&D is harder to prove and, yet, it is there.

Willis H. Shapley and Don I. Phillips, writing for the American Association for the Advancement of Science, believe it is generally accepted that R&D is beneficial to the economy and that "Advances in knowledge have been the biggest single factor in economic growth and productivity gains in the United States over the past four decades... The rate of return on investments in R&D is generally high, both the private return and the public, or social, rate of return...."[1]

The Federal Role

The role of the federal government is central to any discussion of R&D and economic growth since 50 percent of all R&D funding in 1979 was supported by the government. In the early 1960s, the level of federal support was still higher—approximately 65 percent.[2] Nonetheless, there are always proponents of a smaller federal role. Often, their arguments center on a belief that industry will pick up where the federal government leaves off.

The lack of a clear relationship between R&D and economic growth clouds the issue, too, where federal support is concerned. Willis and Shapley point out that while: "Government-supported R&D has had a significant economic impact... this is not clearly seen in the economic measures now generally used. Increases in the government's productivity are not reflected in standard GNP and growth accounting, since the output of government services is usually measured only by its cost. Attempts to measure 'spill-over' effects of federal R&D expenditures in the private economy have yielded varying and controversial results, from zero or even negative to overall social rates of return of 40 percent or higher. Studies of federal R&D in civil sector problems have likewise shown results ranging from negative to decidedly positive."[3]

In a time when innovation is on the decline and economic growth is faltering, the important link between R&D, innovation and economic growth warrants examination. Certainly, the federal role in supporting R&D is an important aspect of the relationship.

Federal R&D and U.S. Economic Strength

The study reported here looked at the role of federal R&D in determining the strength of the U.S. economy, beginning with a look at the trends in overall federal R&D funding. While, in current dollars, the trend appears to be upward, constant dollar figures show total funding in the last ten years (FY 1972-FY 1981) to be 9 percent below the level of the previous decade. Instead of a steady upward trend, defense R&D has actually decreased 17 percent and the space effort is about half the total for the FY 1962-FY 1971 period. While civil R&D has increased substantially, in defense and space a significant funding cutback has occurred. Overall, even with the increase in civil R&D, total national funding has declined.

Viewed as a percentage of GNP, the same downward trend in federal R&D funding is obvious: Total government funding is down 34 percent from the previous decade. Defense R&D is down 38 percent and space R&D funding has decreased by 60 percent. A look at apportionment of funds between basic and applied research and between defense and non-defense R&D reveals some upward movement in funding in recent years with the greatest increase in FY 1981. Basic and applied research are up somewhat; the notable increase is in defense—a result of the defense emphasis in the FY 1981 budget. The figures, however, must be viewed in perspective, as funding was significantly low in the mid-1970s—20 percent lower overall. R&D has not been funded at sustained levels over the last 15 years and recent increases cannot be viewed as compensating totally for the cutbacks of the mid-1970s.

An important point to be made is that R&D expenditures in the areas of defense and space have implications for progress in many other areas. Over the years, spinoff

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[1] W. H. Shapley and D. I. Phillips, *R&D in the Federal Budget: FY 1979 – R&D, Industry, and the Economy*, Research & Development AAAS Report III (Washington, D.C.: American Association for the Advancement of Science, 1978), pp. 77-78.

[2] *Science Indicators 1978* (Washington, D.C.: National Science Foundation, 1979), p. 47.

[3] *Op. cit.*, p. 78.

and technology transfer have resulted in the civil application of much defense and space-related research. The past investment in aerospace R&D, for example, has paid off heavily for civil aviation in the 1970s. In 1979, the value of aerospace civil exports was nearly five times greater than that of military exports ($9.7 billion in civil exports against $2 billion in military exports). As the defense budget growth rate has declined, however, and the product mix has shifted, few military programs are as broadly applicable to civil aircraft development as in the past, casting a shadow over the possibilities for similar spinoff benefit in the future.

The study then investigated the relationship of R&D to the international trade competitive position of individual sectors of the U.S. economy and examined the role of R&D in the world market strength of the aerospace industry. There was a strong correlation between high levels of R&D and a healthy trade position. The findings showed that:

- R&D-intensive industries (those performing in excess of 2.5 percent of R&D on total sales) show a *positive net trade* position (eight out of nine industries) over a 21-year period.

- Eight out of nine non-R&D-intensive industries show *negative net trade* positions,

- The aerospace industry is by far the most R&D- and technology-intensive industry of the U.S. economy; it spends 24 cents of every dollar of sales on R&D.

- The aerospace industry is the largest contributor to *positive net trade* in the United States.

Strong evidence also exists to suggest that industries that perform high levels of federally-funded R&D outperform other sectors of the U.S. economy in international trade (see *Results*, Appendix A, p. 43).

Aerospace R&D and Trade Performance

The link between R&D and trade performance was looked at more closely in terms of the aerospace industry which has been predominant in R&D effort, and industry-sponsored R&D, throughout the past two decades. Despite the contention that industry will make up the difference when federal funding is cut back, it has not happened in aerospace. Substantial percentage cutbacks in spending levels since the end of the 1960s occurred in both federal and industry-funded aerospace R&D—cutbacks of 28 and 27 percent, respectively.

The employment of scientists and engineers is another measure of industry R&D activity. After steadily increasing throughout the 1960s, total industry R&D employment remained relatively constant throughout the 1970s but, in aerospace, employment fell by 30 percent from the high of 100,000 in the latter half of the 1960s to a level of about 70,000 in the 1975-1977 period. The trend has been upward in the last two years reflecting some increase in R&D funding but due primarily to development of the newer generation of commercial transport aircraft.

The study analyses did not determine leads and lags in R&D, prototype development, new product introduction, and product life cycles. Other studies, however, have led to estimates of lead-lag times between R&D and production efficiency changes of from 7 to 15 years. In addition, the "product life cycle" theory of trade holds that the first company or country to introduce a product has an advantage of between five to ten years in that product line in world market competition. *The decline in aerospace R&D funding, then, leads one to expect an increasingly negative effect on the competitive market position of the United States.*

The U.S. aerospace industry experienced a strong upward movement of export sales in the late 1960s which—except for 1972 and 1977—continued through the 1970s. Exports reached a highpoint in 1979 at over $11.7 billion. In no other sector of the world economy does the U.S. hold such a preponderant net export position as in aerospace. Of all turbine-engined aircraft in the world airline fleet in 1979, for example, over 68 percent were of U.S. manufacture. Almost 85 percent of all turbojets and more than 80 percent of turbine-powered helicopters were manufactured in the U.S. The stakes for the future—including a world transport market° over the next ten years of as much as $140 billion—are great. But the dominance of the U.S. in this market can no longer be taken for granted. A comparison of aerospace sales of the U.S. and the European Economic Community (EEC) brings to light steady increases in EEC sales—from $4.1 billion in 1970 to $6.3 billion in 1977,°° an increase of 53 percent.

Meanwhile, total U.S. aerospace sales declined 15 percent from $22.3 billion to $19 billion during the 1970-1977 period. As a result, EEC sales in 1977 represented 33 percent of U.S. industry sales as compared to 19 percent in 1970. Seen from another vantage point, as a percentage of gross domestic product, European sales are also registering impressive increases, and reflecting the increasingly positive economic performance of the EEC.

The EEC's expansion of output in aerospace was achieved with a relatively constant workforce from 1972-1977, indicating a strong increase in the productivity of European aerospace workers. While the U.S. still leads in productivity, there is no question that the European aerospace industry has strongly increased its relative standing in the 1970s.

A look at government funding of aeronautics and space R&D shows that, in 1977, in all of the key countries of the EEC, aeronautical and space R&D made up a substantial

°Excluding USSR-built aircraft.

°°Latest year available, since there is generally a lag of three to four years in the reporting of statistical data by the European Economic Community.

portion (between 48 and 55 percent) of total government funding to increase industrial productivity (Table 11). The total U.S. effort for aeronautics and aerospace represented about 52 percent of funding and the European countries are now spending at a level nearly equal to or, in some cases, surpassing the U.S. effort. While the U.S. effort in space and aeronautics has been decreasing, the European effort has increasingly expanded, particularly in space (Spacelab) and civilian aeronautics (A300-A310 development and SST technology).

Soviet R&D and Defense Efforts

Although the Soviet Union plays a minor role in the high-technology world market, its investment in R&D and technology is considerable, with important political and military implications for the United States. In today's world, U.S. economic, political and military strength are intertwined and depend alike on technological leadership. Any assessment of the R&D foundations of U.S. economic strength would be incomplete without a comparison of the technological investments of the U.S. and the Soviet Union. To a large extent this involves a focus on defense efforts.

It is generally agreed the Soviet Union has exceeded the U.S. in total defense outlays and in many areas of tactical and strategic importance. In 1979, total Soviet defense outlays were nearly 50 percent higher and their level of strategic forces about three times that of the United States. Generally, U.S. weapon systems have been credited with technological superiority—with greater accuracy, precision and effectiveness. Given developments in the relative R&D efforts of the two countries, however, there are serious questions about whether even the technological lead of the United States can be maintained.

Any comparison of expenditures between the United States and the Soviet Union is open to question and the level of R&D funding is no exception. To avoid dollar comparisons, a more accurate indication of the general level of R&D funding would be the total manpower pool developed, available and applied in both countries. With respect to scientific and engineering manpower, there is every indication the Soviets have outpaced the United States. While U.S. R&D employment peaked in 1968, it then declined and stabilized in the mid-1970s and has since increased relatively slightly. As of the end of the 1960s, Soviet manpower figures exceeded those of the U.S. The annual rate of manpower growth in the U.S. pulled ahead between 1975 and 1978 but, in 1978, there were nearly 30 percent fewer scientists and engineers employed in R&D efforts in the United States (595,000) than in the Soviet Union (828,100).

A close look at the composition of the manpower pool indicates the Soviets were graduating, by 1976, about twice as many in the natural sciences and engineering as the United States. In terms of the manpower pool for R&D in the "hard sciences," the Soviets lead by about three to two—a ratio that should increase as the Soviet rate of graduation of new scientists and engineers continues at high levels.

If, in the long run, rough equivalence between trained researchers can be assumed, at what point will the U.S. qualitative lead in strategic and tactical military technology erode to the point of *qualitative* parity?

CONCLUSIONS

Although increased R&D funding is not proposed as a total solution to the decline in U.S. innovation, R&D has provided the foundation for high-technology innovations that, clearly, are major contributors to U.S. economic strength today.

But the world has changed and the U.S. does not stand alone in the arena of technological achievement. A comparison of the trends in R&D funding in the U.S. and other countries indicates the U.S. effort is declining relative to that of other nations and leaves open to question whether the U.S. will continue to reap economic benefits from its high-technology industrial sector.

In aerospace, while the U.S. still enjoys a dominant position based on technological superiority, R&D funding developments and trends in world market sales indicate there is little room for complacency.

Generally, the expansion of aerospace R&D funding in the U.S. has reflected inflationary rather than real growth. For a time during the 1970s, aerospace sales reflected largely inflationary growth as well. More recent real increases in industry output have been due largely to the introduction and sale of new commercial jetliners and to significant growth in general aviation and commercial helicopter sales. Sales should continue at high levels as the world commercial transport market may reach an estimated $140 billion by 1990. Over-optimism, however, must be tempered. The European aerospace industry has achieved increasingly higher levels of productivity as well as technological sophistication and made real inroads in the world market. There is every reason to believe European competition will be stepped up during the decade ahead. There will be competition, too, from other nations now beginning to penetrate the world market, or planning to do so. U.S. competitors, it is worth noting, frequently have strong government support in the area of R&D funding as well as in export and innovation incentives. Trends indicate the U.S. market share is very likely to decrease substantially.

Although, in a commercial sense, the technological progress of the Soviet Union has no current direct bearing on the aerospace industry, trends in Soviet science and technology have serious military and national policy implications. The military posture of the United States relies no longer on numerical superiority—but on technological superiority alone. Furthermore, the widening gap between Soviet and U.S. scientific and engineering manpower pools—in favor of the Soviet Union—prompts the question of how much longer U.S. technological superiority can be maintained.

This study looked at the effects of R&D on the competitive position of individual sectors of the U.S. economy, and especially aerospace, in international trade. Strong, positive relationships were observed between R&D and the net trade position for each sector. The effects of federally-funded R&D performed by industry were found to have an equally strong favorable impact. If anything, industries that perform federally-funded R&D outperform other sectors of the U.S. economy in worldwide trade.

In light of the unfavorable U.S. balance of trade in recent years, every effort should be made to encourage and provide the necessary support for those high-technology industry sectors that contribute to a positive balance.

One conclusion that can be drawn from the above observations is that the United States does need a long-term R&D and technology policy based on a partnership between government and industry. The federal role in R&D and technology support has been lagging and new and significant initiatives are warranted.

RECOMMENDATIONS

In the fall of 1979, the Administration released recommendations to Congress aimed at spurring industrial innovation. Its recommendations were the culmination of an 18-month Domestic Policy Review and ranged from changes in federal procurement to improvements in the regulatory system. Still, the proposals do not go far enough in the direction of substantive action—particularly fiscal policy change—to reverse the downward trend in innovation.

Since that time, the U.S. has faced abruptly the realities of international confrontation and economic crisis. Spiraling energy costs are central in both matters and it is more clear than ever that policies and legislation should not stymie but, rather, *encourage* innovation. National and world economic stability and, ultimately, peace itself depend upon economic health and growth. These, in turn, depend upon innovative technology—particularly with respect to alternate energy sources. The events of late 1979 and early 1980 point up the importance of adopting and implementing the following recommendations.

For Presidential Direction

Essential steps in improving the environment for innovation require direction of the Administration. The Aerospace Industries Association recommends:

- Continuation of strong initiatives toward increased defense funding, including emphasis on military R&D.
- Development, by the Office of Science and Technology Policy, the National Science Foundation and the Department of Commerce working in consonance, of a long-range national R&D policy.
- Development of definitive rules for the establishment of private sector consortia to develop high potential international markets.
- Establishment of a policy under which federal agencies would not require delivery of proprietary data except where an absolute government need is established—and fair compensation made.
- Adoption of recommendations of the Commission on Government Procurement on federal cost recovery/recoupment and cost sharing.

For Congressional Action

Sound federal policy decisions cannot be made without thorough knowledge of their possible effects on innovation and an essential first step is modification of federal policies that lack unity and coherence, and that retard rather than stimulate innovation and technological advance. Accordingly, Congress should take action to:

- Recognize the important role of research and development in the solution of economic problems and assure full and stable funding levels based on a long-range national R&D policy.
- Revise tax laws to permit depreciation allowances based on the reacquisition cost of capital.
- Provide new tax credits for industry investment in R&D.
- Substantially increase the tax credit for investment in plant and equipment employed in R&D programs.

- Amend the tax system to stimulate export expansion with emphasis on depreciation, investment tax credit, and other tax incentives.
- Monitor multilateral trade negotiation agreements to reduce trade barriers between countries and insure agreements are adhered to and amended as required by evolving national and international agreements.
- Extend close cooperation to the Administration during the transition of trade functions between the Department of Commerce and the Office of the U.S. Trade Representative.
- Base government regulations on conclusions of cost-benefit analyses.
- Provide for evaluation and rejustification of all regulations on a regular basis.
- Provide for evaluation of regulatory agencies on a regular basis.
- Clarify Congressional intent in existing statutes regarding patents developed under government contract.
- Establish a patent license policy for all federal agencies.
- Preclude acquisition or dilution by the government of contractors' rights in background patents.
- Prohibit use of narrow patent authorization and consent provisions or clauses.
- Provide a procedure for "instant licensing" by all federal agencies.
- Remove restraints placed on Independent Research and Development (IR&D) by current law.
- Recognize IR&D as a necessary cost of doing business.
- Provide that IR&D be truly independent as regards the performer's choice and execution.
- Free IR&D from technical audit and judgment by government.
- Recognize government should not seek license in intellectual property such as patents, copyrights, or technical data developed during company-initiated and company-funded work.
- Amend the Freedom of Information Act to provide effective mandatory safeguards for proprietary data.

For Industry Action

While government must take the lead in establishing policy and a climate supportive of innovation, industry must accept responsibility for utilizing its resources as imaginatively and cost-effectively as possible and for making the greatest possible commitment to future technological development. Industry should take action to:

- Promote sustained, appropriate federal R&D funding based on long-range policy, as well as industry R&D funding on a matching funds basis.
- Take initiative in proposing funding for specific high-potential projects.
- Continue to pursue joint venture possibilities with other nations.
- Promote and support more imaginative job training programs—such as internships—to attract young people to industry, with emphasis on developing programs that facilitate mobility of specific manpower resources.
- Increase funding for R&D.
- Increase capital investment to improve productivity, encourage innovation, enhance product quality and lower unit cost, in order to be more competitive in world markets.

THE DECLINE IN FEDERAL FUNDING OF R&D

Although overall federal R&D funding is headed upward in terms of current dollars, the picture is quite different when viewed in terms of the more realistic and comparable measure of constant dollars.

Summarized in Table 1 are the trends in the conduct of R&D by major program area in current dollars for the past 21 years. Total federal funding of R&D increased from \$66.9 billion (1962-1966) to \$147.4 billion (1977-1981). Particularly noticeable is the \$56.9 billion increase from the third to the fourth period (more than 60 percent). Defense R&D shows a steady upward trend from \$37.6 billion to \$70.9 billion. Civilian R&D increased more than five-fold from \$10.6 billion to \$58.0 billion. The only item which fares badly is space; in that area funding decreased 30 percent in the 1972-1976 period from the highpoint of the late 1960s. The trend is again upward but funding is still less than at any time during the 1960s.

This favorable view of federal R&D funding is seriously misleading, however, as shown in Table 2 and Figure 1. Here, funding is presented in constant dollars and, in these terms, total dollar funding of federal R&D in the last ten years is 9 percent below that of the 1962-1971 period. Instead of experiencing a steady upward trend, total dollar defense R&D for the last ten years has actually decreased nearly 17 percent from the previous decade. Current dollar figures for space R&D funding for 1977-1981 appear to reflect a return to the level of funding of the 1962-1971 period. Actually, in constant dollars, the funding of the last decade represents a 50 percent cutback over the previous ten years. The only positive development is the nearly two and one-half-fold expansion of civil R&D from \$14.5 billion to \$34.7 billion. But, in defense and space, an absolute dollar funding cutback of significant proportions has occurred.

The percent of GNP columns in Table 1 show, too, the downward trend in federal R&D funding. Total funding for the last ten years, expressed as a percentage of GNP, is down 34 percent from the previous decade. In civil R&D the trend continues upward but the commitment of funds to defense R&D is down 38 percent from the previous ten-year period and space R&D funding has decreased by 60 percent.

A look at the apportionment of funds between basic and applied research and between defense and non-defense R&D in Table 3 reveals some upward movement in constant dollar funding in recent years with the greatest increase occurring in 1981. The notable increase is in defense—a result of the defense emphasis in the FY 1981 budget. Basic and applied research funding are up somewhat for 1981—about 4 percent over 1980. Most importantly,

TABLE 1

TRENDS IN CONDUCT OF FEDERAL R&D BY MAJOR PROGRAM AREA 1962-1981

(Billions of Current Dollars)

Year	Defense	Percentage of GNP	Civil (Other than Space)	Percentage of GNP	Space	Percentage of GNP	TOTAL[a]	Percentage of GNP
1962-1966	37.6	1.2%	10.6	0.3%	18.7	0.6%	66.9	2.1%
1967-1971	41.4	0.9	18.7	0.4	18.9	0.4	78.8	1.7
1972-1976	47.0	0.7	30.3	0.4	13.2	0.2	90.5	1.3
1977-1981	70.9	0.6	58.0	0.5	18.5	0.2	147.4	1.2

SOURCE: The Office of Management and Budget, "Special Analysis K, Research and Development," *Special Analyses—Budget of the United States Government—Fiscal Year 1981*, p. 335.

a Details may not add to totals because of rounding.

TABLE 2

TRENDS IN CONDUCT OF FEDERAL R&D BY MAJOR PROGRAM AREA 1962-1981

(Billions of Constant Dollars—1972 = 100[a])

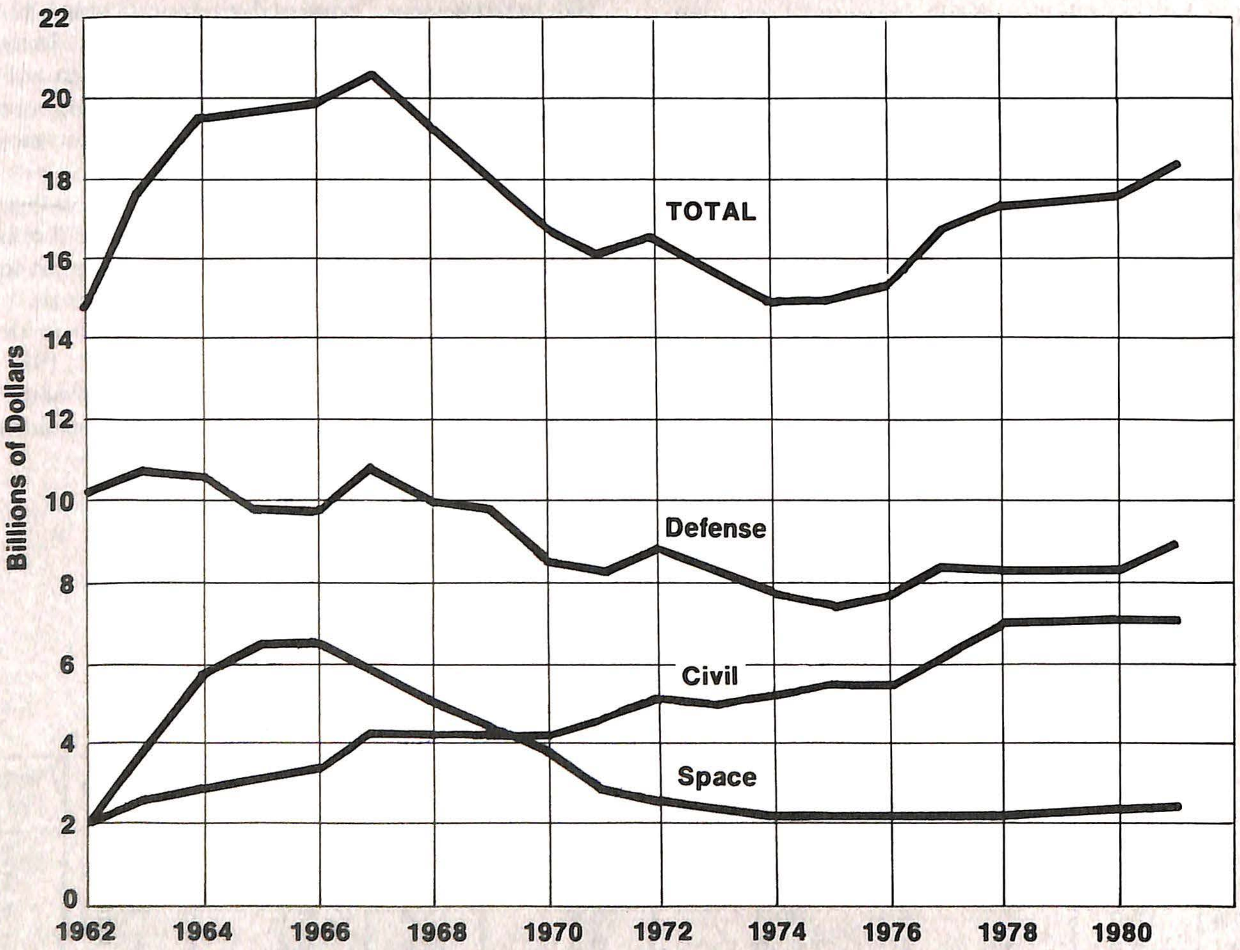
Year	*Defense*	*Civil (Other than Space)*	*Space*	*TOTAL[b]*
1962-1966	51.4	14.5	25.3	91.1
1967-1971	47.9	21.5	22.0	91.0
1972-1976	40.6	25.8	11.6	78.0
1977-1981	42.3	34.7	11.0	87.9

a GNP implicit price deflator.
b Details may not add to totals because of rounding.

FIGURE 1

TRENDS IN CONDUCT OF FEDERAL R&D BY MAJOR PROGRAM AREA 1962-1981

(Billions of Constant Dollars—1972 = 100[a])



a GNP implicit price deflator.

TABLE 3

TRENDS IN CONDUCT OF FEDERAL BASIC, APPLIED AND DEFENSE R&D 1967-1981

(Billions of Dollars)

Year	TOTAL OBLIGATIONS	Basic	Applied	Defense	Other
CURRENT DOLLARS					
1967	16.5	1.8	14.7	8.6	7.9
1968	15.9	1.8	14.1	8.3	7.6
1969	15.6	1.9	13.7	8.4	7.2
1970	15.3	1.9	13.4	8.0	7.3
1971	15.5	2.0	13.5	8.1	7.4
1972	16.5	2.2	14.3	8.9	7.6
1973	16.8	2.2	14.6	9.0	7.8
1974	17.4	2.4	15.0	9.0	8.4
1975	19.0	2.6	16.4	9.7	9.3
1976	20.8	2.8	18.0	10.4	10.4
1977	24.0	3.3	20.7	11.9	12.1
1978	26.4	3.7	22.7	12.6	13.8
1979	28.9	4.1	24.8	13.6	15.3
1980[E]	32.0	4.5	27.5	14.9	17.1
1981[E]	36.1	5.1	31.0	17.9	18.2
CONSTANT DOLLARS[a]					
Year	TOTAL OBLIGATIONS	Basic	Applied	Defense	Other
1967	20.9	2.3	18.6	10.9	10.0
1968	19.3	2.2	17.1	10.1	9.2
1969	18.0	2.2	15.8	9.7	8.3
1970	16.7	2.1	14.6	8.7	8.0
1971	16.1	2.1	14.0	8.4	7.7
1972	16.5	2.2	14.3	8.9	7.6
1973	15.9	2.1	13.8	8.5	7.4
1974	15.0	2.1	12.9	7.8	7.2
1975	15.0	2.0	13.0	7.6	7.4
1976	15.6	2.1	13.5	7.8	7.8
1977	16.9	2.3	14.6	8.4	8.5
1978	17.4	2.4	15.0	8.3	9.1
1979	17.5	2.5	15.0	8.2	9.3
1980[E]	17.7	2.5	15.2	8.3	9.4
1981[E]	18.4	2.6	15.8	9.1	9.3

a GNP implicit price deflator.
E Estimated.

however, constant dollar figures for the fifteen-year period show total funding for 1981 at 12 percent less than in the late 1960s, when funding peaked at $20.9 billion. A comparison of 1981 funding with that of the late 1960s shows notably lower levels (15 and 17 percent, respectively) for applied and defense R&D. Although in recent years, then, an upward trend can be perceived, funding has not reached the levels of the late 1960s.

Moreover, Table 3 shows clearly that the upward trend must be viewed in perspective, as funding was significantly low in the mid-1970s. In 1974 and 1975, for example, the overall level of funding was nearly 20 percent less than that estimated for 1981. For every program category, the mid-1970s level was between 15 and 22 percent less than for 1981. R&D has not been funded at sustained levels over the period shown and recent increases cannot be viewed as compensating totally for the significant cutbacks of the mid-1970s.

It should be noted that considerably greater amounts of money are being spent on applied rather than basic research, an indication investment is not being made where important longer-term payoffs in innovation will occur.

The figures, adjusted for inflation, show a downward trend in federal R&D funding in all areas except civil R&D. Overall, expressed in constant dollars and as a percentage of GNP, funding has decreased. But the figures themselves must be viewed in a larger context—in terms of the relationship of R&D to innovation, to a stronger U.S. market position, and a healthier economy. This study investigates, specifically, the link between R&D and positive net trade balance and places the results in this broader context.

At this point, the question has to be asked: If R&D has a beneficial effect on innovation and a stronger international market position, what will be the long-term effect of funding cutbacks?

THE LINK BETWEEN R&D AND INTERNATIONAL TRADE

Economists have attempted to gain a scientific understanding of just how—and how much—R&D helps the economy and a brief review of work in this area is presented on page 39. Frequently, economists disagree over methodology in *measurement* of the effects of R&D but there is among them—and among those concerned with public policy regarding science and technology—a general consensus of the overriding importance of innovation resulting from R&D in building the economy.

Willis and Shapley note that: "When the net effect (of innovation arising out of R&D) is an increase in production and consumption, the result is overall economic growth. Through both of these mechanisms, innovation also makes a crucial contribution by helping our economy maintain or improve its competitive position in foreign markets. To the extent that increased efficiency and new products increase foreign sales of our products, there is an improvement in our balance of trade position and a positive contribution to our economic growth."[1]

This study, in exploring that link between R&D and balance of trade, found strong evidence of the *overriding importance of R&D to the trade position of the United States in world markets.* The results showed statistically the *very significant contribution R&D has made to the net trade balance of the United States and the strong apparent contribution made by federally-funded R&D.*[°] Fifteen major Standard Industrial Classification (SIC) commodity groups were used to investigate these relationships using data for a 21-year period.

R&D-intensive industries, it was found, are a major contributor to a positive balance of trade. In Table 4, R&D efforts and trade performance of major U.S. industries—averaged over 21 years—are summarized. The table summarizes the more detailed statistical findings reported in Appendix A and shows that those industries which devote the largest proportional effort to R&D tend also to be leaders in exports. This is especially obvious in the net trade column (exports minus imports), where it can be seen that industries with large R&D efforts are net exporters and those with small efforts are net importers.

The aerospace industry has been by far the largest relative net export industry of the United States economy over the 21-year period (1958-1978). Net trade amounted to nearly 12 percent of total aerospace sales during that time. (In 1979, net trade was 22 percent of total aerospace sales). The next ranked industries, in terms of net trade, are non-electrical machinery (10.3 percent), non-drug chemicals (5.3 percent), and instruments (5.1 percent)—each of them R&D-intensive industries.[°°]

At the bottom of net trade performance among the industries considered are the paper and primary metals (ferrous and non-ferrous) industries. Each of these industries also lacked in R&D and innovation over the 21-year period. The relatively low R&D effort of the food industry over the period is surprising; the small relative surplus of this industry in 1978 (Figure 2a) must be attributed more to the vast agricultural base of the United States than to any recent innovation or competitive advantage of the industry itself.

In Figures 2a and 2b, R&D intensity versus export intensity of major U.S. industries are shown relative to total sales, for 1978 and for 1958 to 1978 (21 years). The one industry that dominates in relative R&D intensity and export intensity for 1978 and for the 21-year period is the aerospace industry. R&D activities in aerospace amount to about one-fifth of total sales. Even among the highly innovative industries, aerospace performed substantially greater levels of R&D—three times more than the electric and electronic equipment industry and five times as much as instruments and drugs. Similarly, the R&D-intensive industries enclosed in the shaded area in the center of Figures 2a and 2b perform more R&D—generally three to five times as much—as the *non*-innovative, *non*-R&D-intensive industries shown to the lower left.

In Figures 2a and 2b, the industries are also plotted in terms of net trade as a percentage of sales, and an obvious correlation can be seen between high levels of R&D and net positive trade, and between low levels of R&D and a negative trade balance. In Figure 2b, which presents averages for the 1958-1978 period, only one R&D-intensive in-

[1] Willis and Shapley, *op. cit.*, p. 75.

[°] Appendix A., p. 42.

[°°] *R&D-intensive industries* are defined as those industries that perform R&D above the national average of R&D as a percentage of GNP (about 2.5 percent in the 1958-1978 period).

dustry – non-aerospace transportation – experienced a trade deficit. Figure 2a focuses on 1978 – the most recent year for which data are available. In that year, the transportation industry as a whole and the electric and electronic equipment industry also had trade deficits. The deficit of the transportation industry, and non-aerospace transportation particularly, apparently reflects the poor performance of the U.S. auto industry in recent years against foreign competition. The lagging performance of the electric and electronic equipment industry reflects increased imports of consumer electronic goods, particularly from Japan.

Non-drug chemicals can be seen (Figure 2a) to have slipped somewhat in R&D effort in 1978 from its 21-year average and is ranked, accordingly, with non-R&D intensive industries. Over the 21-year period, however, the R&D effort of the industry was above 2.5 percent of sales and this effort is reflected in its sizeable trade surplus.

As can be seen from Table 4 and Figures 2a and 2b, R&D and *net trade* performance by various sectors of the U.S. economy are, apparently, strongly related when averaged over the 21-year period.

A more recent breakdown of net trade performance of some key industrial sectors for 1979 is shown in Table 5. The same results, roughly, obtain when individual year "snapshots" are taken from 1960, 1965, 1970 and 1975. Year for year and decade for decade, the aerospace industry has been the most *research*-intensive and most *trade*-intensive industry of the United States, in terms of net contributions to the U.S. balance of trade. Aerospace contributed about twice as much to net trade as the next highest group of R&D-intensive industries. Aerospace also undertook R&D to the extent of 24 cents on every sales dollar compared to three to seven cents on every sales dollar for the R&D-intensive chemical, instrument and electric and electronic equipment industries.

Recently, trade balances of manufactured goods and of some high-technology goods have been eroding. In contrast, the contribution of aerospace exports in 1978 amounted to $10 billion compared to $7.5 billion for 1977, a growth of about 33 percent and 1979 figures reflect exports amounting to $11.7 billion, a further 17 percent increase.

As can be seen in Figure 2b, all other industries that are R&D-intensive for the 1958-1978 period also show a positive net trade balance with the single exception of the non-aircraft transportation industry (i.e., automobiles, trucks and buses); it is on the margin of R&D intensity (due, in part, to calling "restyling" R&D) and shows a

TABLE 4

AVERAGE R&D EFFORT AND TRADE PERFORMANCE OF MAJOR U.S. INDUSTRIES 1958-1978

SIC Commodity Groups	*R&D As A Percentage Of Sales*	*Scientists & Engineers As A Percentage Of Total Employment*	*Exports As A Percentage Of Sales*	*Net Trade As A Percentage Of Sales*
Transportation	8.34%	6.03%	8.02%	1.87%
Aerospace	23.74	12.91	13.24	11.80
Non-Aerospace	2.69	2.16	6.24	-1.48
Electric and Electronic Equipment	7.30	4.90	5.27	1.07
Instruments	4.88	3.15	10.17	5.11
Chemicals	3.21	4.12	7.43	5.13
Drugs	4.74	7.08	6.07	4.24
Non-Drugs	2.92	3.61	7.73	5.32
Non-Electrical Machinery	3.05	2.07	13.93	10.32
Rubber and Plastics	1.38	1.19	3.16	-.13
Stone, Clay, Glass	.90	.61	2.72	-.46
Petroleum and Coal	.77	4.50	1.14	-2.06
Paper	.69	.62	4.63	-3.53
Fabricated Metal	.63	.54	4.21	2.07
Primary Metals	.57	.50	3.70	-4.52
Non-Ferrous	.73	.71	4.44	-6.29
Ferrous	.70	.40	3.32	-3.62
Food	.21	.34	3.02	-.49

TABLE 5

UNITED STATES FOREIGN TRADE STATISTICS
1979
(Millions of Dollars)

Commodity Classification	*Exports*	*Imports*	*Balance of Trade*
Food and Live Animals	$22,245	$16,299	$ 5,946
Beverage and Tobacco	2,337	2,822	(485)
Crude Materials (inedible)	20,755	11,409	9,346
Mineral Fuels, Lubricants, etc.	5,616	63,861	(58,245)
Animal and Vegetable Oils and Fats	1,845	782	1,063
Chemicals	17,306	7,899	9,407
Manufactured Goods Classified by Material	16,236	32,103	(15,867)
Machinery and Transport Equipment	70,491	56,438	14,053
Misc. Manufactured Articles	12,643	22,333	(9,690)
Commodities and Transactions Not Classified According to Kind	9,103	4,982	4,121
Principal Sectors Included in Machinery And Transport Equipment			
Aerospace Products	$11,747	$1,624	$10,123
Special Purpose Machinery	9,882	4,563	5,319
General Industrial Machinery and Equipment	8,562	3,802	4,760
Office Machines and Computers	6,475	2,593	3,882
Power Generating Machinery (includes Aircraft Engines)	6,840	3,587	3,253
Electrical Machinery	8,635	6,813	1,822
Metalworking Machinery	1,391	1,530	(139)
Radio, TV, and other Telecommunications Equipment	2,957	6,404	(3,447)
Automobiles, Buses, Trucks and Parts	15,077	17,899	(2,822)
Analysis of Aerospace Balance of Trade			
Total Aerospace products	$11,747	$1,624	$10,123
Civil (including Transports)	9,772	1,622	8,150
Transport Aircraft	4,998	200	4,798
Military	1,975	2	1,973

SOURCE: U.S. Department of Commerce, *Highlights of U.S. Export and Import Trade,* Report FT 990, December 1979.

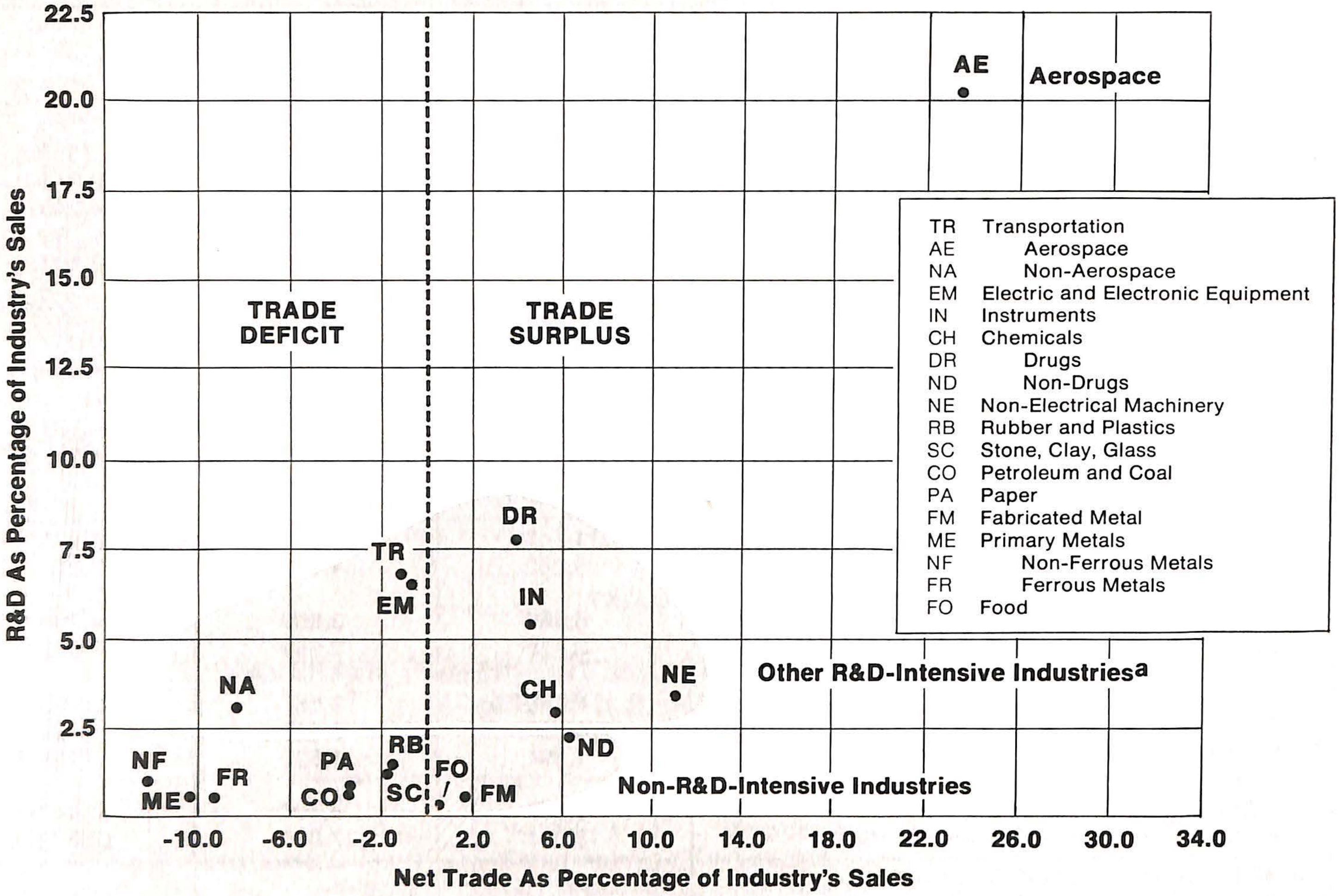
negative trade balance. Of the non-R&D-intensive industries, eight industry sectors show a negative trade balance and only one, fabricated metals, shows a positive net trade balance of 2 percent on every sales dollar. The food industry, over the 21-year period, has experienced a negative balance. It is quite export-intensive in some sectors (grain, soybeans) but is also quite import-intensive in many others (cocoa, coffee, sugar). In the sectors that are export-intensive, an existing and extensive R&D program is being conducted through the U.S. Department of Agriculture and private institutions.

The message of these summary data is quite clear: the industry sectors that perform a high level of R&D also export at high levels and make positive net trade contributions to the U.S. position in world trade. The sectors that lag in R&D efforts, lag in export and net trade contributions.

Some of the industry sectors that lag in R&D may not be amenable to research, innovation, new ideas and new processes. Nonetheless, if the U.S. is relying on R&D and innovation, where trade balance is concerned—and the level of R&D funding and innovation is down—the U.S.

FIGURE 2a.

R&D EFFORT AND TRADE PERFORMANCE OF MAJOR U.S. INDUSTRIES 1978



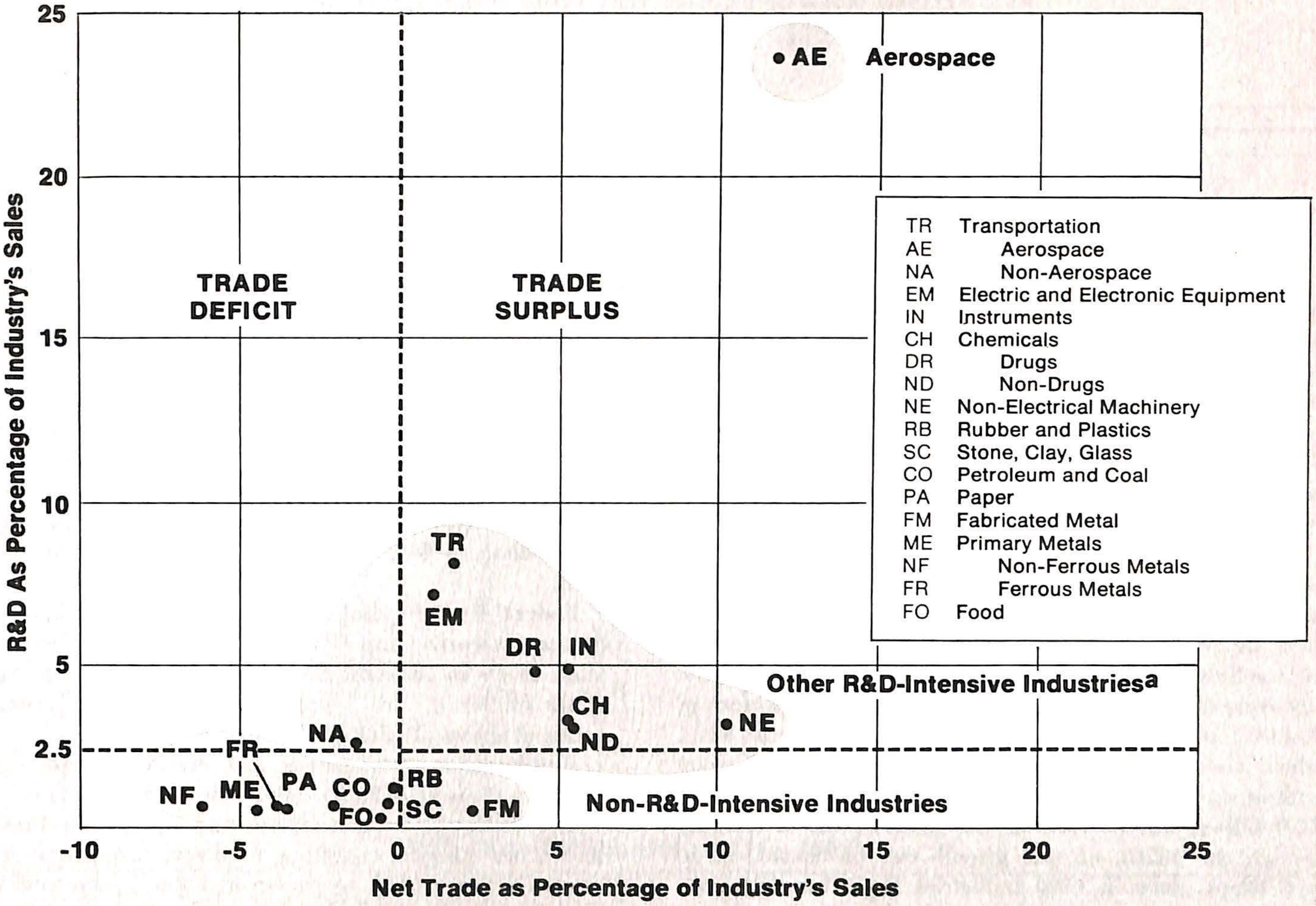
a Industries that perform R&D in excess of 2.5 percent of sales.

may be in a position of relative disadvantage to other economies.

The significant contributors to the U.S. balance of trade, then, whether expressed in terms of gross exports or net trade over sales, are nearly exclusively R&D-intensive industries. Industries with little or no R&D funding make little or no contribution to U.S. exports; rather, these industries show substantial trade deficits. The evidence suggests the issue of R&D funding is not set in a vacuum of scientific pursuit of pure knowledge, independent of economic matters. Rather, it has a direct bearing on the very substantive, competitive position of the U.S. economy in world trade: a position that can be greatly helped by an active science and technology policy cognizant of this connection.

FIGURE 2b.

AVERAGE R&D EFFORT AND TRADE PERFORMANCE OF MAJOR U.S. INDUSTRIES
1958-1978



a Industries that perform R&D in excess of 2.5 percent of sales.

AEROSPACE R&D AND TRADE PERFORMANCE

The aerospace industry has been predominant in R&D effort throughout the past two decades. In 1978, nearly 25 percent of all R&D performed by industry occurred in aerospace. Throughout the 1960s, in fact, aerospace performed an even greater portion of R&D than in more recent years—about one-third of the total—peaking in 1964 at 38 percent. Thus, developments in aerospace R&D must play a substantial part in any national R&D and technology policy discussion.

Total aerospace R&D expenditures from 1960-1978, and the amounts supported by federal and industry funds, are listed in Table 6. All industrial R&D expenditures are listed as well. In current dollar terms, total industrial R&D activity seems to have expanded steadily since 1960. However, if expressed in constant 1972 dollars (bottom of Table 6), industrial R&D funds peaked in 1969 at $21.1 billion, and then dipped below that level until 1977 when funding was again $21.1 billion. Funding for 1978 reached $22.0 billion but in view of the lower levels of funding through the 1970s, no real growth can be considered to have taken place in total industrial R&D funding since 1969.

Of the $7.7 billion of R&D performed by the aerospace sector in 1978, about 75 percent was funded by the federal government and 25 percent by industry ($5.8 billion and $1.9 billion, respectively). In current dollars, these figures indicated an 8 percent increase in total aerospace funding over the previous year ($7.7 billion over 7.1 billion). What current dollars fail to convey is that in *real* terms the 1978 funding of aerospace R&D constitutes a 27 percent cutback compared to the funding level of 1968, a decade earlier. The substantial percentage cutbacks occurred in both federal and industry funded R&D—cutbacks of 28 and 27 percent, respectively.

In real terms, aerospace R&D funding increased sharply in the early 1960s to a high of about $7.2 billion in 1966-67 and then steadily declined to a low of $4.5 billion by 1975. Funding has increased somewhat since that low point to $5.1 billion in 1978 but this figure reflects a lower level of funding than at any time since 1960.

A widespread, persistent notion in the economic community has been that if government funding of R&D were cut back, industry would make up the difference. No such developments are apparent in aerospace in the past decade. The average annual level of aerospace R&D funded by industry has been $1.1 billion through the 1970s compared to an average annual level of $1.3 billion in the second half of the 1960s (the years when wide body aircraft technology was being introduced in civil aircraft markets). In terms of constant (1972) dollars, federal funding of aerospace R&D has steadily declined since 1964—from a high of $6.3 billion to $3.9 billion by 1978, a cutback of 38 percent.

Federal R&D funding of aerospace—a key component of national security—has not been maintained at even constant levels in constant dollar terms, nor has funding for R&D efforts in this critical area remained constant in terms of shares of GNP (Table 1).

Employment of scientists and engineers can also be used as a measure of R&D activity since most R&D is "man-years" dedicated to such efforts with equipment, materials and other support changing in direct proportion to the man-effort expended. As shown in Table 7, the total number of scientists and engineers employed in industry in the United States for research and development, after steadily increasing throughout the 1960s, remained relatively constant in the 1970s, fluctuating between 350,000 and 400,000 until 1979, when it reached 427,800. Aerospace employment of scientists and engineers for R&D fell by 30 percent from a high of 101,100 in the latter half of the 1960s (staying constant at roughly 100,000 from 1964 to 1969) to a level of about 70,000 in the 1975-1977 period. The trend in aerospace R&D employment has been upward in the last two years reflecting some increase in R&D funding but due primarily to development of the newer generation of commercial transport aircraft. The figures show some parallel movement between funding and employment of scientists and engineers.

Neither the funding nor the employment figures present a particularly encouraging picture of U.S. aerospace R&D effort at either the national or industrial level for the past 10 to 15 years. The figures become more significant, however, when compared with the relative efforts of other countries, including the Soviet Union (see page 33).

TABLE 6

INDUSTRIAL RESEARCH AND DEVELOPMENT ALL INDUSTRIES AND THE AEROSPACE INDUSTRY Calendar Years 1960 - 1978

(Billions of Dollars)

	All Industries	Aerospace Industry		
Year	*TOTAL*	*TOTAL*[a]	*Federal Funds*	*Industry Funds*
CURRENT DOLLARS				
1960	10.5	3.5	3.2	.4
1961	10.9	3.8	3.4	.4
1962	11.5	4.0	3.6	.5
1963	12.6	4.7	4.3	.5
1964	13.5	5.1	4.6	.5
1965	14.2	5.1	4.5	.6
1966	15.5	5.5	4.7	.8
1967	16.4	5.7	4.5	1.1
1968	17.4	5.8	4.5	1.2
1969	18.3	5.9	4.5	1.4
1970	18.1	5.2	4.0	1.2
1971	18.3	4.9	3.9	1.0
1972	19.6	5.0	4.0	1.0
1973	21.2	5.1	3.9	1.2
1974	22.9	5.3	4.0	1.3
1975	24.2	5.7	4.4	1.3
1976	27.0	6.3	4.9	1.4
1977	29.9	7.1	5.5	1.6
1978	33.4	7.7	5.8	1.9
CONSTANT DOLLARS (1972 = 100)[b]				
1960	15.3	5.1	4.5	.6
1961	15.7	5.5	4.9	.6
1962	16.3	5.7	5.1	.7
1963	17.6	6.6	6.0	.7
1964	18.6	7.0	6.3	.7
1965	19.1	6.9	6.1	.8
1966	20.2	7.2	6.1	1.0
1967	20.8	7.2	5.7	1.4
1968	21.1	7.0	5.4	1.5
1969	21.1	6.8	5.2	1.6
1970	19.8	5.7	4.4	1.3
1971	19.1	5.1	4.1	1.0
1972	19.6	5.0	4.0	1.0
1973	20.0	4.8	3.7	1.1
1974	19.7	4.6	3.4	1.1
1975	19.0	4.5	3.5	1.0
1976	20.2	4.7	3.7	1.0
1977	21.1	5.0	3.9	1.1
1978	22.0	5.1	3.9	1.1

SOURCE: National Science Foundation.

a Details may not add to totals because of rounding.
b GNP implicit price deflator.

TABLE 7

TOTAL AND AEROSPACE EMPLOYMENT OF SCIENTISTS AND ENGINEERS FOR RESEARCH AND DEVELOPMENT 1960-1979

(Thousands of Employees)

Year	*TOTAL*	*Aerospace*	*Aerospace As A Percentage of TOTAL*
1960	292,00	72,400	24.8%
1961	312,100	78,500	25.2
1962	312,000	79,400	25.4
1963	327,300	90,700	27.7
1964	340,200	101,100	29.7
1965	343,600	99,200	28.9
1966	353,200	99,300	28.1
1967	367,200	100,400	27.3
1968	376,700	101,100	26.8
1969	387,100	99,700	25.8
1970	384,200[r]	92,200	24.0
1971	367,000[r]	78,200	21.3
1972	350,200[r]	70,800	20.2
1973	357,700[r]	72,100	20.2
1974	360,000[r]	70,600	19.6
1975	363,300[r]	67,500	18.6
1976	364,400[r]	66,900	18.4
1977	382,800[r]	72,000	18.8
1978	403,700[r]	82,000[r]	20.3[r]
1979	427,800	86,600	20.2

SOURCE: National Science Foundation; Aerospace Industries Association, *Aerospace Facts and Figures, 1979/80.*
NOTE: Data for Years 1969-1978 were revised by the Bureau of the Census.
r Revised

Impact of R&D Funding Changes on the Aerospace Industry

While the statistical analyses described in Appendix A show a persistently strong relationship between R&D and trade balance position of various U.S. industries over the past two decades, statistical techniques do not lend themselves easily to a determination of leads and lags in R&D, prototype development, new product introduction, and product life cycles.

An important hypothesis of international trade is known as the "product life cycle" explanation of trade: that is, that the first company or country to introduce a product has an advantage of between five to ten years in that particular product line in worldwide competition. Findings of one research study by ECON of the telecommunications industry of the United States[1]—relating research and development to productivity increases and output changes for that industry—have led to estimates of lead-lag times between R&D and production efficiency changes of from seven to 15 years. If product life cycle theories of international trade hold, and if the findings on R&D and productivity for the telecommunications industry also hold for other industrial sectors, increasingly negative effects can be expected from cutbacks in aerospace R&D on the competitive posture of the United States in civil as well as military markets for aerospace products. And, although the following discussion is limited to developments in aerospace markets, adverse developments in the aerospace sector should give rise to broader concerns of national economic and science and technology policy.

The United States Position in World Aerospace Markets

Exports by the aerospace industry saw a dramatic upward development in the late 1960s and into the mid-1970s. This strong upward movement of export sales seems to confirm, or be consistent with, either the "product life cycle" theory of international trade or the time lags between R&D and production functions in the telecommun-

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[1] *The Effects of Research and Development Activities on Technological Change and Economic Welfare: A Review of Analytical Approaches and Empirical Evidence*, Vol. 1, Executive Summary; Vol. 2, Final Report. Performed for National Aeronautics and Space Administration by ECON, Inc., March 8, 1976.

TABLE 8

TOTAL AND AEROSPACE BALANCE OF TRADE
Calendar Years 1960 - 1979
(Millions of Dollars)

Year	*TOTAL U.S. Trade Balance*[a]	Aerospace			*Aerospace Trade Balance As A Percentage of U.S. TOTAL*
		Trade Balance	*Exports*	*Imports*	
1960	$ 5,369	$ 1,665	$ 1,726	$ 61	31.0%
1961	6,096	1,501	1,653	152	24.6
1962	4,180	1,795	1,923	128	42.9
1963	6,061	1,532	1,627	95	25.3[r]
1964	7,555	1,518	1,608	90	20.1
1965	5,875	1,459	1,618	159	24.8
1966	4,524	1,370	1,673	303	30.3
1967	4,409	1,961	2,248	287	44.5[r]
1968	1,133	2,661	2,994	333	234.9
1969	1,599	2,831	3,138	307	177.0
1970	2,834	3,097	3,405	308	109.3
1971	-2,024[b]	3,830	4,203	373	NA
1972	-6,351	3,230	3,795	565	NA
1973	1,222	4,360	5,142	782	356.8
1974	-2,996	6,350	7,095	745	NA
1975[r]	9,630	7,045	7,792	747	73.2
1976[r]	-7,786	7,267	7,843	576	NA
1977[r]	-28,970	6,850	7,581	731	NA
1978	-31,798	9,058[p]	10,001	943	NA
1979	-27,345	10,099	11,556	1,457	NA

SOURCE: Bureau of the Census, *U.S. Exports, Schedule B, Commodity and Country,* Report FT 410; *U.S. Imports, General and Consumption, Schedule A, Commodity and Country,* Report FT 135; *Highlights of U.S. Export and Import Trade,* Report FT 990 (all monthly publications).

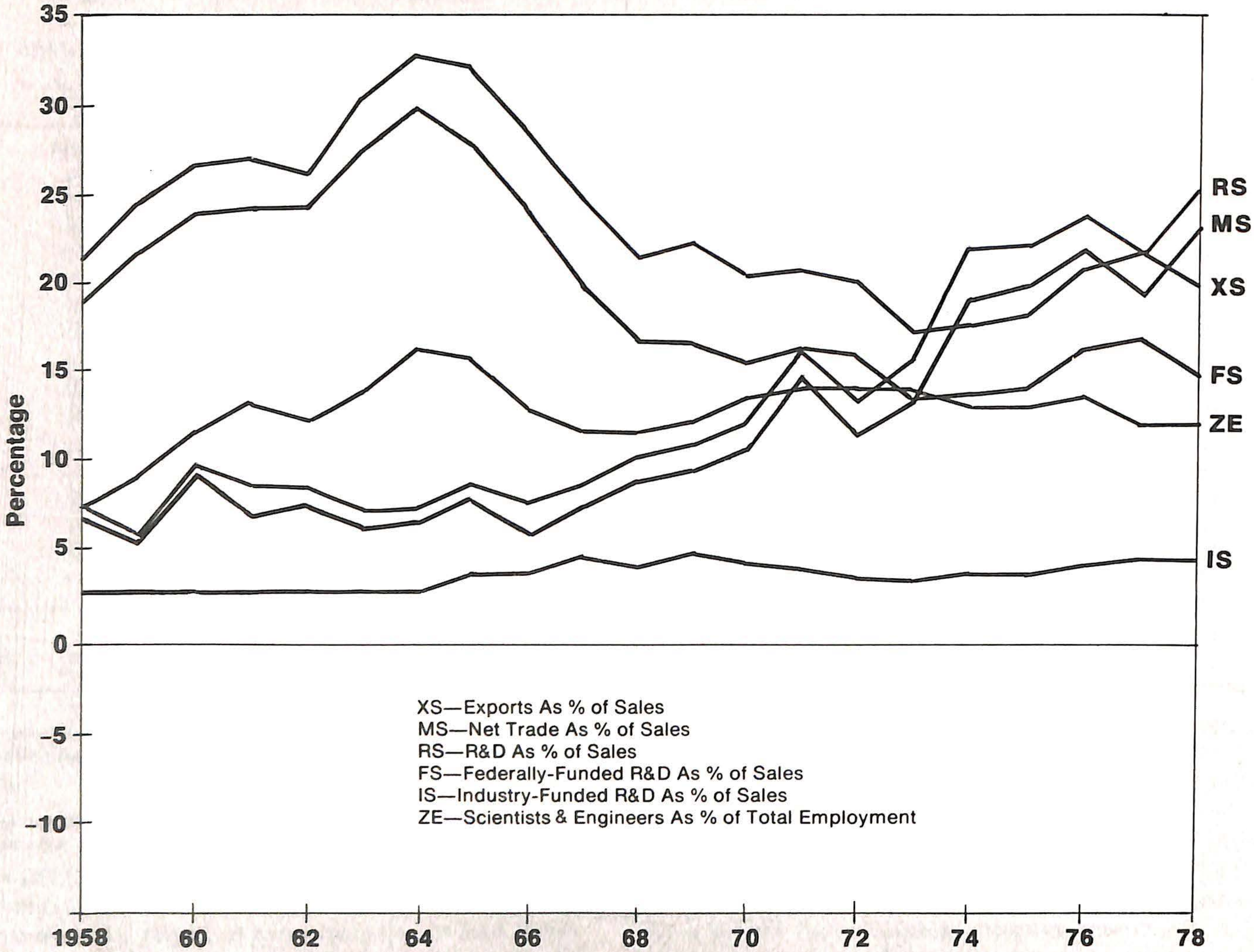
a U.S. Balance of Trade is the difference between exports of Domestic Merchandise, including Department of Defense shipments, and imports for consumption (Customs Value Base).
b First negative U.S. Balance of Trade since 1888.
NA Not Applicable since "Total U.S. Trade Balance" was negative.
r Revised.
p Preliminary figures.

ications industry. At the same time, the reduction of R&D funding since then, particularly by the federal government, lends strong support to the hypothesis that in the next decade the competitive advantage of the U.S. aerospace industry in international markets will decrease—with a concurrent decrease of the U.S. world market share. With a continuing relative lack of aerospace R&D, the U.S. position in civil as well as military markets can be expected to erode.

The U.S. aerospace balance of trade from 1960 to 1979 is shown in Table 8. Except for downturns in 1972 and 1977, aerospace export sales expanded continuously for more than a decade. And, as mentioned earlier, preliminary figures indicate 1979 exports will reach $11.5 billion. The late 1970s highpoint in aerospace exports is largely the result of an upturn in demand for transport aircraft to re-equip the world civil airline fleet. To a lesser extent, the strong competitive position of aerospace products in world markets can be attributed to the weak position of the dollar resulting from the increasing U.S. trade balance deficit. At question is whether the industry's strong export position will carry over into the mid-1980s and beyond in view of increasing world competition. The European Airbus and the United Kingdom's efforts in transport aircraft pose serious competition. There is evidence of possible competition from Japan and even from such smaller countries as Brazil which has made great strides in general aviation and is increasingly pene-

FIGURE 3

AEROSPACE INDUSTRY EXPORTS, NET TRADE AND R&D AS A PERCENTAGE OF SALES AND EMPLOYMENT OF SCIENTISTS AND ENGINEERS AS A PERCENTAGE OF TOTAL EMPLOYMENT



trating the world small aircraft market. Unless the United States invests in R&D on a scale sufficient to maintain its dominance, the position of present and potential competitors in the world aircraft market will be strengthened to its detriment.

A diminishing of U.S. market dominance in aerospace is especially serious in light of the industry's contribution to the U.S. trade balance. In no other sector of the world economy has the United States held such a preponderant position as in aerospace. Of all turbine-engined aircraft in the world airline fleet in 1979, for example, over 68 percent (5,341 of a total of 7,787) were manufactured in the United States. Nearly 85 percent of all turbojet aircraft and more than 80 percent of all turbine-powered helicopters in service were of U.S. manufacture.

As to the future, it is estimated that the transport market over the next ten years will be as much as $140 billion. Obviously, the economic stakes, and the competition for aerospace markets, will be great.

Since the study results described in Appendix A suggest a very strong statistical relationship between R&D and export performance of various sectors of the U.S. economy, adverse trends might be expected to develop for the United States in world aerospace products markets. If the life cycle theory of international trade flow holds, a five to ten-year gap might also be expected between R&D expenditures and noticeable negative effects in the export performance of the aerospace sector. Clearly, to establish any precise time lag, or statistical proof of such a correlation, longer time series or substantially better cross-sectional data bases would be required than are currently available.

Shown in Figures 3 and Appendix B are data for 18 major U.S. industry sectors for exports, net trade and R&D expenditures (broken down into federally-funded and industry-funded R&D)—all as a percentage of total sales—as well as the employment of scientists and engineers as a percentage of total employment. In Figure 3, aerospace industry data are plotted while comparable data are shown for each of the other industry sectors in Appendix B, page 53.

A comparison of aerospace industry developments in Figure 3 with those of other U.S. industries (Figure 10) leads to the observation that nearly all other industries have seen little if any change from year to year throughout the past two decades in terms of the relative development of R&D funding, exports, net trade, and employment of scientific manpower. Nearly all of the variables plotted in the respective diagrams are "steady state" extensions with little change from year to year.

As is evident from Figure 3, the aerospace industry underwent several dramatic changes when expressed in relative terms. The notable change, as a percentage of sales dollars, is in federal R&D funding: it increased substantially in the late 1950s to the mid-1960s and then decreased in the next decade. The industry-funded portion of R&D stayed nearly constant throughout the two decades but federally-funded R&D, after increasing from around 18 percent in the late 1950s to nearly 30 percent at the peak of the mid-1960s, thereafter dropped to a level of about 15 percent of sales by the mid-1970s. Compared to the level of the mid-1960s, this was a 50 percent relative cutback. The substantial and closely parallel changes in scientific manpower employment, of course, relate to the level of R&D funding.

A few industries for which data is plotted (pages 53-57) showed some exceptions from the typical steady state, but in each case those movements took place with regard to exports and net trade. R&D activities, including federally-funded R&D and the employment of scientists and engineers, remained unchanged in each of the other industries if measured as a percentage of sales. In transportation (other than aerospace), a positive development of exports is more than offset since the mid-1960s by increasing car imports leading to a growing negative net trade balance. In part, this is explained by the greater energy efficiency of most imported cars. In the non-electrical machinery industry, the positive developments in computers led to a substantial and expanding export balance as well as net trade balance through the mid-1970s. Most of the other industries can be considered as static, with little or no change.

Because only aerospace shows large relative changes in R&D activity, there is but one time series to test the hypothesis that there is a time-lag relationship between the level of R&D funding and exports. In addition, if the lead-lag position were ten years or more, not enough time has elapsed to prove statistically the relationship between the downturn of aerospace funding and a possible downturn in the U.S. export position in aerospace products.

Nevertheless, a comparison of aerospace sales of the United States and several European countries, and the EEC as a whole, from 1970 to 1977, is illustrative of possible developments. The most recent comparable figures, based on 1970 constant prices to eliminate inflationary effects, are summarized in Table 9. The trends in EEC

TABLE 9

UNITED STATES AND EUROPEAN AEROSPACE INDUSTRY SALES IN 1970 CONSTANT PRICES 1970-1977

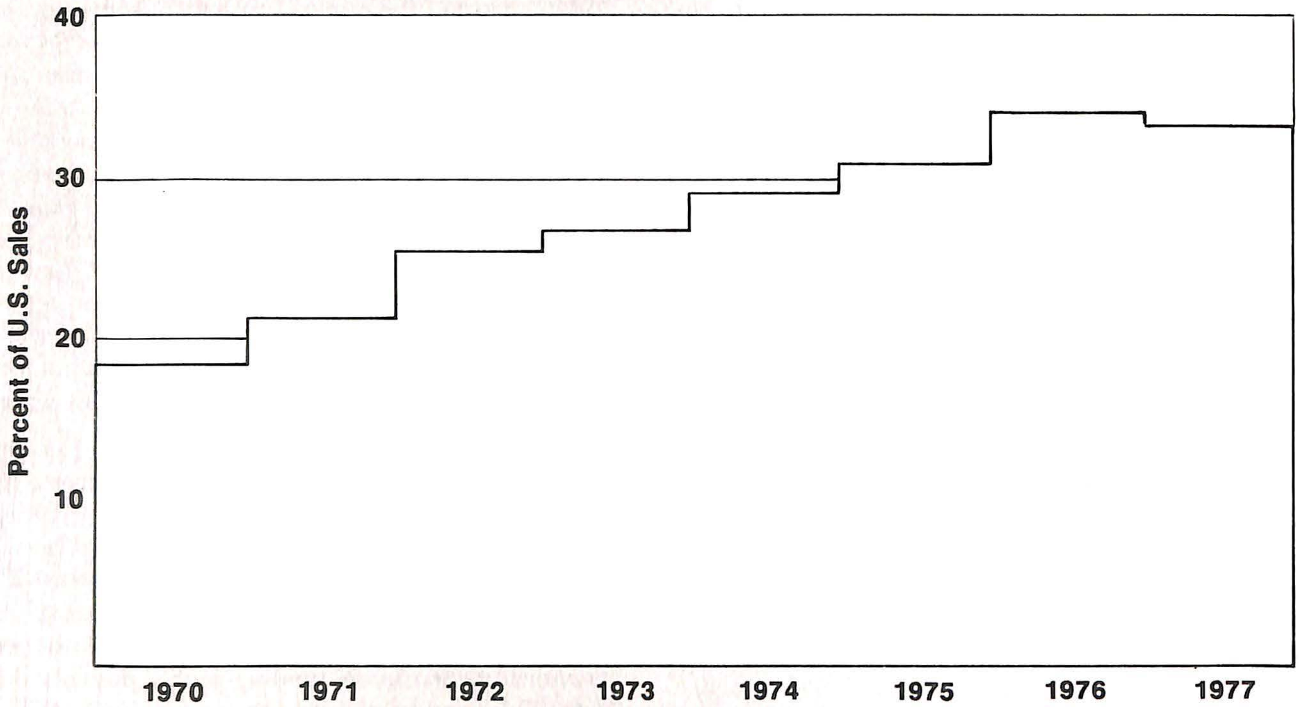
(Millions of U.S. Dollars)

Year	West Germany	Belgium	France	Italy	Netherlands	United Kingdom	EEC	United States
1970	$ 787	$40	$1,339	$232	$115	$1,611	$4,124	$22,258
1971	800	52	1,372	215	115	1,549	4,102	19,152
1972	853	65	1,522	358	156	2,128	5,082	20,242
1973	1,013	59	1,945	385	142	2,447	5,991	22,365
1974	919	60	2,014	352	105	2,481	5,930	20,476
1975	925	73	2,206	444	155	2,568	6,371	20,568
1976	903	65	2,419	387	150	2,372	6,297	18,468
1977	786	60	2,430	414	144	2,488	6,323	18,977

SOURCE: Commission of the European Communities, *The European Aerospace Industry, Trading Position and Figures,* July 2, 1979.

FIGURE 4

EUROPEAN ECONOMIC COMMUNITY AEROSPACE INDUSTRY SALES AS PERCENTAGE OF U.S. SALES 1970-1977 (Millions of U.S. Dollars)



and U.S. sales are clear. EEC sales have steadily increased from $4.1 billion (1970) to $6.3 billion (1977), an increase of 53 percent. U.S. sales have declined from $22.3 billion (1970) to $19 billion (1977), a decrease of 15 percent. In 1970, EEC aerospace sales represented 19 percent of U.S. industry sales; in 1977, the percentage reached 33 percent (Figure 4). By any measure, this must be considered a significant development in favor of the European aerospace industry.

In addition, total U.S. sales declined as a percentage of gross domestic product from 2.26 percent in 1970 to 1.55 percent in 1977. At the same time, the EEC's total aerospace sales increased their relative share of GDP from 0.67 percent (1970) to 0.83 percent by 1977.[2] What appears, as a percentage of GDP, to be a relatively minor increase is actually a 23 percent improvement in sales and an expression of the more positive economic performance of the EEC in the 1970s.

Trends in sales in the aerospace industry from 1970-1977 are presented in Table 10. The United States experienced a 23.6 percent decline in sales overall. West Germany's sales also declined (10.5 percent) but the other key members of the EEC showed substantial growth ranging from 11.5 percent (Netherlands) to 62.6 percent (France). All of the EEC countries, and the U.S., showed positive sales growth, as a percentage of GDP. The mean annual growth rate was positive for all but the U.S. and West Germany. Each nation experienced a positive mean annual growth rate in sales, as a percentage of GDP.

The EEC achieved its expansion of output in aerospace with a relatively constant workforce ranging between 409,000 to 437,000 workers from 1972-1977.[3] At the same time, the U.S. aerospace industry work force was cut back from 1.2 million (1970) to 893,000 (1977).[4] Employment then rose to 1.1 million in 1979, the highest level of em-

[2] *The European Aerospace Industry, Trading Position and Figures*, Commission of the European Communities (Brussels: July 2, 1979); *Main Economic Indicators*, Organization for Economic Co-operation and Development (Paris: January, 1979).

[3] *European Aerospace Industry, Trading Position and Figures, ibid.*

[4] *Aerospace Facts and Figures, 1980-81*, Aerospace Industries Association (Washington, D.C.: August, 1980), p. 20.

ployment since 1970. However, by 1977, aerospace employment had dropped about 40 percent from the peak year (1968) level and, in 1979, was still nearly 30 percent below that level. Comparable employment figures for the European aerospace industry since 1977 are not yet available.

Despite a substantial increase in the productivity of European aerospace workers, the United States still holds a significant lead in this area. Contributing factors include larger U.S. production runs and structural differences between the U.S. and European aerospace industries. While the higher productivity of U.S. workers through the early Seventies was balanced, in part, by lower wages for European workers, this has been less and less the case as unit labor costs in the United States have dropped relative to those of other industrialized nations, including many of our European competitors. At the same time, European productivity increases have been offset, to some extent, by the substantial devaluation of the dollar over the same period. As a result, the competitive position of the United States has been affected less adversely than changes in productivity alone would indicate. Nevertheless, the European aerospace industry has substantially increased its relative standing versus the United States in the 1970s.

Funding comparisons between countries, and particularly between the United States and the European community, are quite difficult in the area of R&D, technology and science; differences in semantics, definitions, institutional approaches and accounting definitions, as well as tax laws, make a fair overall R&D comparison in dollar terms nearly impossible. The best approach would be a detailed manpower breakdown of scientists and engineers by field and degree of specialization engaged actively in R&D, by field of industrial and aerospace activity (e.g., civilian aeronautics R&D, space science and applications R&D, military aeronautics R&D, etc.). Such a breakdown is not readily available, however, and in many ways comparisons are as difficult to arrive at in these areas as they are with funding.

Shown in Table 11 are 1977 figures reflecting the best available approximations of government financing of aeronautics and space R&D in Europe and the United States. The European budgets are roughly comparable to the expenditures of the United States in definition and scope. In all of the key countries of the EEC (France, West Germany, Italy and the United Kingdom), aeronautical and space R&D made up a substantial portion of total government funding of research and development geared to increase industrial productivity and the technology base (somewhere between 48 and 55 percent of total government funding). As a percentage of gross domestic product, expenditures ranged from 0.04 to 0.10 percent. As a percentage of total industrial funding, the European countries are now spending on about the same level as the U.S. in aeronautics and space. And, while the relative level of expenditures in the United States on space and aeronautics has been steadily decreasing in the 1970s, the European effort has undergone a steady expansion, particularly in space (the Spacelab program) and civilian aeronautics (the A300-A310 development and SST technology).

Sales and R&D figures for the European countries beyond 1977 are not available. European sales have remained strong, however. U.S. sales stayed approximately constant in real dollars from 1976 to 1977 and then showed a real increase of nearly 8 percent in 1978 and of 12 percent in 1979. The U.S. increase, as mentioned earlier, is due mainly to the introduction and sale of new commercial airliners. The growing number of new aircraft

TABLE 10

TRENDS IN SALES IN THE AEROSPACE INDUSTRY 1970-1977

	West Germany	Belgium	France	Italy	Netherlands	United Kingdom	EEC	United States
Percentage Change-Over The Period, 1970-1977								
Sales	-10.5	35.9	62.6	59.9	11.5	38.4	37.4	-23.6
Percentage of Gross Domestic Product	19.9	27.9	31.1	21.2	26.4	14.3	22.3	23.9
Mean Annual Growth Rate								
Sales	neg.	4.5	7.2	6.9	1.6	4.7	4.6	neg.
Percentage of Gross Domestic Product	2.7	3.6	4.0	2.8	3.4	1.9	2.9	3.1

SOURCE: Commission of the European Communities, *The European Aerospace Industry, Trading Position and Figures*, July 2, 1979.

TABLE 11

GOVERNMENT FINANCING OF R&D IN AERONAUTICS AND SPACE EUROPE AND THE UNITED STATES 1977

(Millions of U.S. Dollars)

	West Germany	*France*	*Italy*	*United Kingdom*	*Other*[a]	*EEC*	*United States*
FUNDING	$312	$371	$68	$133	$57	$2	$5,517
As Percent of Total Government R&D Funding for Industrial Productivity	49.0%	54.9%	46.1%	48.2%	42.8%	8.0%	52.3%
As Percent of Gross Domestic Product	0.06%	0.10%	0.04%	0.05%	0.02%	b	0.29%

SOURCE: Commission of the European Communities, *The European Aerospace Industry, Trading Position and Figures,* July 2, 1979.

a Belgium, Netherlands, Ireland, and Denmark.
b Less than 0.005%.

orders received by European manufacturers as compared to the U.S., however, is a strong indication that the European share of the overall aerospace market is growing. The total number of A300 and A310 aircraft on order reached 230 in the fall of 1979, approaching one-third the number of commercial air transports on order from U.S. manufacturers and representing significant inroads in the overall world market.

SOVIET R&D AND DEFENSE EFFORTS

Any assessment of the R&D foundations of U.S. economic strength would be incomplete without a comparison of the technological investments, and strengths, of the United States and the Soviet Union. At this time, the Soviet Union plays a minor role in the high-technology world market as evidenced in part by its continuing interest in free-world technology, even where basic production facilities are concerned. Nonetheless, Soviet investment in R&D and technology is considerable, with important political and military implications for the United States.

A reality of today's world is that, for the United States, economic, political and military strength are intertwined and depend alike on technological leadership. U.S. economic strength will increase the nation's stature and contribute to world economic and political stability. The nation's ability to defend itself and to preserve democratic institutions depends in large measure on both economic and political strength but also, quite directly, on the superior strength of strategic and tactical forces.

A comparison of R&D and defense efforts by the Soviet Union and the United States, whether in dollar terms or in any other, is bound to encounter difficulties concerning data sources, comparability of data, definitions, and uses of R&D resources. Recent reviews comparing strategic and tactical forces of the Soviet Union and the U.S. have run into consistent difficulties in adequately assessing current as well as projected strengths of the two nations. In terms of simple absolute numbers, however, there is no question the Soviet Union now exceeds the U.S. in many areas of tactical as well as strategic importance. Soviet investment in new military equipment and facilities exceeds the U.S. in such areas as missile launchers (ICBMs and SLBMs), strategic defense interceptors, and total delivery vehicles. Only in the numbers of bombers and operational strategic warheads does the United States have a substantial quantitative lead.

Figures 5 and 6 show total defense outlays and strategic offense forces for both nations from 1970-1979. U.S. outlays are compared with estimated dollar costs of Soviet activities if duplicated in this country. Comparisons are made in 1979 constant dollars.

For the 1970-1979 period, estimated dollar costs of Soviet defense activities exceeded U.S. outlays by almost 30 percent.[1] Trends of defense activities of the two countries differed markedly. In constant dollars, Soviet activities increased at an average annual rate of 3 percent and evidence indicates the Soviet investment will continue into the 1980s at about the same rate of growth. Beginning with the Vietnam peak of 1968, U.S. outlays fell continuously through 1976. Increases in procurement; research, development test and evaluation (RDT&E); and operations and maintenance to offset declines in personnel costs and construction, caused U.S. outlays to increase somewhat since 1976, and U.S. military investment grew by more than 3 percent through 1979.

The Soviets matched U.S. defense outlays for the first time in 1971 and exceeded them by a widening margin through 1979. In 1979, the Soviet total outlay of about $165 billion was approximately 50 percent higher than the U.S. outlay of $108 billion.

If uniformed personnel costs are excluded, estimated dollar costs of Soviet defense activities were greater than U.S. outlays in 1979 by 40 percent—and 15 percent greater for the decade.

As a percent of GNP, Soviet defense efforts through the 1970s are estimated at 11 to 12 percent. U.S. defense activities were approximately 8 percent of GNP in 1970 and 5 percent in 1979.

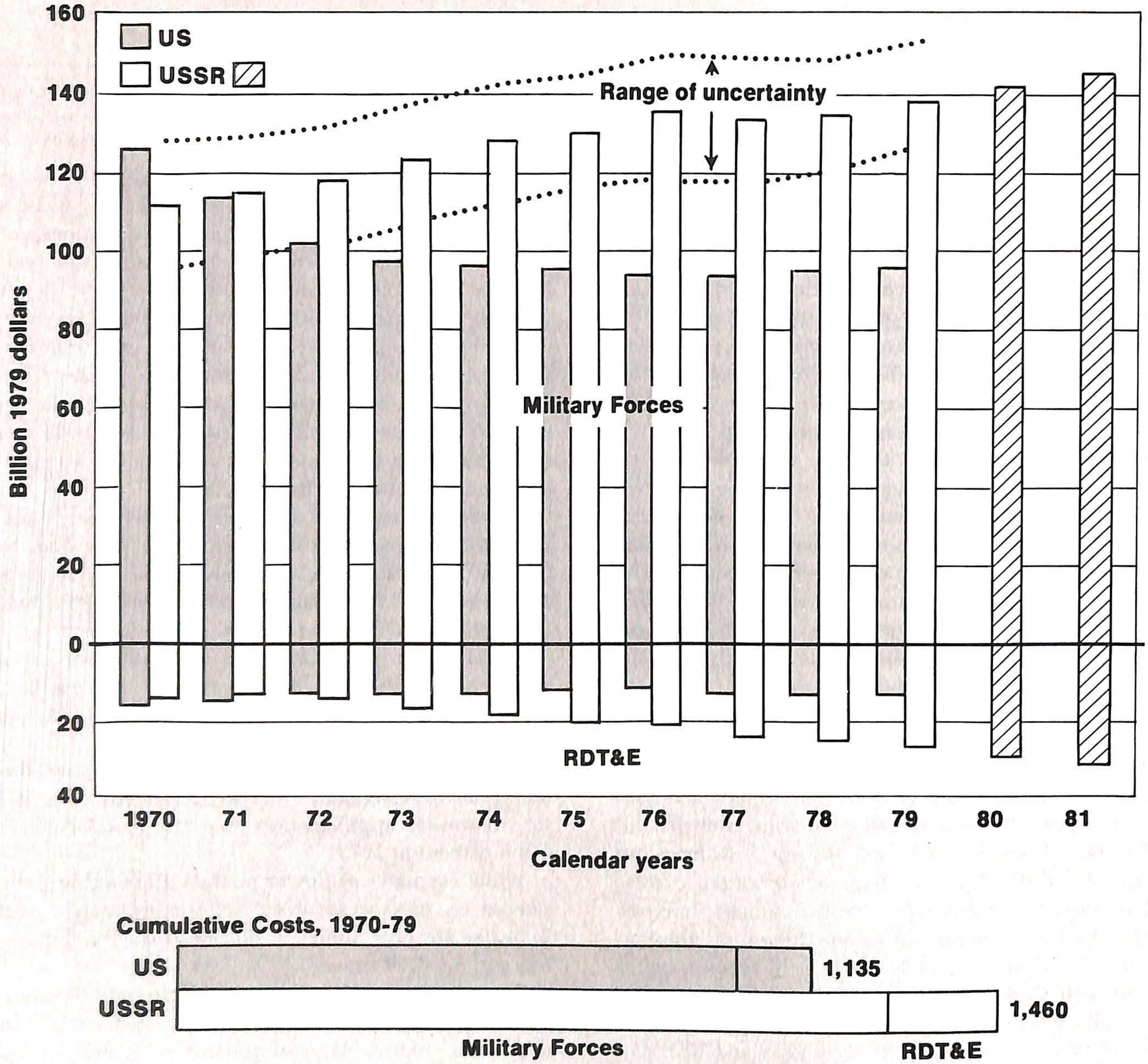
While estimates of Soviet military RDT&E are not considered as precise as other defense estimates, evidence indicates Soviet activities in this area over the decade were one and one-half times U.S. outlays.

From 1970 to 1979, Soviet strategic force funding, not including RDT&E, was two and two-thirds times that of the United States. As third-generation ICBM deployment programs were completed in the early 1970s, Soviet investment dipped slightly then rose again in the mid-1970s as fourth-generation systems were deployed. On the other hand, U.S. spending declined steadily until 1976 when it began growing at a slow rate. In 1979, as a result, the Soviet level of strategic forces was about three times that of the United States.

[1] *Soviet and U.S. Defense Activities, 1970-1979: A Dollar Cost Comparison*, Central Intelligence Agency National Foreign Assessment Center, SR 80-10005 (Washington, D.C.: January, 1980).

FIGURE 5

TOTAL U.S. AND SOVIET DEFENSE OUTLAYS[a]
1970-1979
(Billions of 1979 dollars)



SOURCE: *Soviet and U.S. Defense Activities, 1970-1979: A Dollar Cost Comparison,* Central Intelligence Agency National Foreign Assessment Center (Washington, D.C., January 1980).

NOTE: Costs shown for military forces are investment and operating costs, excluding pensions. Costs for Soviet RDT&E are estimates derived in the aggregate and provide only rough measures; for that reason, they are shown separately from dollar costs of military forces.

a A comparison of U.S. outlays with estimated dollar costs of Soviet activities if duplicated in the United States.

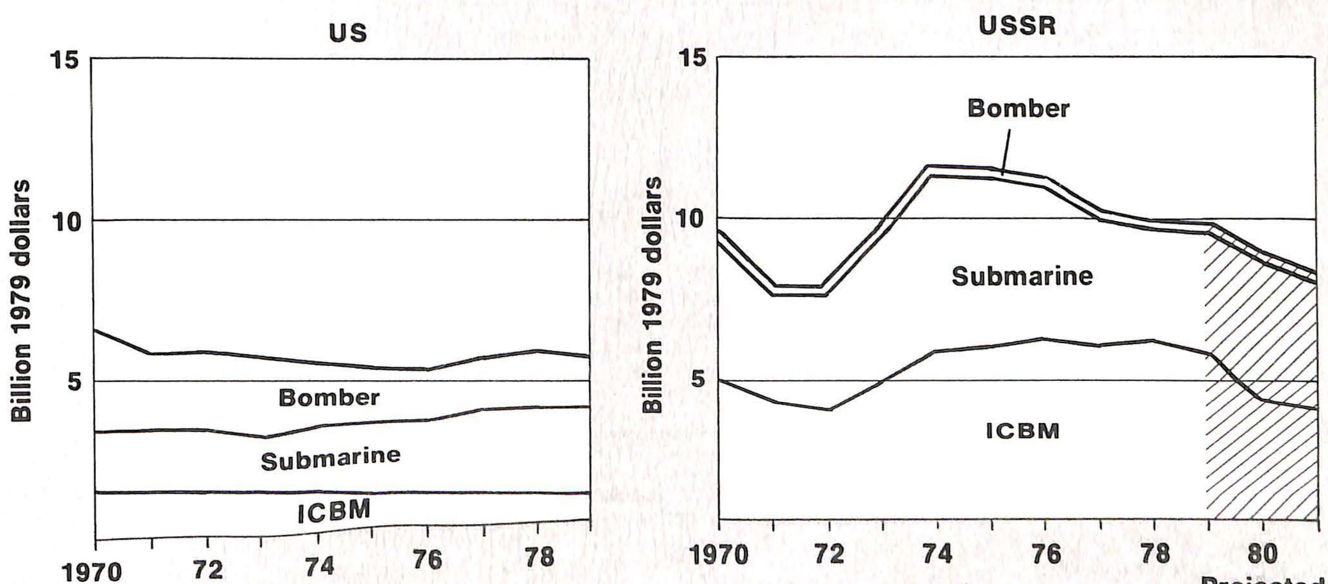
Given the quantitative advantage of the Soviets in strategic and tactical force levels, the recourse in discussions of comparative Soviet and U.S. strengths has been the *qualitative* superiority of U.S. weapon systems. As demonstrated in the U.S. space effort, as well as in the military field, the accuracy, precision and effectiveness of U.S. strategic as well as tactical systems have greatly exceeded those of the Soviet Union. In essence, the U.S. defense posture relies on technological superiority over quantitative superiority by the Soviet Union. To what extent, however, can this technological superiority be maintained given developments in the relative efforts that both countries dedicate to RDT&E and defense?

Estimates of Soviet expenditures are often attacked on the basis of statistical, semantic and economic questions as, for example, the appropriateness of exchange rates between Soviet and U.S. currencies. It is now generally agreed, however, that while the U.S. effort in real dollar terms has remained static over the past decade, the Soviet Union has experienced a steady and considerable expansion. Nonetheless, to avoid dollar comparisons, a more accurate indication of the general level of R&D funding would be the total manpower pool developed, available and applied in both countries. Figure 7 shows that through the 1960s, based on estimates of comparable manpower levels, the U.S. was well ahead in number of scientists and engineers employed. U.S. R&D employment peaked, however, in 1969, declined through 1973, then stabilized and has increased steadily—by about 90,000—since that time. In 1968, the U.S. employed 552,800 in R&D against 524,200 in the Soviet Union. The Soviets pulled ahead of the U.S. the following year and stayed ahead with an ever-increasing lead through 1978. In that year, 828,100 scientists and engineers were estimated to be employed in R&D activities in the Soviet Union while only 595,000—nearly 30 percent fewer—were similarly employed in the United States.

The average annual rates of growth in scientific and engineering R&D manpower for both countries since 1950 are shown in Figure 8. Since the Soviet Union pulled ahead of the United States in the late 1950s (an average annual growth rate of 9.6 percent against 8.4 percent for the United States), the growth of the Soviet manpower pool exceeded that of the United States until 1975-1978 when the U.S. again moved ahead (3.6 percent growth against 2.1 percent for the Soviets).

FIGURE 6

U.S. AND SOVIET FORCES FOR INTERCONTINENTAL ATTACK[a]
1970-1979
(Billions of 1979 dollars)



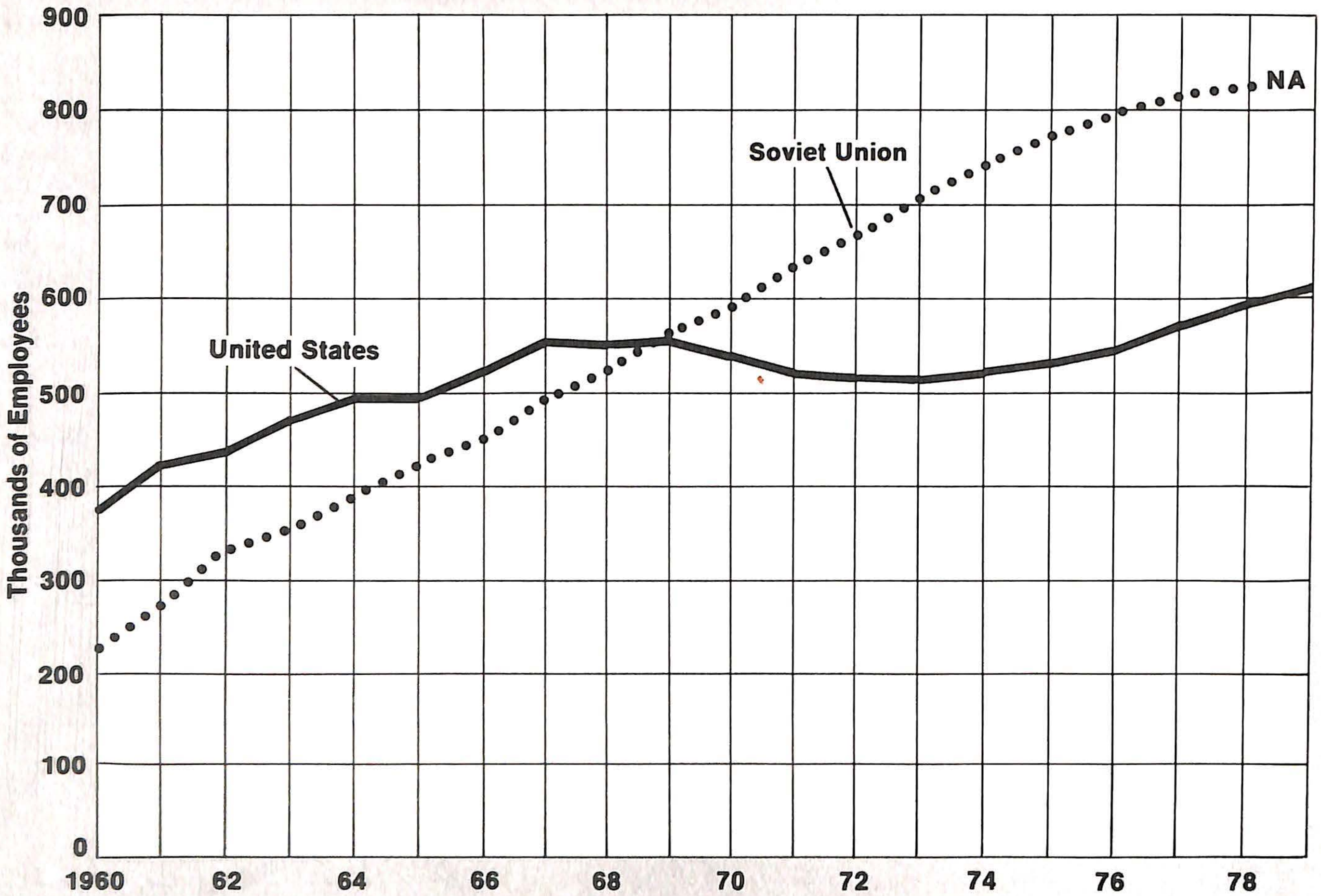
SOURCE: *Soviet and U.S. Defense Activities, 1970-1979: A Dollar Cost Comparison*, Central Intelligence Agency National Foreign Assessment Center (Washington, D.C., January 1980).

a A comparison of U.S. outlays with estimated dollar costs of Soviet activities if duplicated in the United States.

FIGURE 7

SCIENTISTS AND ENGINEERS EMPLOYED IN R&D IN THE UNITED STATES AND THE SOVIET UNION 1960-1979

(Thousands of Employees)



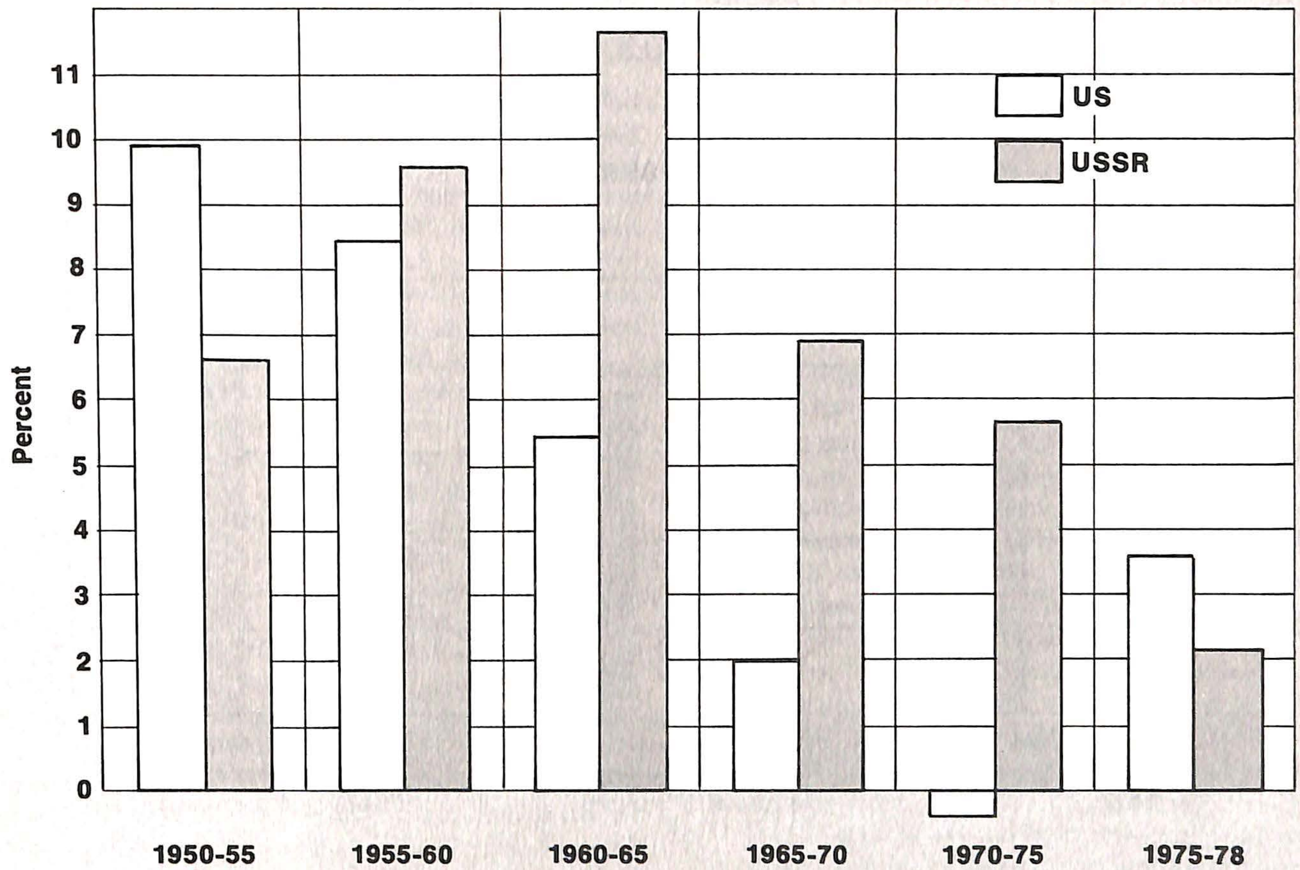
SOURCE: *Soviet Economy In A Time of Change—A Compendium of Papers Submitted to the Joint Economic Committee, Congress of the United States,* U.S. Government Printing Office (Washington, D.C., October 10, 1979), p. 746. Data drawn from U.S. Bureau of Labor Statistics and National Science Foundation estimates; Bronson, David W., "Scientific and Engineering Manpower in the USSR and Employment in R&D," *Soviet Economic Prospects for the Seventies,* U.S. Congress Joint Economic Committee, U.S. Government Printing Office, (Washington, D.C., 1973); and Soviet scientific worker series.

NOTE: U.S. figures are National Science Foundation estimates except for 1962-64 and 1966-68. NSF estimates exclude all humanities specialists and social scientists and psychologists in industry plus scientists and engineers in R&D employed in state and local governments. Annual average. Figures for 1962-64 are BLS estimates which exclude social scientists, psychologists and humanities specialists. USSR figures represent adjusted Soviet scientific worker series less specialists in social sciences and humanities. End of year figures.

NA Not available.

FIGURE 8

AVERAGE ANNUAL RATES OF GROWTH IN THE NUMBER OF SCIENTISTS AND ENGINEERS EMPLOYED IN R&D IN THE UNITED STATES AND THE SOVIET UNION 1950-1978
(In percent)



SOURCE: *Ibid.*, p. 747.

Comparable R&D employment figures beyond 1978 are not available. The scientific and engineering R&D employment for the United States was estimated to be 610,000 (see Figure 7)—still 218,000 behind the previous year figure for the Soviet Union.

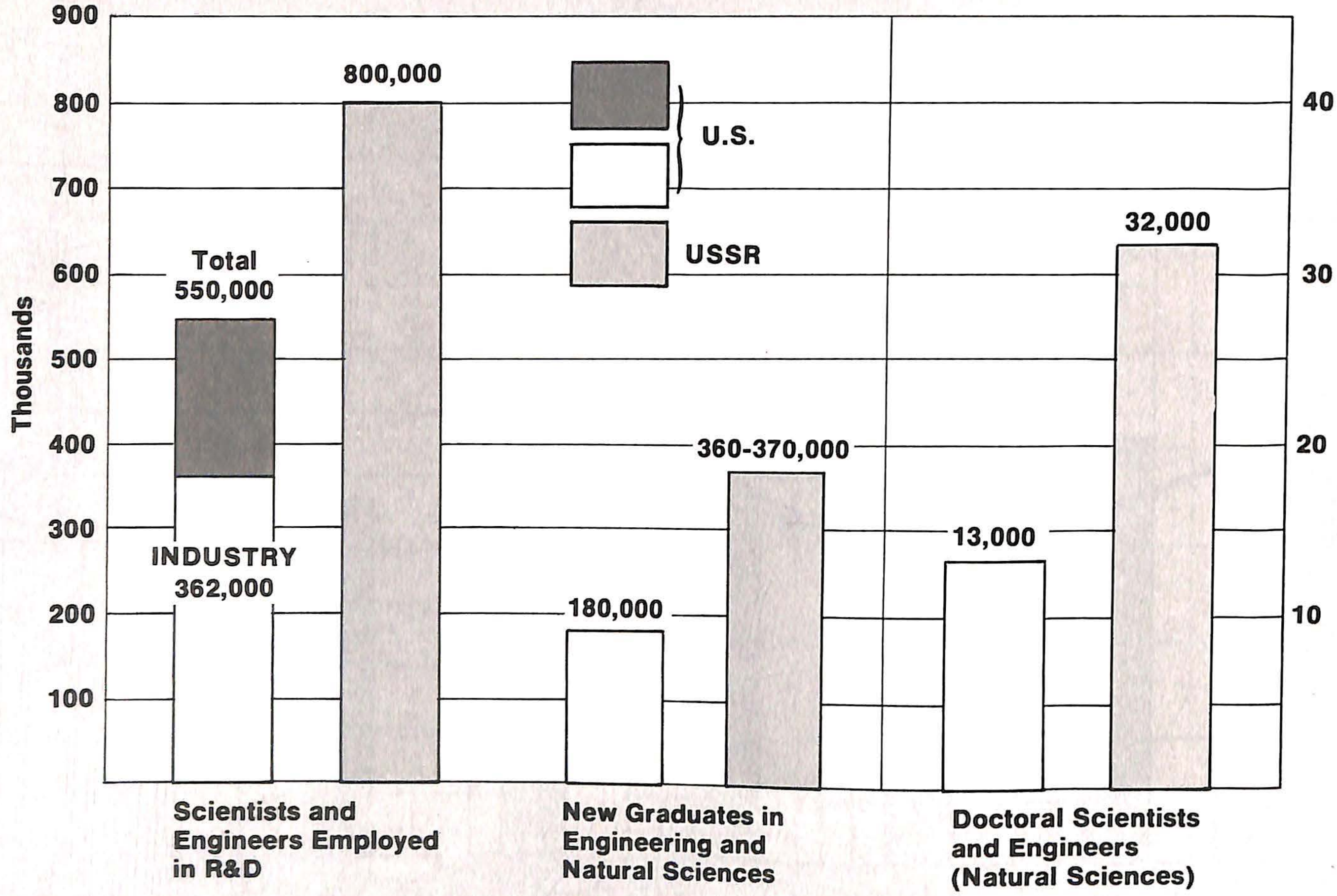
A closer look at the composition of the Soviet scientific and engineering manpower pool, as presented in Figure 9, leads to some implications for the future. In 1960, the Soviet Union graduated about 100,000 engineers and 45,000 students in the natural sciences for a total of 145,000 new graduates. In 1976, the Soviets graduated about 260,000 engineers and over 100,000 students in the natural sciences—a total of between 360,000 and 370,000. In the United States, between 90,000 and 100,000 U.S. students obtained bachelor's and first-professional degree awards in engineering and the natural sciences in 1960. By 1976, the U.S. graduated about 180,000 in those fields, about half those graduated in the Soviet Union.

To the extent that science and technology is advanced by Ph.D. scientists, the comparative numbers again show a disturbing Soviet advantage. In 1976, about 32,000 candidate degrees (roughly equivalent to the Ph.D.) were awarded in the Soviet Union. Eighty percent were conferred in natural sciences and engineering. In comparison, the U.S. awarded about 13,000 to 14,000 Ph.D.s per year through the mid-1970s. Of those graduated, about 67 percent were in the natural sciences. Total U.S. Ph.D. scientists in fields with military or engineering applications were about 42 percent of all graduates.

Preliminary 1977 figures on natural science and engineering graduates indicate the Soviet Union has, at the

FIGURE 9

U.S. AND SOVIET MANPOWER IN ENGINEERING AND THE NATURAL SCIENCES 1976



least, remained at the same level as 1976 (360,000-370,000). In 1977, the United States awarded, according to preliminary estimates, over 200,000 bachelor's and master's degrees and just over 11,000 doctoral degrees in engineering and the natural sciences for a total of more than 211,000—still significantly behind the Soviet Union.

There has been an improved manpower growth rate in the U.S. yet, overall, the Soviet Union has shown a steadily greater expansion of the manpower pool for R&D in the "hard sciences" at all levels. In terms of total employment in R&D, the lead of the Soviet Union grew to about a three to two ratio by 1976, a ratio that should continue to increase as the Soviet rate of graduation of new scientists and engineers continues at high levels.

It would appear that U.S. technological superiority cannot continue into the 1980s and 1990s if the Soviet Union has a technologically-trained manpower pool two to three times larger than our own. And if, in the long run, rough equivalence between equally trained researchers can be assumed, when will the U.S. qualitative lead in strategic and tactical military technology erode to the point of qualitative parity? At that point, it would seem the Soviets could take the lead based on a quantitatively superior deployment of arms and manpower.

Commercially, the Soviet Union has been particularly inept in translating its technology and engineering manpower base into a significant share of the world civil aircraft market. In current aerospace world trade, the Soviet Union continues to play a minor role. A strong factor may be the near total neglect of R&D and new product development in the consumer sectors of these economies. The human and capital resources of Communist nations seem to go foremost into military R&D and hardware with a neglect of market goods, services and capital investments. Central planning, rather than market price response and a full and efficient use of capabilities, may continue to relegate the Soviet Union to the status of market good technology importation and imitation.

ECONOMISTS LOOK AT R&D AND ITS ROLE IN THE ECONOMY

R&D investment, as economists see it, increases society's stock of technical knowledge—and that implies anything from a new theory in physics to a more efficient method for assembling toasters. But just how and to what extent there is a measurable economic "payoff" on R&D investment is not clear.

Theoretically, things should progress nicely from basic through applied research, development and technological innovation—and from there to increased productivity and economic welfare. It is not that simple, of course. For one thing, not all R&D results in innovation. Innovation is a complex process and what succeeds in the R&D stage may abort somewhere before production—and, even if produced, may not sell. Assuming new technology leads to innovation, conditions may not be favorable for taking advantage of it. There may not be, for example, sufficient capital to put it to work most effectively. Government, social and business conditions are important to successful innovation and may, at times, create a situation in which earlier expenditures and positive progress are unproductive.

Nonetheless, many successful innovations have been rooted in R&D and, for that reason, R&D plays a significant role in improving national productivity. Historically, advances in productivity have reduced inflation, created jobs and improved the overall balance of trade. This is not to say that productivity is not also influenced by other important factors including the age of a nation's plant and equipment, the quality and breadth of its education, and the demographic characteristics of its labor force. In turn, achievement of the desirable national goals of lower unemployment, higher per capita income, and so on, depends as well on forces other than productivity. Government spending, availability of natural resources, the level of private investment and personal consumption are all important.

In recent years, there has been a significant amount of research on the effects of R&D on technological change and economic welfare. Much of it has been prompted by concern over whether the total level of federal and private R&D activity is appropriate for optimal economic growth and maximum social welfare. Also at question is whether economic returns on federally-funded R&D can be compared favorably with those from private R&D. Any investigation of the impact of R&D necessarily leads to questions concerning the measurement of productivity° as can be seen by the following review of current literature on the subject. This review attempts to provide a background on the various studies and the differing positions held by those knowledgeable in the field.

Technology, Productivity and Growth

Generally, economists do agree that technological change has contributed to productivity increases. Agreement is not unanimous, however, on the role of productivity in the economy. There is also a difference of opinion on the proper method for measuring productivity.

The essential difference between economists lies, not in the data used nor in the quality of scholarship, but in aggregation techniques. There are slight differences in calculation among the many empirical studies that have attempted to find the national rate of productivity growth. As a result, any economist who attempted to link R&D to a national productivity estimate could then vastly alter the final results by using another of the various productivity time series available.

Due in part to doubts concerning national productivity estimates, some economists have approached the measurement of productivity and the impact of R&D by individual sectors of the economy. The thinking is that the detailed nature of such a study would remove at least some of the errors involved in a national aggregation. But to accomplish this task for every sector of the economy would be prohibitively expensive; moreover, complex interrelationships between sectors would be almost impossible to account for without using the national data. Given the current limitations, it appears a universally acceptable national productivity estimate is impossible.

°To assess the benefits of R&D investment, it is necessary to measure the level of productivity through time, gauge the contribution of R&D to productivity increases and, finally, estimate the influence of R&D investment on the national welfare via the productivity effect. Theoretically, this analysis can be performed at the national (macro) level or at various micro levels such as a sector of the economy, an industry or an individual project. An example: the National Aeronautics and Space Administration might use this analysis to gauge the result nationally of their R&D to improve weather forecasting, to judge the impact of aeronautical R&D on the air transportation industry, or to assess the net economic benefit of a specific project such as the Space Shuttle.

At issue then, when assessing the impact of R&D spending, is which level of analysis—the national, sector, industry or project level—is more credible for a given purpose. When data are available, and the problem of sector aggregation is minimal, studies at the sector, industry or project levels are considered to be credible. The state-of-the-art of this analysis is fairly well developed in both the federal and private sectors. Industry has frequently studied R&D performance at these levels and, in both government and industry, cost-benefit analysis of R&D projects is common. There are still serious difficulties with sector, industry and project analyses but the problems are mostly study-specific; the methodology used to examine the impact of R&D expenditures at these levels is generally accepted by economists.

One area of disagreement is over precise measurement and proper classifications of technological change. A considerable amount of literature is concerned with whether technical progress may be "neutral" or biased in some sense, or whether it may be factor-augmenting or "embodied" in either capital or labor. Numerous studies have purported to settle one or the other of these issues. Frequently, technical progress is used as a synonym for productivity increase without clearly defining the meaning of "productivity." The word is commonly used to mean the *average* productivity of *labor*. The *average* productivity of labor, however, is not necessarily the same as its *marginal* productivity. Furthermore, the average and marginal productivities of capital must also be recognized.

Pioneering studies of technological change and economic growth have attempted to measure the advance of technology in terms of changes in "total factor productivity," i.e., taking into account all input factors or production resources. Although several individuals, including M. Abramowitz[1] and S. Fabricant,[2] contributed significantly to understanding the relationship between technological change and economic growth, a paper by R. Solow[3] has been most influential in many respects. His approach for segregating *shifts* of the aggregate production function from *movements* around it has been criticized; nevertheless, it is still frequently applied, largely because of its relative simplicity. Solow did not attempt to examine the sources of technical progress or productivity increase. This complex task was attempted by E. Denison[4] whose comprehensive work has provided considerable insights into the nature of economic growth. According to Denison, the "advance of knowledge" has contributed significantly to economic growth. However, in his opinion, only about one-fifth of the contribution made by the "advance of knowledge" can be attributed to formally organized R&D activities.

Efforts to estimate public and private rates of return on R&D investment have yielded impressively high figures. W. Fellner[5] discussed the issue of technological change using a definition of "progress activities (those generating technological progress)" that includes educational activities and is considerably broader than the usual concept of R&D efforts. He concluded that "the present average social rate of return from the progress-activities is substantially in excess of 13 percent on the all inclusive cost-base, and substantially in excess of 18 percent on the cost-base limited to institutionally profit-oriented progress-inputs." Fellner said the rate of return appeared to tend downward in the long run and indicated that *marginal* social rates of return are probably lower than his estimates of *average* social rates.

Using a more narrowly defined concept of R&D at the individual industry level, J. Kendrick and associates [6,7] demonstrated the rate of growth of total factor productivity was significantly related to R&D intensity as measured by the ratio of R&D expenditures to sales. In an agricultural study, Z. Griliches[8] investigated the relationship between output per farm and the amount of land, labor, fertilizer and machinery per farm as well as average education and expenditures for research and extension service. He concluded the return on R&D investment in agriculture was extremely high. Studies on the return on R&D investment in manufacturing industries or the relationship between productivity increase and R&D expenditures, both at the industry and the company level, were made by E. Mansfield. [9,10] He showed the rate of productivity change was significantly related to the rate of growth of cumulated R&D expenditures. Other studies including those of J. Minasian [11] and Brown and Conrad [12] tended

[1] M. Abramowitz, "Resource and Output Trends in the U.S. Since 1870," *American Economic Review*, Vol. 46, No. 2 (May, 1956).

[2] S. Fabricant, *Economic Progress and Economic Change*, 34th Annual Report of National Bureau of Economic Research (New York, 1954).

[3] R. Solow, "Technical Change and the Aggregate Production Function," *Review of Economics and Statistics* (August, 1957), pp. 312-320.

[4] E. F. Denison, *The Sources of Economic Growth in the United States and the Alternatives Before Us* (New York: Committee of Economic Development, 1962).

[5] W. Fellner, *American Economic Review*, Vol. 60 (March, 1970), p. 2.

[6] J. Kendrick, *Productivity Growth in the U.S.* (New Jersey: Princeton University Press, 1961).

[7] J. Kendrick, *Post War Productivity Trends in the United States, 1948-1969* (New York: National Bureau of Economic Research, 1973), p. 134.

[8] Z. Griliches, "Research Expenditures, Education, and the Aggregate Agricultural Production Function," *American Economic Review*, Vol. 54, No. 6 (December, 1964).

[9] E. Mansfield, "Technological Changes: Stimuli, Constraints, Returns," *American Economic Review* (May, 1965), pp. 310-321.

[10] E. Mansfield, *The Economics of Technical Change* (New York: W. W. Norton and Co., 1968).

[11] J. Minasian, "Research and Development Production Functions and Rates of Return," *American Economic Review* (May, 1969), pp. 80-85.

[12] M. Brown and A. Conrad, "The Influence of Research and Education on CES Production Relations" in M. Brown, ed., *The Theory and Empirical Analysis of Production* (New York: National Bureau of Economic Research, 1967).

to reinforce this general finding. In a more recent study, B. Branch [13] examined not only how R&D may affect a firm's profitability but also whether past profitability may affect present R&D. In general, Branch concluded, there was a tendency for R&D to influence future profitability and to be influenced, in turn, by past profitability.

Many studies, then, have attempted to examine the relationship between R&D and productivity increase or economic growth. Central to this research is the concept of either the macro or microproduction function, since technological change or productivity increase is defined as a shift of the production function. Conceptually, various types of shifts can be distinguished though, in practice, different shifts are usually indistinguishable. That is true for most measures of "total factor productivity" such as those suggested by Kendrick [14] and Solow. [15] Both Kendrick and Solow are aware that their "residual" measures include everything not explicitly considered as inputs—interindustry shifts, for example. There has been some question about the nature of these measurements and, in a reply to a comment on his method, Solow stressed it was "free of assumptions about the exact form of the production function and about the nature of technical progress." [16] Yet, his procedure has been criticized on these very grounds, especially by M. I. Nadiri. [17]

Crude as aggregate measures of technological change may be, Solow's approach is perhaps the least controversial for studying the relationship between R&D and economic growth. It is recognized that knowledge of the sources of technological change is limited and that understanding of the mechanism by which productivity increase is transformed into economic growth is inadequate. Moreover, it is not self-evident that economic growth necessarily implies greater economic welfare—much less greater general welfare. The difficulties of using aggregate measures such as the GNP or National Income as indicators of economic welfare were discussed by P. Samuelson [18] when the National Income approach began to be widely accepted. Economists do not believe that real GNP or National Income are complete measures of welfare; however, they do carry strong connotations about economic health.

In contrast to the macroeconomic approach centering around aggregate production function, microeconomic approaches have also been employed, usually in terms of consumer surplus based on a demand function for a given commodity. Such an approach has difficulties as well, since effects of R&D activities are not usually traceable. Furthermore, technological change generally involves factor substitution arising from changes in factor prices and product substitution resulting from changes in product prices. It may, then, be extremely misleading to attribute cost reductions entirely to any given R&D activity.

Many prominent economists, including Samuelson, [19] have serious reservations about the concept of consumer surplus. However, A. Harberger argues that the consumer surplus approach should be considered seriously, since it "incorporates a greater degree of subtlety of economic analysis than does national income methodology." [20]

There are, then, possible limitations in various approaches to the measurement of productivity and of R&D investment in productivity. To point these out, however, is not to say that the various approaches are without value. Rather, an awareness of the difficulties and differences involved in such studies provides a useful context for new work in this area.

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[13] B. Branch, "Research and Development Activity and Profitability: A Distributed Lag Analysis, *Journal of Political Economy*, Vol. 83, No. 5 (September/October, 1974).

[14] J. Kendrick, *Productivity Growth in the U.S.* (New Jersey: Princeton University Press, 1961).

[15] Solow, *op. cit.*

[16] R. Solow, "Reply," *American Economic Review* (November, 1958), pp. 412-413.

[17] M. I. Nadiri, "Some Approaches to the Theory and Measurement of Total Factor Productivity," *Journal of Economic Literature*, Vol. 8 (December, 1970), p. 1141.

[18] P. A. Samuelson, "Evaluation of Real National Income," *Oxford Economic Review* (1950), pp. 1-29.

[19] P. A. Samuelson, *Foundations of Economic Analysis* (originally published by Harvard University Press, 1947), p. 195.

[20] A. C. Harberger, "Three Basic Postulates for Applied Welfare Economics: An Interpretive Essay," *Journal of Economic Literature* (September, 1974).

APPENDIX A – METHODOLOGY

In a study, first published in the *Journal of Political Economy* in February 1967, by William Gruber, Dileep Mehta and Raymond Vernon,[1] the authors investigated the impact of R&D expenditures on the trade balance of the United States. Their hypothesis was that U.S. industries characterized by an intense R&D effort also performed well in terms of export balance. The basis of this belief is that firms can compete with each other by introducing new or differentiated products which enjoy monopoly status until a competitor can duplicate research efforts which led to their introduction. A similar kind of transient market power might accrue to any firm which put its effort into process innovation in order to lower costs for an existing product. Even if domestic competitors are able to erode these market monopolies fairly quickly, information takes longer to cross national borders; firms could thus pursue R&D programs for gains at the expense of foreign competitors rather than domestic rivals.

This study sought to extend earlier efforts in several ways: First, by making another sampling at a more recent date to reverify the findings and check that the relationship present in 1962 was still affecting trade balances; second, by improving on the measures of export intensity and R&D effort. Because data for any particular year will contain a large component of "noise" obscuring the long-run relationships, several alternative longitudinal measures of the variables were tested with the intent of capturing the accumulation of the impact of R&D effort on current exports. In addition, correlations were calculated for moving averages for both sets of variables in an attempt to discern a steady-state relationship. All correlations were run over as long a time period as possible to check for stability over time. Finally, the study looked at the independence and relative strength of federal versus industry research efforts.

Methods Used In The Current Study

The basic procedure was to calculate rank order correlations for various measures of R&D effort with various measures of export strength. The data in each correlation were cross-sectional with each datum corresponding to an industry [a two-digit SIC (Standard Industrial Classification) category].

Effort was made to retain the work of Gruber and associates in data sources and this was possible except for the trade figures for the various SIC categories. The earlier trade data were collected according to the Standard Industrial Trade Classification (SITC) and converted to SIC groupings with the aid of a concordance reported in a *Journal of Political Economy* article. Currently, trade figures by SIC category are kept by the Bureau of the Census using a slightly different concordance, and these figures were used for the current study. The data for measures of R&D effort came from the National Science Foundation and the Bureau of Labor Statistics; and those for total sales of industrial categories from the Securities and Exchange Commission (see Bibliography).

Study data are cross-sectional where categories are two-digit SIC classifications among manufacturing industries. In any cross-sectional project, however, there is a certain arbitrariness in the boundaries of the categories. In this study, industries with very different technological characteristics can be found within a two-digit category. The transportation category (SIC 37), for example, includes sophisticated jet aircraft as well as buses. Clearly, any effect of R&D on aircraft exports would tend to be masked by being averaged in with the effects of low technology industries. It was not possible to proceed with a finer breakdown than afforded by a two-digit scheme as data for such a precise study are usually unavailable or, when available, tend to be unreliable due to reporting phenomena. Although it was not possible to break down all categories, reliable data were found which allowed a finer division of three of the two-digit categories: chemicals, metals, and transportation. Each was broken into two sub-categories resulting in: drugs and non-drugs, ferrous and non-ferrous metals, and aircraft and non-aircraft. A separate set of correlations was calculated over the sample period replacing each of these three categories with its pair of sub-categories. Thus Tables 12 to 19 at the end of this Appendix are described as representing either 12 or 15 SIC categories. It was not possible, however, to run a similar set of correlations for the federal and industry R&D expenditures variables as data were unavailable. Tables 18 and 19, then, represent just 12 categories.

[1] W. Gruber, D. Mehta and R. Vernon, "The R&D Factor in International Trade and International Investment of U.S. Industries, *Journal of Political Economy*, Vol. 75, No. 1 (February, 1967).

Concerning the regrouping of cross-sectional data, it is important to note that, in this case, each of the subgroupings was at least as large in total sales as the smallest two-digit category and there was good reason to believe that the R&D experience of the pair of sub-categories was different.

The Results

R&D effect on exports reported in the study by Gruber and associates was duplicated; it has persisted over 21 years. All correlations computed were greater than zero, strongly confirming that an important outcome of R&D effort is a healthy export situation. The results of the study are presented in Tables 12 through 19. In each table, those numbers which are 0.5 and above are statistically significant at the 95 percent confidence level. (Insofar as the probability of a single pair of unrelated variables having a positively signed correlation coefficient is one-half, the fact that all of the coefficients calculated were positive is extremely unlikely on the basis of random fluctuation alone.)

Table 12 shows that, for 12 SIC categories, both gross exports and net trade (exports minus imports) as a percentage of total sales show a strong correlation with R&D expenditures. Almost all of the correlations presented in this table are significant at the 95 percent level. The only exceptions are for the years 1972-73 and 1976-78 for the net export measure; the combination of the lifting of exchange rate controls and enabling the foreign money markets to float with demand has probably caused the disruption in the international trade picture. Nevertheless, all of the correlations are positive.

Results were comparable for the 15 industrial categories for which data are presented in Table 13 except that the finer breakdown leads to correlations which are both larger in absolute magnitude and larger relative to the confidence bound.

Exports and net trade as a percentage of total sales were correlated with full-time equivalent (FTE) scientists and engineers as a percentage of total employment. In Tables 14 and 15, the results are presented for the 12 and 15 SIC categories, respectively. For the 12 categories, correlations of the two export measures with R&D intensity, as measured by FTE scientists and engineers as a percentage of the industry's total employment, show a somewhat weaker relationship than noted in Tables 12 and 13. All of the correlations are positive but only a small number are significant at the 95 percent confidence level. There are, however, good reasons to believe these results are biased towards zero. Firms tend to keep research personnel in house so they can be available for projects when resources are available. Reasons for this are the large acquisition and training costs of highly technical personnel, the need for some experience with an industry before a researcher can be aware of the most profitable directions for new work, or the requirements of industrial confidentiality in high technology activities. The significance of the results of the correlations, however, is greatly improved by the finer breakdown of categories in Table 15.

In an effort to discover an ongoing or steady-state relationship between the measures of trade strength and R&D effort, previous five-year averages of exports and net trade as a percentage of sales were correlated with both five and ten-year averages of R&D expenditures as a percentage of total sales, and of FTE scientists and engineers as a percentage of total employment. This was done, again, for both the 12 and 15 SIC categories and the results are shown in Tables 16 and 17. In Table 16 (12 SIC categories), the use of moving averages neither improves nor detracts from the results presented in Tables 12-15. Again, the link between the employment measure of R&D effort and trade is weaker than the comparable link using the expenditure measure of R&D effort. With the finer breakdown for 15 categories (Table 17), correlations were, by and large, more significant than in Table 16 and the employment measure of R&D effort again makes a poorer showing than the expenditures measure.

Finally, exports and net trade as a percentage of total sales were correlated with both federal and industry-funded R&D expenditures as a percentage of total sales for the 12 SIC categories. In Table 18, federally-funded R&D expenditures for work performed by industry show a very strong relationship with the two measures of trade strength. Virtually all of the correlations are significant for exports and for net trade (except for the unusual years of 1972-73 and 1976-78), and the absolute magnitudes of the correlations are quite large. Industry-financed R&D expenditures (Table 19) show a somewhat weaker though still significant relationship with export strength and are on a par with federally financed R&D for net trade. Federally-financed R&D, then, generally showed a stronger relationship with trade strength than did industry-financed R&D.

A number of other observations can be made about the study results:

- Generally, export correlation coefficients increase in magnitude over the 21-year period indicating an increasing importance of R&D—and federally-funded R&D in particular—in the export performance of the U.S. economy. The increase is apparent in most instances, except where the correlation has fluctuated around the average values through the past 21 years.
- Industry-funded R&D related less to export performance than did federally-funded R&D but it seemed to influence net trade just as much.
- Export performance is more strongly correlated with R&D expenditures than net trade performance.
- The statistically weaker net trade results for the years 1972-73 and 1976-78 may reflect adjustments in net trade flows due to currency devaluations or energy trade disruptions in those years.
- There is a noticeable downward trend in the five and ten-year average R&D expenditure/net trade correlation

coefficients. This may indicate an increase in high technology import competition in U.S. domestic markets, apparently not affecting the export strength of R&D-intensive industries in world markets. This may be evidence of a certain complementarity of worldwide high technology industries in the sense that different countries enjoy competitive advantages within high technology product groups (e.g., photographic equipment, film, calculators). It may also be evidence that other countries are increasingly entering U.S. markets in these areas.

- The results probably substantially underestimated the effect of government R&D funding. The variable employed included only federal funds distributed directly to industry, understanding the total federal R&D budget by about 50 percent. The other half of the budget is composed of intramural research done by the government itself and of government-funded research at non-profit institutions and universities. Federally-funded R&D, even when not performed by industry, has a positive effect on the economic health of industry generally and would certainly have some payoff where industry exports are concerned. It seems logical that the areas in which the government found it productive to conduct intramural research would probably be the same as those in which it was felt productive to finance research by industry. If this is the case, coefficients for the federal spending variables in Table 18 would be much larger, reinforcing the contention that federally-funded research has a greater effect on export strength than does industry-funded research.

Are there potential third causes for the correlation of trade strength and R&D effort? The only candidate is that exports and net trade move in response to cyclical variations in the level of economic activity. Any such pattern is not revealed, however, in the recession years (1958, 1961, 1969, 1974) covered in the sample.

TABLE 12

EXPORTS AS A PERCENTAGE OF TOTAL SALES CORRELATED WITH R&D EXPENDITURES AS A PERCENTAGE OF SALES (12 SIC Categories)

	Current Year	*Previous 5 Years*	*Previous 10 Years*	*Previous 10 Years (Weighted Average)*
AVERAGE	0.6327	0.6232	0.6270	0.6375
1958	0.6853			
1959	0.5664			
1960	0.5175			
1961	0.5664			
1962	0.5594	0.5594		
1963	0.5455	0.5455		
1964	0.5105	0.5105		
1965	0.5245	0.4895		
1966	0.5035	0.4825		
1967	0.6364	0.5944	0.5594	0.5524
1968	0.5944	0.5944	0.5594	0.5524
1969	0.6853	0.5944	0.5664	0.5664
1970	0.6224	0.6364	0.5734	0.5734
1971	0.7203	0.6503	0.6084	0.6084
1972	0.7063	0.6434	0.5944	0.5944
1973	0.6434	0.6434	0.5524	0.6014
1974	0.7203	0.7203	0.6853	0.6853
1975	0.7273	0.7203	0.6853	0.6853
1976	0.7832	0.7692	0.7413	0.7832
1977	0.7972	0.7552	0.7273	0.7762
1978	0.6713	0.6853	0.6713	0.6713

NET TRADE AS A PERCENTAGE OF TOTAL SALES CORRELATED WITH R&D EXPENDITURES AS A PERCENTAGE OF SALES (12 SIC Categories)

	Current Year	*Previous 5 Years*	*Previous 10 Years*	*Previous 10 Years (Weighted Average)*
AVERAGE	0.6057	0.5648	0.5280	0.5367
1958	0.8741			
1959	0.8182			
1960	0.7832			
1961	0.7692			
1962	0.7762	0.7762		
1963	0.7832	0.7832		
1964	0.7343	0.7343		
1965	0.6294	0.6853		
1966	0.5664	0.6503		
1967	0.6364	0.6923	0.7273	0.7133
1968	0.6503	0.6503	0.6923	0.6853
1969	0.5385	0.5664	0.6713	0.6713
1970	0.5594	0.5035	0.5664	0.5664
1971	0.5385	0.5035	0.5664	0.5664
1972	0.3776	0.3846	0.3776	0.3776
1973	0.3776	0.3776	0.3846	0.3916
1974	0.6154	0.6154	0.6294	0.6294
1975	0.5944	0.6643	0.6853	0.6853
1976	0.3916	0.3636	0.3846	0.4196
1977	0.3636	0.3147	0.3077	0.3427
1978	0.3427	0.3357	0.3427	0.3916

NOTE: Numbers which are 0.5 and above are statistically significant at the 95 percent confidence level.

TABLE 13

EXPORTS AS A PERCENTAGE OF TOTAL SALES CORRELATED WITH R&D EXPENDITURES AS A PERCENTAGE OF SALES (15 SIC Categories)				
	Current Year	*Previous 5 Years*	*Previous 10 Years*	*Previous 10 Years (Weighted Average)*
AVERAGE	0.6682	0.6679	0.6658	0.6726
1958	0.6464			
1959	0.6714			
1960	0.6214			
1961	0.6393			
1962	0.6250	0.6107		
1963	0.5893	0.6000		
1964	0.6107	0.6107		
1965	0.6357	0.6000		
1966	0.5964	0.6179		
1967	0.6643	0.6393	0.5536	0.5893
1968	0.5929	0.5929	0.5786	0.5714
1969	0.6071	0.5536	0.5500	0.5500
1970	0.5536	0.5536	0.5179	0.5179
1971	0.7000	0.6643	0.6321	0.6321
1972	0.7357	0.7071	0.6679	0.6679
1973	0.6893	0.7036	0.6393	0.6714
1974	0.7500	0.7679	0.7464	0.7464
1975	0.7357	0.7679	0.7571	0.7571
1976	0.8143	0.8321	0.8143	0.8250
1977	0.8214	0.8000	0.8036	0.8143
1978	0.7321	0.7321	0.7286	0.7286

NET TRADE AS A PERCENTAGE OF TOTAL SALES CORRELATED WITH R&D EXPENDITURES AS A PERCENTAGE OF SALES (15 SIC Categories)				
	Current Year	*Previous 5 Years*	*Previous 10 Years*	*Previous 10 Years (Weighted Average)*
AVERAGE	0.6888	0.6832	0.6551	0.6539
1958	0.7750			
1959	0.8679			
1960	0.8071			
1961	0.7893			
1962	0.7893	0.8143		
1963	0.8429	0.8500		
1964	0.7786	0.7786		
1965	0.7071	0.7393		
1966	0.7107	0.7714		
1967	0.7000	0.7286	0.7607	0.7536
1968	0.7321	0.7321	0.7500	0.7464
1969	0.6929	0.7143	0.7321	0.7321
1970	0.6250	0.6250	0.6214	0.6214
1971	0.6464	0.6571	0.6607	0.6607
1972	0.6464	0.6643	0.6536	0.6536
1973	0.4929	0.5750	0.5750	0.5786
1974	0.6036	0.6536	0.6857	0.6857
1975	0.5964	0.6714	0.7250	0.7250
1976	0.5393	0.5536	0.5929	0.5964
1977	0.5643	0.5286	0.5429	0.5321
1978	0.5571	0.5571	0.5607	0.5607

NOTE: Numbers which are 0.5 and above are statistically significant at the 95 percent confidence level.

TABLE 14

EXPORTS AS A PERCENTAGE OF TOTAL SALES CORRELATED WITH FTE SCIENTISTS AND ENGINEERS AS A PERCENTAGE OF TOTAL EMPLOYMENT (12 SIC Categories)				
	Current Year	*Previous 5 Years*	*Previous 10 Years*	*Previous 10 Years (Weighted Average)*
AVERAGE	0.3876	0.3801	0.3951	0.3951
1958	0.5175			
1959	0.4266			
1960	0.3497			
1961	0.4056			
1962	0.3217	0.4126		
1963	0.3077	0.3217		
1964	0.3497	0.2837		
1965	0.3357	0.3077		
1966	0.2797	0.2657		
1967	0.3916	0.3916	0.3636	0.3427
1968	0.3846	0.3916	0.3636	0.3636
1969	0.3497	0.3846	0.3427	0.3427
1970	0.3497	0.3846	0.3357	0.3706
1971	0.4196	0.4126	0.4196	0.4196
1972	0.3846	0.3846	0.3916	0.3916
1973	0.3566	0.3497	0.3566	0.3566
1974	0.4336	0.4266	0.4336	0.4266
1975	0.4895	0.4336	0.4336	0.4266
1976	0.5245	0.4685	0.4685	0.4685
1977	0.4266	0.4406	0.4406	0.4406
1978	0.3357	0.3916	0.3916	0.3916

NET TRADE AS A PERCENTAGE OF TOTAL SALES CORRELATED WITH FTE SCIENTISTS AND ENGINEERS AS A PERCENTAGE OF TOTAL EMPLOYMENT (12 SIC Categories)				
	Current Year	*Previous 5 Years*	*Previous 10 Years*	*Previous 10 Years (Weighted Average)*
AVERAGE	0.3959	0.3447	0.2966	0.2850
1958	0.6923			
1959	0.7063			
1960	0.6503			
1961	0.6503			
1962	0.5804	0.6503		
1963	0.5734	0.5874		
1964	0.5035	0.5734		
1965	0.4266	0.5245		
1966	0.3776	0.4755		
1967	0.4615	0.4615	0.5455	0.5385
1968	0.4126	0.4685	0.5664	0.5664
1969	0.3217	0.4056	0.4266	0.4266
1970	0.3217	0.2937	0.3776	0.3497
1971	0.3497	0.2937	0.3497	0.3497
1972	0.0559	0.0559	0.1119	0.1119
1973	0.1399	0.0839	0.1399	0.1399
1974	0.3636	0.3077	0.3636	0.3077
1975	0.4685	0.4126	0.4126	0.3636
1976	0.1748	0.1189	0.1189	0.1189
1977	0.0070	0.0420	0.0420	0.0420
1978	0.0769	0.1049	0.1049	0.1049

NOTE: Numbers which are 0.5 and above are statistically significant at the 95 percent confidence level.

TABLE 15

EXPORTS AS A PERCENTAGE OF TOTAL SALES CORRELATED WITH FTE SCIENTISTS AND ENGINEERS AS A PERCENTAGE OF TOTAL EMPLOYMENT (15 SIC Categories)				
	Current Year	*Previous 5 Years*	*Previous 10 Years*	*Previous 10 Years (Weighted Average)*
AVERAGE	0.4735	0.4721	0.4658	0.4670
1958	0.5929			
1959	0.5607			
1960	0.4964			
1961	0.5036			
1962	0.4714	0.4964		
1963	0.4429	0.4679		
1964	0.4393	0.4464		
1965	0.4607	0.4679		
1966	0.4500	0.4536		
1967	0.4750	0.4750	0.4393	0.4393
1968	0.3786	0.4000	0.3750	0.3750
1969	0.3214	0.3750	0.3536	0.3536
1970	0.2964	0.3250	0.3179	0.3464
1971	0.4500	0.4286	0.4429	0.4500
1972	0.4821	0.4821	0.4786	0.4786
1973	0.4500	0.4571	0.4571	0.4571
1974	0.5214	0.5321	0.5321	0.5321
1975	0.5107	0.5214	0.5214	0.5214
1976	0.5821	0.5750	0.5750	0.5679
1977	0.5643	0.5786	0.5714	0.5714
1978	0.4929	0.5429	0.5250	0.5107

NET TRADE AS A PERCENTAGE OF TOTAL SALES CORRELATED WITH FTE SCIENTISTS AND ENGINEERS AS A PERCENTAGE OF TOTAL EMPLOYMENT (15 SIC Categories)				
	Current Year	*Previous 5 Years*	*Previous 10 Years*	*Previous 10 Years (Weighted Average)*
AVERAGE	0.5560	0.5286	0.4881	0.4911
1958	0.7286			
1959	0.7821			
1960	0.6536			
1961	0.6571			
1962	0.5929	0.6250		
1963	0.6786	0.6714		
1964	0.6000	0.6036		
1965	0.5571	0.5964		
1966	0.5500	0.6143		
1967	0.5464	0.5464	0.6000	0.6000
1968	0.6107	0.5893	0.6321	0.6321
1969	0.5571	0.5500	0.5571	0.5571
1970	0.5000	0.4893	0.4750	0.4679
1971	0.5036	0.5214	0.5000	0.5036
1972	0.4929	0.4929	0.4714	0.4714
1973	0.4500	0.4286	0.4286	0.4286
1974	0.4714	0.4643	0.4643	0.4643
1975	0.5321	0.5179	0.5179	0.5179
1976	0.4107	0.3857	0.3857	0.4107
1977	0.3786	0.4214	0.3964	0.3964
1978	0.4214	0.4679	0.4286	0.4429

NOTE: Numbers which are 0.5 and above are statistically significant at the 95 percent confidence level.

TABLE 16

PREVIOUS FIVE-YEAR AVERAGES OF EXPORTS AND NET TRADE AS A PERCENTAGE OF SALES CORRELATED WITH: (12 SIC Categories)

	5-Year Averages Of R&D Expenditures As A Percentage Of Total Sales	*5-Year Averages Of FTE Scientists And Engineers As A Percentage Of Total Employment*
EXPORTS:		
AVERAGE	0.6211	0.3776
1962	0.5524	0.3916
1963	0.5524	0.3357
1964	0.5455	0.3357
1965	0.5455	0.3427
1966	0.5524	0.3357
1967	0.5315	0.3357
1968	0.5315	0.3357
1969	0.5664	0.3706
1970	0.6364	0.3846
1971	0.6364	0.3846
1972	0.6434	0.3846
1973	0.6853	0.3846
1974	0.6853	0.3846
1975	0.6853	0.3916
1976	0.7133	0.4266
1977	0.7483	0.4476
1978	0.7483	0.4476
NET TRADE:		
AVERAGE	0.6236	0.4068
1962	0.7762	0.6503
1963	0.7762	0.5944
1964	0.7622	0.5944
1965	0.7622	0.5874
1966	0.7622	0.5734
1967	0.6783	0.4406
1968	0.6853	0.4685
1969	0.5664	0.4056
1970	0.5594	0.3497
1971	0.5594	0.3497
1972	0.6014	0.3287
1973	0.5315	0.2937
1974	0.5524	0.2517
1975	0.5594	0.3147
1976	0.4755	0.2378
1977	0.4965	0.2378
1978	0.4965	0.2378

PREVIOUS TEN-YEAR AVERAGES OF EXPORTS AND NET TRADE AS A PERCENTAGE OF SALES CORRELATED WITH: (12 SIC Categories)

	10-Year Averages Of R&D Expenditures As A Percentage Of Total Sales	*10-Year Averages Of FTE Scientists And Engineers As a Percentage of Total Employment*
EXPORTS:		
AVERAGE	0.6002	0.3718
1967	0.5524	0.3427
1968	0.5594	0.3636
1969	0.5594	0.3357
1970	0.5315	0.2937
1971	0.5315	0.3357
1972	0.5315	0.3357
1973	0.5944	0.3916
1974	0.6434	0.3916
1975	0.6434	0.3916
1976	0.6783	0.4266
1977	0.6783	0.4266
1978	0.6993	0.4266
NET TRADE:		
AVERAGE	0.6387	0.4138
1967	0.7762	0.5874
1968	0.7762	0.5874
1969	0.7203	0.4755
1970	0.6713	0.4755
1971	0.6853	0.4685
1972	0.6224	0.4056
1973	0.6224	0.4056
1974	0.6154	0.4056
1975	0.6224	0.3986
1976	0.5245	0.2587
1977	0.5245	0.2587
1978	0.5035	0.2378

21-YEAR AVERAGES OF EXPORTS AND NET TRADE AS A PERCENTAGE OF SALES CORRELATED WITH:

	21-Year Averages Of R&D Expenditures As A Percentage Of Total Sales	*21-Year Averages Of FTE Scientists And Engineers As A Percentage Of Total Employment*
EXPORTS:	0.6434	0.4336
NET TRADE:	0.6224	0.4056

NOTE: Numbers which are 0.5 and above are statistically significant at the 95 percent confidence level.

TABLE 17

PREVIOUS FIVE-YEAR AVERAGES OF EXPORTS AND NET TRADE AS A PERCENTAGE OF SALES CORRELATED WITH: (15 SIC Categories)		
	5-Year Averages Of R&D Expenditures As A Percentage Of Total Sales	*5-Year Averages Of FTE Scientists And Engineers As A Percentage Of Total Employment*
EXPORTS:		
AVERAGE	0.6683	0.4754
1962	0.6464	0.4929
1963	0.6036	0.4786
1964	0.6214	0.4714
1965	0.6143	0.4679
1966	0.6250	0.4536
1967	0.6179	0.4571
1968	0.6357	0.4821
1969	0.6393	0.4679
1970	0.6143	0.3964
1971	0.6214	0.3929
1972	0.6750	0.4429
1973	0.7286	0.4750
1974	0.7286	0.4857
1975	0.7143	0.4714
1976	0.7643	0.5321
1977	0.7429	0.5429
1978	0.7679	0.5714
NET TRADE:		
AVERAGE	0.7130	0.5630
1962	0.8464	0.6679
1963	0.8321	0.6857
1964	0.8143	0.6286
1965	0.8107	0.6500
1966	0.7893	0.6250
1967	0.7321	0.5536
1968	0.7321	0.5464
1969	0.7357	0.5429
1970	0.7071	0.5714
1971	0.7071	0.5714
1972	0.6964	0.5536
1973	0.6571	0.5321
1974	0.6000	0.4857
1975	0.6250	0.5071
1976	0.6071	0.4714
1977	0.6214	0.4821
1978	0.6071	0.4964

PREVIOUS TEN-YEAR AVERAGES OF EXPORTS AND NET TRADE AS A PERCENTAGE OF SALES CORRELATED WITH: (15 SIC Categories)		
	10-Year Averages Of R&D Expenditures As A Percentage Of Total Sales	*10-Year Averages Of FTE Scientists And Engineers As A Percentage Of Total Employment*
EXPORTS:		
AVERAGE	0.6655	0.4866
1967	0.6143	0.4786
1968	0.6357	0.4857
1969	0.6357	0.4750
1970	0.6214	0.4571
1971	0.6071	0.4607
1972	0.6107	0.4607
1973	0.6464	0.4643
1974	0.6929	0.4857
1975	0.6929	0.4786
1976	0.7250	0.5107
1977	0.7464	0.5393
1978	0.7571	0.5429
NET TRADE:		
AVERAGE	0.7113	0.5503
1967	0.8000	0.6357
1968	0.7964	0.6357
1969	0.7607	0.5643
1970	0.7286	0.5571
1971	0.7250	0.5250
1972	0.7143	0.5500
1973	0.7143	0.5714
1974	0.7071	0.5714
1975	0.7000	0.5607
1976	0.6607	0.4857
1977	0.6250	0.4857
1978	0.6036	0.4607

21-YEAR AVERAGES OF EXPORTS AND NET TRADE AS A PERCENTAGE OF SALES CORRELATED WITH:		
	21-Year Averages Of R&D Expenditures As A Percentage of Total Sales	*21-Year Averages Of FTE Scientists And Engineers As A Percentage Of Total Employment*
EXPORTS:	0.6964	0.5321
NET TRADE:	0.6893	0.5321

NOTE: Numbers which are 0.5 and above are statistically significant at the 95 percent confidence level.

TABLE 18

EXPORTS AS A PERCENTAGE OF TOTAL SALES CORRELATED WITH FEDERAL R&D EXPENDITURES PERFORMED BY INDUSTRIES AS A PERCENTAGE OF TOTAL SALES (12 SIC Categories)

	Current Year	*Previous 5 Years*	*Previous 10 Years*	*Previous 10 Years (Weighted Average)*
AVERAGE	0.7046	0.7195	0.7432	0.7394
1958	0.7939			
1959	0.6606			
1960	0.5636			
1961	0.7091			
1962	0.7091	0.6727		
1963	0.6545	0.6485		
1964	0.5636	0.6121		
1965	0.5315	0.6818		
1966	0.6818	0.6818		
1967	0.7203	0.7182	0.7697	0.7697
1968	0.7455	0.7182	0.7697	0.7697
1969	0.8182	0.7364	0.7455	0.7455
1970	0.7182	0.7364	0.7000	0.7000
1971	0.7818	0.8091	0.8091	0.7636
1972	0.6853	0.7455	0.7455	0.7455
1973	0.7818	0.7455	0.7000	0.7000
1974	0.7909	0.7909	0.7455	0.7455
1975	0.7909	0.7909	0.7909	0.7909
1976	0.6905	0.6905	0.6905	0.6905
1977	0.6905	0.6905	0.6905	0.6905
1978	0.7143	0.7619	0.7619	0.7619

NET TRADE AS A PERCENTAGE OF TOTAL SALES CORRELATED WITH FEDERAL R&D EXPENDITURES PERFORMED BY INDUSTRIES AS A PERCENTAGE OF TOTAL SALES (12 SIC Categories)

	Current Year	*Previous 5 Years*	*Previous 10 Years*	*Previous 10 Years (Weighted Average)*
AVERAGE	0.6247	0.5842	0.5152	0.5106
1958	0.8424			
1959	0.7818			
1960	0.7333			
1961	0.7909			
1962	0.7545	0.7333		
1963	0.7727	0.7576		
1964	0.7273	0.7333		
1965	0.7203	0.7182		
1966	0.6818	0.6818		
1967	0.7413	0.7091	0.6970	0.6970
1968	0.6364	0.6636	0.6242	0.6242
1969	0.6455	0.6000	0.6000	0.6000
1970	0.4455	0.5636	0.6000	0.6000
1971	0.6000	0.5636	0.5636	0.5091
1972	0.4196	0.3000	0.3000	0.3000
1973	0.3909	0.4000	0.3455	0.3455
1974	0.6727	0.6727	0.6182	0.6182
1975	0.6909	0.6909	0.6909	0.6909
1976	0.4048	0.4048	0.4048	0.4048
1977	0.4048	0.4048	0.4048	0.4048
1978	0.2619	0.3333	0.3333	0.3333

NOTE: Numbers which are 0.5 and above are statistically significant at the 95 percent confidence level.

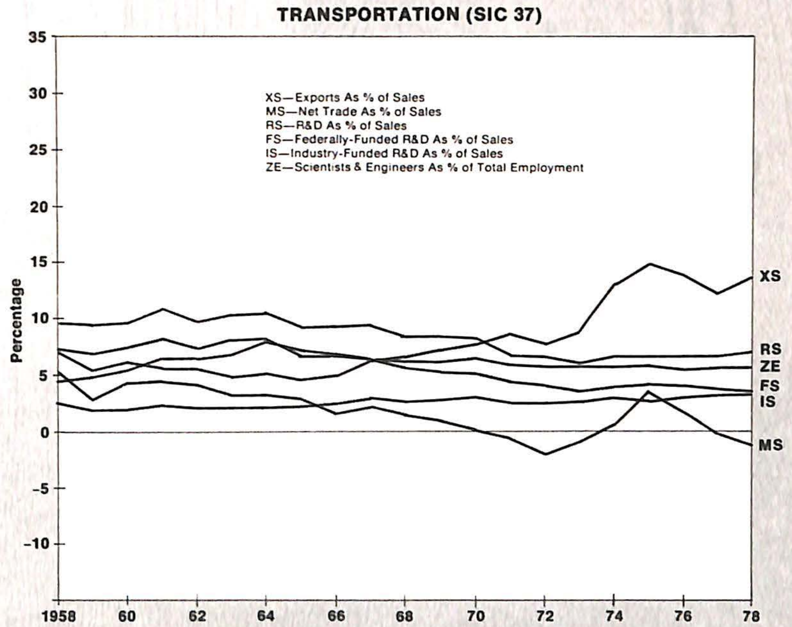
TABLE 19

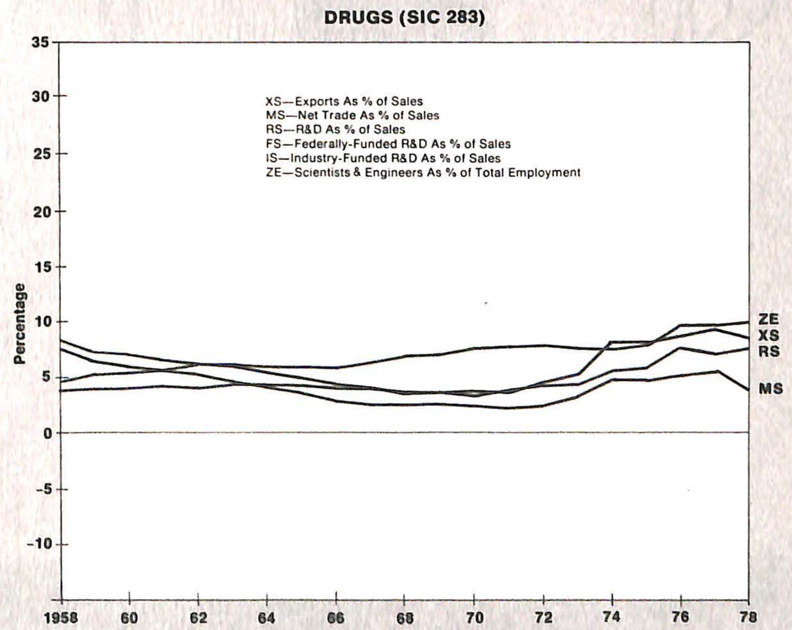
EXPORTS AS A PERCENTAGE OF TOTAL SALES CORRELATED WITH INDUSTRY FUNDED R&D EXPENDITURES AS A PERCENTAGE OF TOTAL SALES (12 SIC Categories)				
	Current Year	*Previous 5 Years*	*Previous 10 Years*	*Previous 10 Years (Weighted Average)*
AVERAGE	0.6537	0.6599	0.6515	0.6573
1958	0.6636			
1959	0.6545			
1960	0.6000			
1961	0.6727			
1962	0.6084	0.6848		
1963	0.6154	0.6727		
1964	0.5944	0.6848		
1965	0.5315	0.6545		
1966	0.5636	0.6455		
1967	0.6224	0.6636	0.7091	0.7091
1968	0.6636	0.6636	0.6970	0.7091
1969	0.6818	0.6455	0.6970	0.6970
1970	0.6182	0.6091	0.6182	0.6182
1971	0.6455	0.6364	0.6364	0.6364
1972	0.6923	0.6818	0.6636	0.6636
1973	0.6364	0.6364	0.6182	0.6182
1974	0.6818	0.6818	0.6727	0.6727
1975	0.6727	0.6818	0.6727	0.6818
1976	0.7381	0.5952	0.5952	0.6190
1977	0.7857	0.6190	0.5952	0.6190
1978	0.7857	0.7619	0.6429	0.6429

NET TRADE AS A PERCENTAGE OF TOTAL SALES CORRELATED WITH INDUSTRY FUNDED R&D EXPENDITURES AS A PERCENTAGE OF TOTAL SALES (12 SIC Categories)				
	Current Year	*Previous 5 Years*	*Previous 10 Years*	*Previous 10 Years (Weighted Average)*
AVERAGE	0.6431	0.5783	0.5114	0.5311
1958	0.7909			
1959	0.8455			
1960	0.7697			
1961	0.7636			
1962	0.8252	0.7697		
1963	0.8531	0.7818		
1964	0.8112	0.8061		
1965	0.6014	0.7091		
1966	0.5727	0.7000		
1967	0.6364	0.6727	0.7212	0.7212
1968	0.6273	0.6273	0.6242	0.6970
1969	0.5727	0.5727	0.5394	0.5394
1970	0.5909	0.5091	0.5636	0.5636
1971	0.6273	0.5091	0.5636	0.5636
1972	0.5035	0.4455	0.4364	0.4364
1973	0.4273	0.4273	0.4000	0.4000
1974	0.6636	0.6636	0.6818	0.6000
1975	0.6182	0.7091	0.6545	0.7091
1976	0.4524	0.3333	0.3333	0.4286
1977	0.5238	0.3095	0.3333	0.4286
1978	0.4286	0.2857	0.2857	0.2857

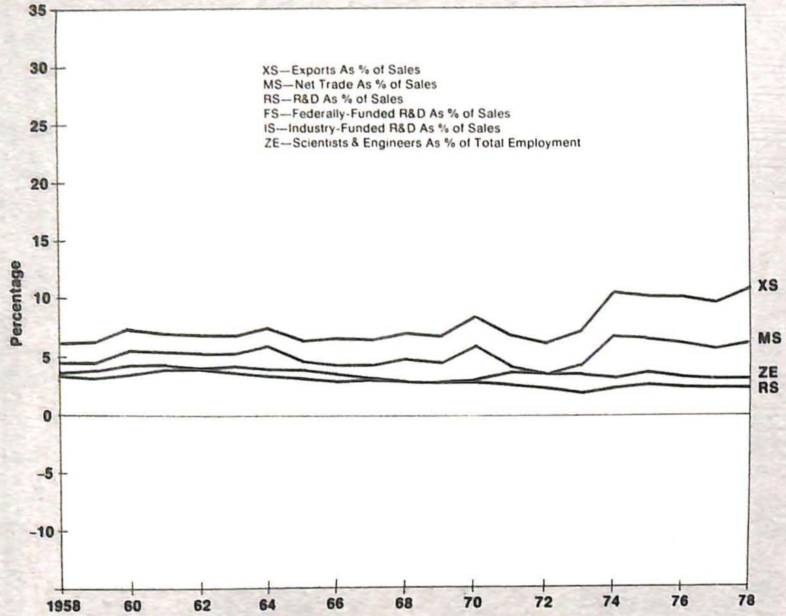
NOTE: Numbers which are 0.5 and above are statistically significant at the 95 percent confidence level.

APPENDIX B - EXPORTS, NET TRADE AND R&D AS A PERCENTAGE OF SALES AND EMPLOYMENT OF ENGINEERS AS A PERCENTAGE OF TOTAL EMPLOYMENT FOR MAJOR U.S. INDUSTRIES

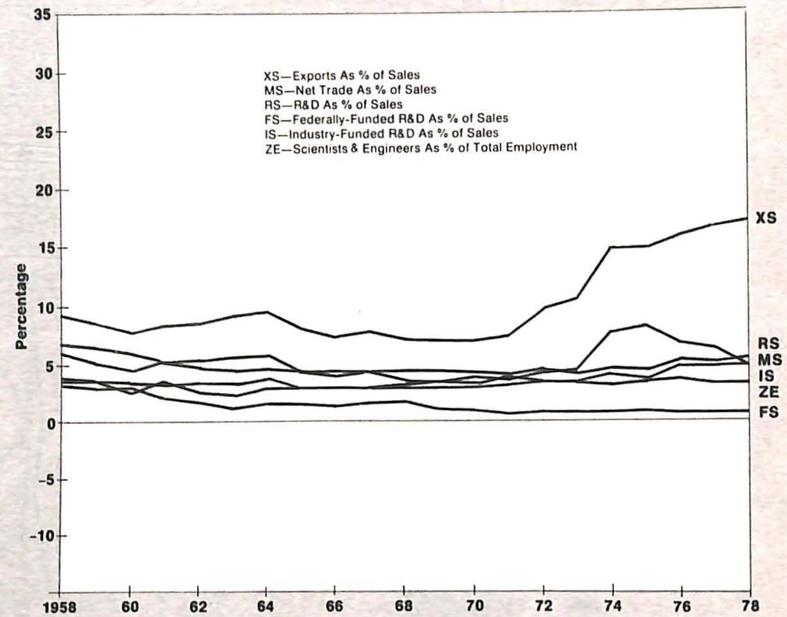




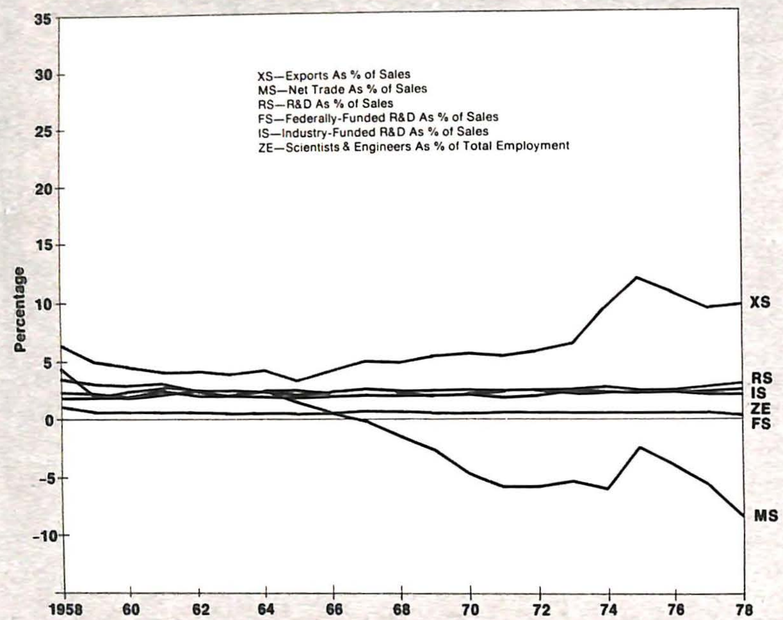
NON-DRUGS (SIC 28_)



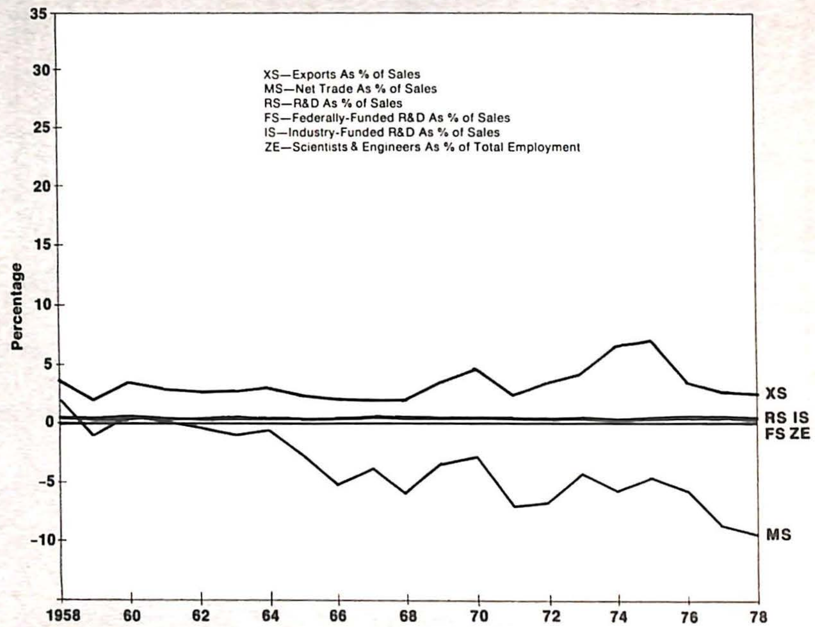
INSTRUMENTS (SIC 38)



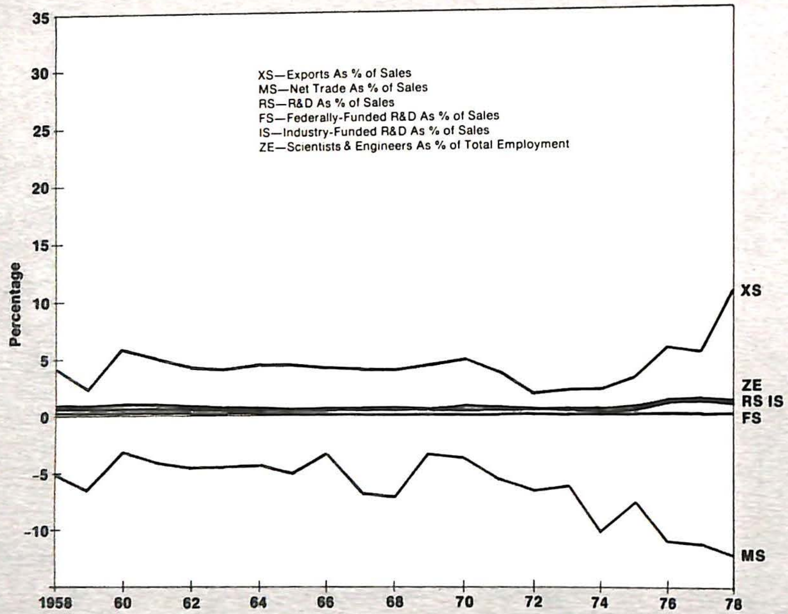
NON-AIRCRAFT TRANSPORTATION (SIC 37_)



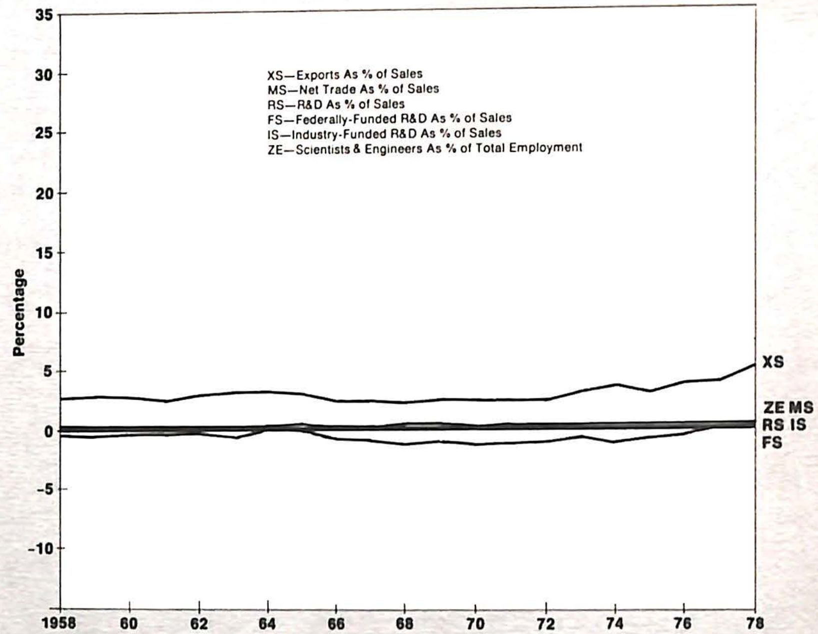
FERROUS METALS (SIC 33_)



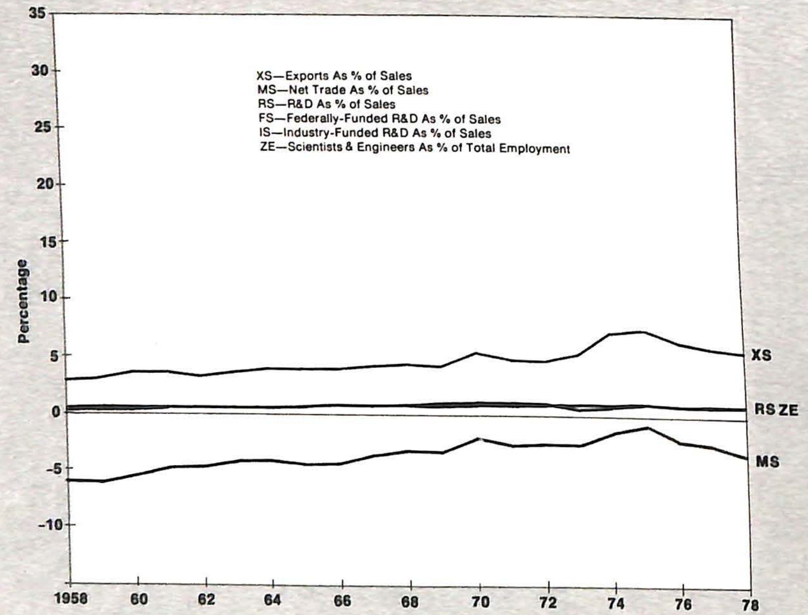
NON-FERROUS METALS (SIC 333)



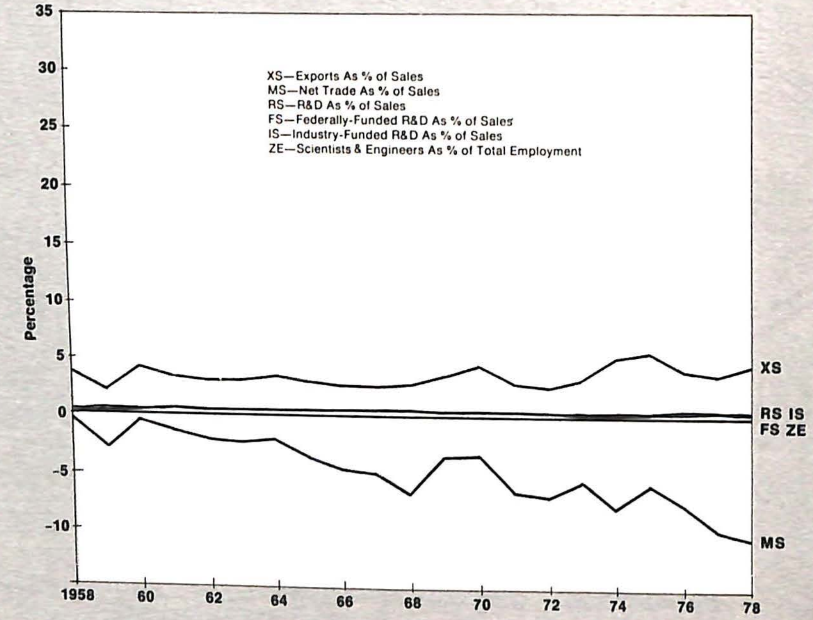
FOOD (SIC 20)



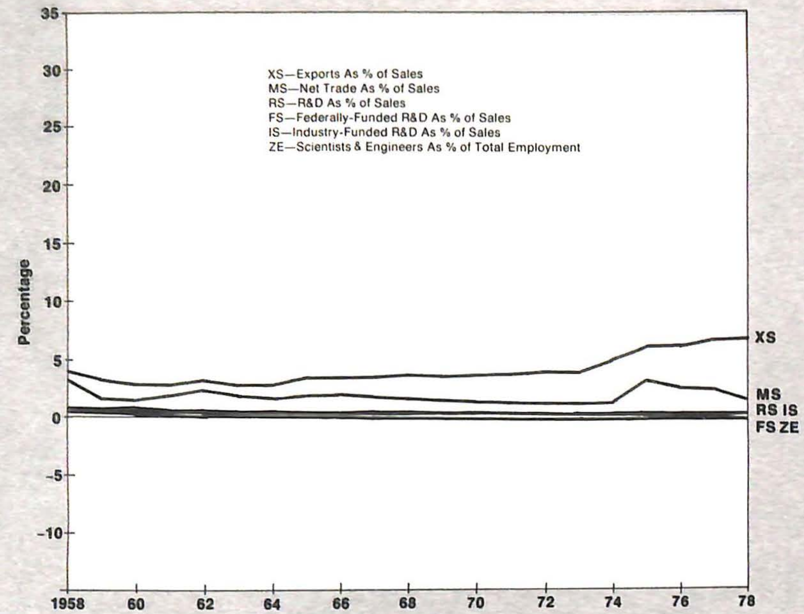
PAPER (SIC 26)



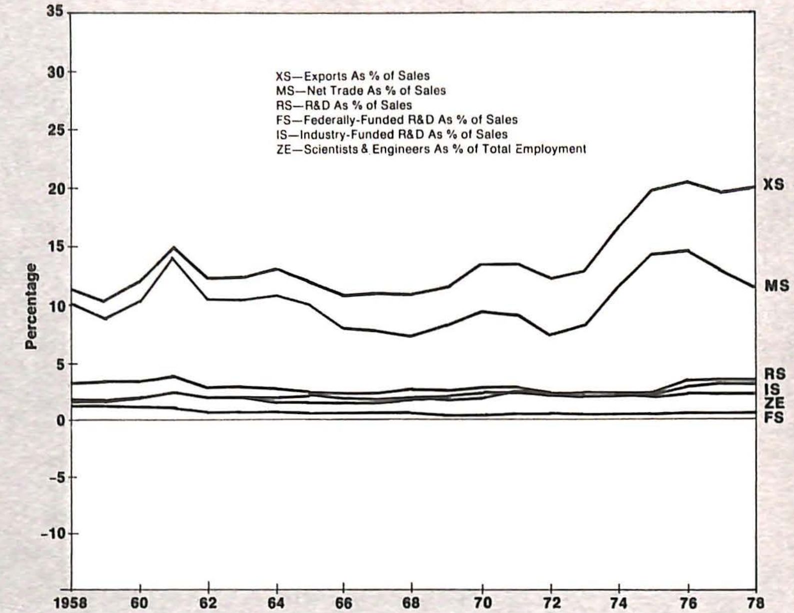
PRIMARY METALS (SIC 33)



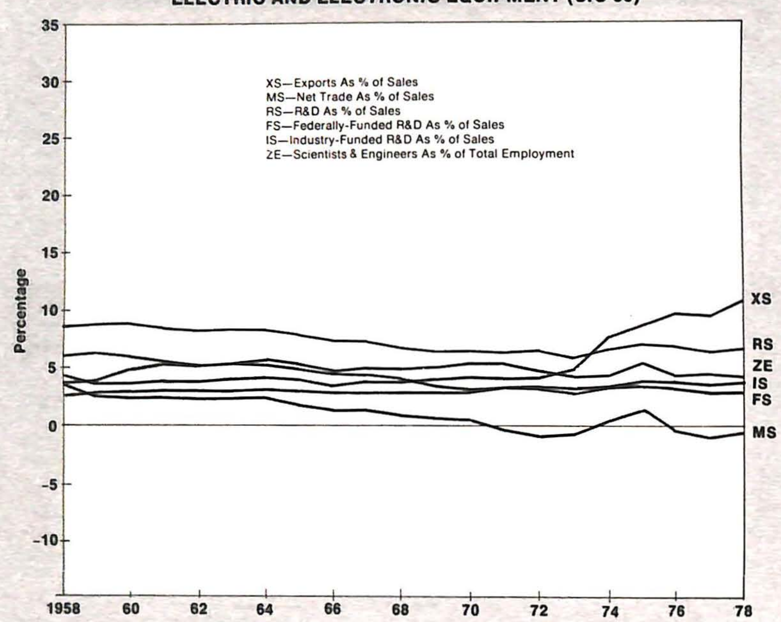
FABRICATED METAL (SIC 34)



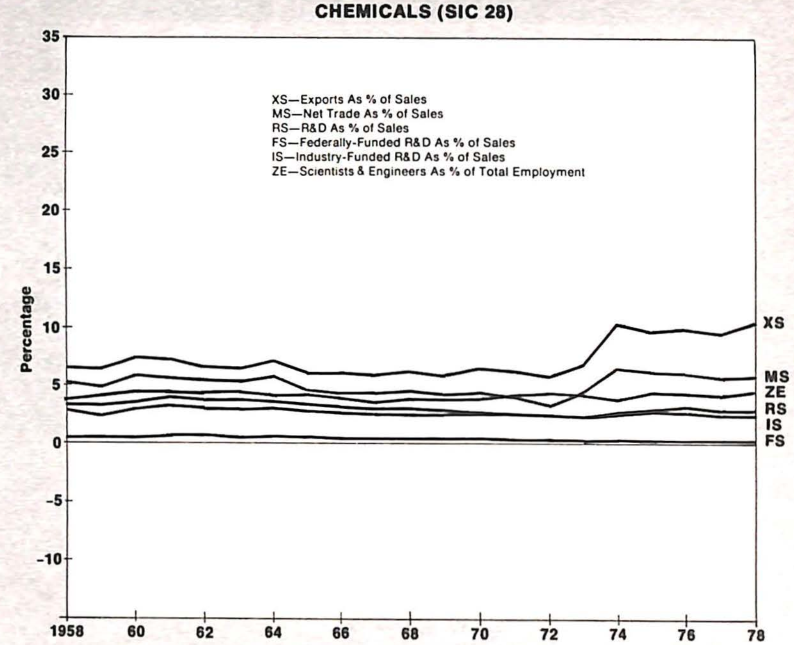
NON-ELECTRICAL MACHINERY – INCLUDES COMPUTERS (SIC 35)



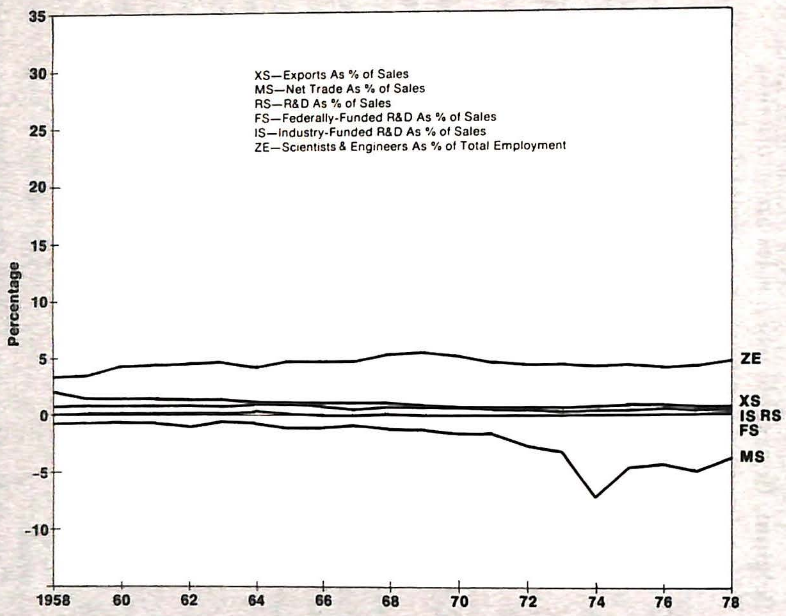
ELECTRIC AND ELECTRONIC EQUIPMENT (SIC 36)



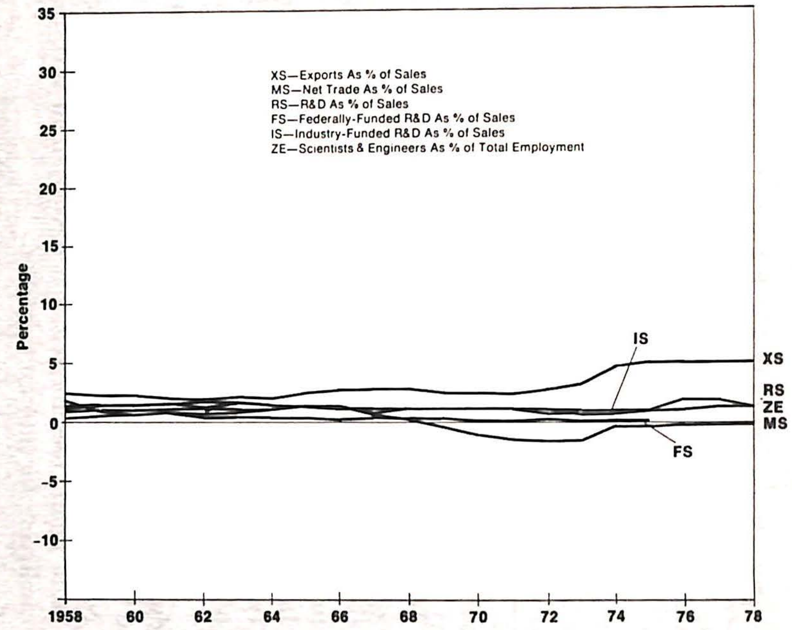
CHEMICALS (SIC 28)



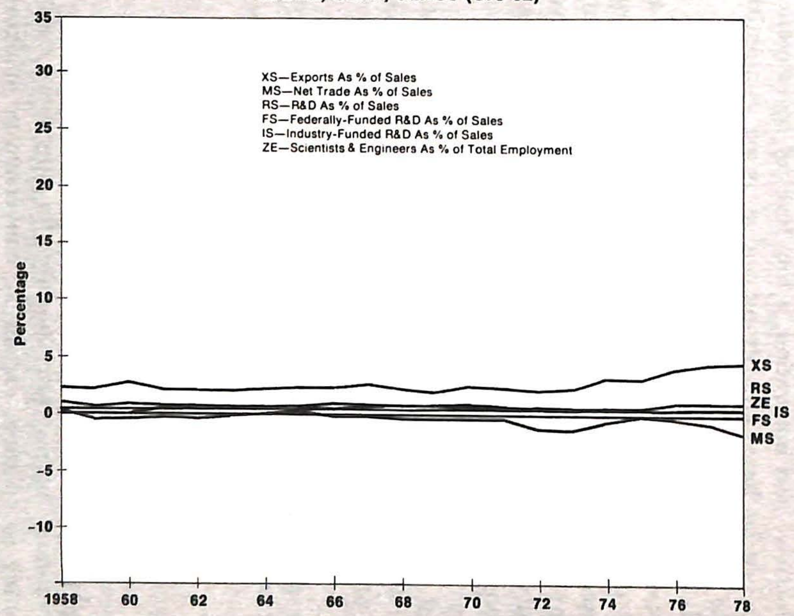
PETROLEUM AND COAL (SIC 29)



RUBBER AND PLASTICS (SIC 30)



STONE, CLAY, GLASS (SIC 32)



APPENDIX C - GOVERNMENT INCENTIVES TO INDUSTRY IN WESTERN EUROPE, JAPAN, CANADA AND THE UNITED STATES

The government's role in stimulating productivity, innovation and industrial development is an increasingly important issue as the United States faces a declining level of productivity and innovation, a low level of investment in its industrial base—and strong and growing competition in the world market.

The following brief summaries of some incentives instituted by various governments in Western Europe, and in Japan, Canada, and the United States permit some comparison of federal initiatives to stimulate industry. Comparisons may be most useful when viewed in terms of results: the relative success in world markets and overall economic health of the various countries, and the United States.

All governments have the broad goal of stimulating overall national economic growth and development. The incentives listed will show, however, that stimulation of the economies of depressed or underdeveloped areas, are also important to many of the United States' major world market competitors.

BELGIUM[1]

Research and Development, Innovation and Productivity Incentives[*]

1. National interest rate subsidies for operations contributing to creation, expansion, conversion or modernization of industrial enterprises.
2. Regional interest rate subsidies for investment in fixed assets or intangible assets including R&D on prototypes and new products, and new manufacturing processes.
3. Progress contracts for investment programs for technical innovation or industrial and/or commercial development, including R&D of new products or production processes.
4. Technological development contracts (interest-free advances to 80 percent of development cost of prototypes, new products and processes). Repayable when project is profitable.
5. Interest-free loans (to 80 percent) for R&D of prototypes, new products and new manufacturing techniques.

Industrial Development Grants, Loans, Guarantees and Other Financial Assistance

1. National guarantees for long-term investment loans.
2. State guarantees for regional development investments qualifying for interest subsidies.
3. Tax-free regional development grants (75 percent of investor's own financial effort) for investment in buildings and equipment.
4. Interest-free loans (to 50 percent) to help companies find new foreign markets for products manufactured in Belgium. Repayable when sales are profitable.
5. Export financing (rate of approximately 4 percent).

Tax Incentives

1. Income tax exemption on capital grants.
2. Exemption from capital registration tax for certain investments.
3. Exemption from taxes on mergers or corporate splits.
4. Exemption on capital gains tax on reinvestment in real assets within three years.
5. Tax relief on headquarters and coordinating offices of multinational companies not engaging in commercial activity.
6. Exemption from withholding tax levied on interest of loans contracted abroad which are in general economic interest.
7. Deduction from taxable income, under certain conditions, of dividends not exceeding annually 5 percent of paid up capital.
8. Regional development accelerated depreciation (essentially depreciation at will, allowing 110 percent in first year) for industrial buildings and machinery.
9. Property tax reductions for investments in fixed assets.
10. Tax deductions on Value-Added Tax levied on investment goods.

[1] R. J. Waldmann and B. Thomas Mansbach, *Investment Incentive Programs in Western Europe* (Washington, D.C., International Division, Chamber of Commerce of the United States, 1978).

[*] "Research and Development, Innovation and Productivity Incentives" include fiscal (tax) and financial incentives specifically earmarked for R&D, innovation and productivity improvement.

DENMARK[2]

Research and Development, Innovation and Productivity Incentives

1. Government participation in investments through loans and shares in projects aimed at new production in companies whose activities depend largely on R&D.
2. Technical and Industrial Development Fund grants for R&D projects aimed at new production, and share subscriptions in companies whose activities depend largely on development work.
3. Loans (to 90 percent for 8-20 years at rates 2-3 percent below market) for experimental activities and trial runs of production machinery in development areas.
4. Guarantees (to 90 percent) for research and testing of plant production equipment.

Industrial Development Grants, Loans, Guarantees and Other Financial Assistance

1. Cash grants (to 25 percent) with deferred taxation (10 years) for investment in industrial enterprises.
2. Loans (to 90 percent for 8-20 years at rates 2-3 percent below market) for development areas.
3. Medium-term loans (to 10 years) for new investments in building and machinery.
4. Special-mortgage credit to extend mortgage loans.
5. Guarantees (to 90 percent) for factory construction, and loans for industries boosting exports or locating in development regions.
6. Loans for regional industrial buildings assistance (100 percent of face value; variable rate of interest).

Tax Incentives

1. Advance depreciation on machinery and equipment (to 30 percent of purchase price above set amount) and allocation of advance depreciation (to 20 percent of profits deductible from taxable income) to an investment fund.

FRANCE[3°]

Research and Development, Innovation and Productivity Incentives

1. Grants (15-25 percent of investment) for businesses that create or expand technical or scientific research activities, including adding research activities to existing industrial operations. Research must tend to assist technological development.

Industrial Development Grants, Loans, Guarantees and Other Financial Assistance

1. Regional development grants (to 25 percent of investment) for machinery and equipment. Effective tax rate on grant reduced from 50 to 33 percent.
2. Site, building and facilities regional development assistance grants for industrial plants.

Tax Incentives

1. Tax exemptions and accelerated depreciation (to 25 percent in first year) to promote investment, employment and economic development in underdeveloped regions.

ITALY[4°]

Research and Development, Innovation and Productivity Incentives

1. Research and Development Fund incentives (from 40 to 60 percent of project costs).
2. Tax deductions for R&D (50 percent in first year; remaining 50 percent in succeeding years—time frame depending on success of research).

Industrial Development Grants, Loans, Guarantees and Other Financial Incentives

1. Subsidies and grants (15-45 percent of capital investment) for establishment or extension of industrial plants. Grants increased 20 percent for priority areas.
2. Mezzogiorno regional loans (at 30 percent of prime rate) for small and medium-sized industrial concerns.
3. Northern and Central Italy regional loans (to 70 percent of expenses at 7 percent rate) to build, reactivate, transform, modernize or expand industrial plants.
4. Special terms for land and buildings for industrial projects in Mezzogiorno.

Tax Incentives

1. Accelerated depreciation (45 percent of investments for expansion or modernization) for all corporations; additional depreciation charged off in three years.
2. Tax exemptions on income and profits for investment in regional development industrial enterprises.

NETHERLANDS[5]

Research and Development, Innovation and Productivity Incentives

1. R&D grants to develop new products, usually for small enterprises.

Industrial Development Grants, Loans, Guarantees and Other Financial Assistance

1. State guarantees for long-term loans for enterprises in certain regions.

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[2] Waldmann and Mansbach, *op. cit.*

[3] Waldmann and Mansbach, *op. cit.*

° Most incentives emphasize development and job creation outside the Paris Basin and Lyon.

[4] Waldmann and Mansbach, *op. cit.*

° Most incentives emphasize development of the Mezzogiorno and North and Central Italy.

[5] Waldmann and Mansbach, *op. cit.*

2. Government participation in investments in new industrial enterprises.
3. National, provincial and municipal improvements in infrastructure for industrial development.

Tax Incentives
1. Premiums (15 to 25 percent of capital expenditure on fixed assets—to 40 percent for investment in certain regions) for new industrial enterprises and expansion in new, permanent premises. NOTE: *Premiums are offset against tax assessments, giving them the character of tax refunds.*
2. Tax premiums of varying amounts (7 to 23 percent) for fixed assets in buildings, ships, aircraft and other investments.
3. Tax premiums for investments in small-scale enterprises, investments in special development areas, and projects requiring major investment for erection of buildings or fixed equipment.

UNITED KINGDOM[6]

Research and Development, Innovation and Productivity Incentives
1. R&D allowances for trade-related scientific research expenditures.
2. Allowances against profits in certain trades for capital expenditures in acquisition of patent rights.
3. Grants (40 to 50 percent) for manufacturing industry projects in Northern Ireland. Includes basic research, related design, prototypes to commercial production, final design and production drawing costs.
4. Accelerated depreciation for capital costs of R&D (100 percent on buildings and equipment) in Northern Ireland.
5. Fixed grants and rent relief for R&D units locating in special development areas.

Industrial Development Grants, Loans, Guarantees and Other Financial Assistance
1. Tax-free regional development grants (20 or 22 percent) for new machinery or plants.
2. National selective assistance for individual projects of benefit to the economy.
3. Grants (15-25 percent of eligible costs) for various sectors including electronic components and instrumentation and automation, for modernization and expansion of plants, machinery and buildings; restructuring and rationalizing; product and process development.
4. Grants (to 25 percent of eligible costs) or shared-cost contracts for manufacturing projects (primarily mechanical and electrical engineering) desirable in terms of national industrial strategy.
5. Manufacturing, mining and construction industry medium-term loans (rates generally 3 percent below prime commercial) for normal capital needs of projects resulting in new capacity, expansion or modernization.
6. Interest relief grants (3 percent for four years) when company finances projects from private sources.
7. Selective investment (normally interest relief grant) in manufacturing industry projects desirable to national interest.
8. Tax-free cash grants (30 to 50 percent) for plant construction, new machinery and equipment in Northern Ireland. Also low rental of ready-built government factories; loan assistance; interest relief grants; cash grants for transferring machinery, equipment and stock; and for start-up and initial operating costs.
9. Government-built factories for purchase at special terms and initial rent-free periods.

Tax Incentives
1. Depreciation allowances (initial allowance of 50 percent on capital expenditures, and writing-down allowances) on industrial buildings and structures, including otherwise unallowable repairs.
2. Machinery and plant allowances (first-year allowance equal to total expenditure, and writing-down allowances).
3. Mines, oil wells and mineral allowances (40 percent of expenditures; 100 percent in development areas and Northern Ireland, and writing-down allowances).
4. Accelerated depreciation for capital costs of machinery and equipment (100 percent first-year allowance), and industrial buildings construction (54 percent during first year and 4 percent per year thereafter) in Northern Ireland.
5. Import duty exemptions for goods destined for re-export—with some qualifications.
6. Property tax reductions for firms entering Northern Ireland (75 percent) and Scotland (50 percent).

WEST GERMANY[7]

Research and Development, Innovation and Productivity Incentives
1. R&D grants (7.5 percent on investments) for acquisition of new, depreciable movable fixed assets or enlargement of buildings, provided such assets are used for R&D for at least 3 years.
2. Grants (to 7.5 percent of investment) for reorganization or rationalization of businesses. Emphasis on substantial change of products or production methods, increase in technical efficiency and financial viability.
3. Tax-free grants (to 30 percent) for new, depreciable movable fixed assets acquired or manufactured in West Berlin, and expansion or enlargement of buildings and related fixed assets when used in R&D.
4. Regional Development Program investment subsidy grants (5-25 percent of investment) for: rationalization

[6] Waldmann and Mansbach, *op. cit.*

[7] Waldmann and Mansbach, *op. cit.*

or reorganization of production facilities and diversification or application of new technologies.

5. Business guarantees (90 percent of set amount) for West Berlin enterprises which increase productivity.
6. Allowances for movable assets (to 50 percent) used exclusively for R&D and immovable assets (to 30 percent) if two-thirds used for R&D.
7. West Berlin fixed assets allowances (depreciation to 75 percent of acquisition or manufacturing costs plus regular depreciation for five years) for movable fixed assets and buildings used more than 80 percent for R&D.

Industrial Development Grants, Loans, Guarantees and Other Financial Assistance

1. Grants (to 7.5 percent of investment) in new, depreciable fixed assets for establishment or expansion of business.
2. Tax-free grants (to 25 percent if for manufacturing or energy production) for new, depreciable movable fixed assets acquired or manufactured in West Berlin and expansion or enlargement of buildings and related fixed assets.
3. Regional Development Program investment subsidy grants (5-25 percent of investment) for: establishment and expansion in manufacturing.
4. West Berlin Investment, Low Cost and General Business Loans (varying rates from 4.5 to 8 percent) for industrial goods purchased from West Berlin (to 50 percent of purchase price); acquisition or manufacture of depreciable fixed assets; establishment and expansion of industrial facilities, small businesses and commerce.
5. European Recovery Program Production Reorganization (5 and 6 percent rates for up to set amount) and Regional Soft Loans (5 and 6 percent for up to set amount) with preference for small and medium-sized businesses.
6. Regional development guarantees (80 percent to set amount) for establishment, expansion, reorganization of projects or investments strengthening economic structure.
7. Government participation in regional business investments.
8. Energy production grants (tax-free, to 7.5 percent of acquisition or manufacturing costs) for individual or corporate taxpayers for acquisition of new assets purchased or manufactured in connection with establishment or enlargement of certain energy producing plants.
9. Site, building and facility construction incentives, credits, loans and guarantees.

Tax Incentives

1. Tax reductions for individuals and companies in and managed from West Berlin.
2. West Berlin sales tax reductions.
3. Tax deductions on West Berlin Capital Development Loans.
4. West Berlin fixed assets allowances (depreciation to 75 percent of acquisition or manufacturing costs plus regular depreciation for five years) for new ships, movable fixed assets and buildings used more than 80 percent for taxpayer's own production of goods or energy, processing of goods, repair of assets.
5. Tax allowances (to 50 percent depreciation for movable assets and to 30 percent for immovable assets) for business investments in East Border areas.
6. Exemptions from real estate acquisition tax (waiver of 7 percent transfer tax) for projects that improve economic structure in state development areas.

JAPAN[8]

Research and Development, Innovation and Productivity Incentives

1. Government participation in investments in large-scale joint research projects for development of new techniques for industrial progress. Emphasis on: urgent need to modernize industry, effectively utilize natural resources, prevent pollution; impact on technological progress in mining and manufacturing; targeted projects; long-term, high-risk large investments; projects requiring government, industry, university cooperation.
2. R&D depreciation writeoff (to 25 percent in first year) for new equipment.
3. Grants (to 50 percent of equipment and facilities) for R&D in: large-scale technology, unexplored technologies, housing system technology, conservation of resources and energy technology, and pollution control technology. Also for R&D to help improve small business technology.
4. Loans (6.5 to 7.1 percent rates, generally) for R&D in: electronic computer development, technological growth of electronics and machinery industries, development of domestic technology.

Industrial Development Grants, Loans, Guarantees and Other Financial Assistance

1. Loans for purchasing equipment (to 70 percent) and financing of long-term working capital (to 50 percent of capital needs at 7.85 to 8.15 percent).
2. Bank guarantees on payment of principal and interest on foreign bank loans and on long-term credits from foreign suppliers (2 to 3 percent on outstanding principal).
3. Industrial relocation subsidies to promote removal, construction and additions to plant in development areas.
4. Collateral loans for movement of employees and machinery and relocation/construction of factories.
5. Bond loans (to 50 percent of operating expenses for three years at 7.65 percent rate) for removal of plant.

[8] Information on Japan is based on material to be published in a forthcoming guide to the investment incentive programs of the Pacific Basin countries by Raymond J. Waldmann under the auspices of the University of California Graduate School of Business Administration.

6. Loans (6.5 to 7.1 percent rates, generally) for nuclear power, oil and other resources, and energy projects.
7. Regional development assistance including grants-in-aid and compensation for interest and principal on local bonds.

Tax Incentives
1. Tax reductions on business, immovable acquisition and fixed asset taxes in development areas.
2. Deferral of taxation on capital gains derived from real property and reinvested in designated areas.
3. Special depreciation on moveable fixed assets (20 to 50 percent of acquisition costs for machinery in first accounting period), and real estate.
4. Tax relief on replaced assets and special depreciation reductions in regional development areas.
5. Customs duty and excise tax reduction on desulphurized imported crude oil.

CANADA[9]

Research and Development, Innovation and Productivity Incentives
1. R&D investment tax credits (5 to 10 percent) for current or capital expenditures.
2. Funds (to 50 percent) for industry energy R&D projects.
3. Industrial applied research assistance (approximately matching) grants.
4. Defense industry productivity assistance.
5. Cost sharing (to 50 percent) or term loan insurance (for 90 percent at one percent annual fee) for small and medium-sized businesses undertaking high risk innovative or adjustment projects in manufacturing and processing. Emphasis on export potential.

Industrial Development Grants, Loans, Guarantees and Other Financial Assistance
1. Regional development grants (non-repayable) and incentives (repayable, or repayable if project achieves certain profitability or objectives) for new manufacturing or processing facilities or new product expansions (15 to 30 percent of approved costs), and modernizations or volume expansions (20 percent). Also loan guarantees.
2. Small business loan guarantees for manufacturing firms for purchase of fixed or moveable equipment, including cost of fixed equipment installation; renovation, improvement or modernization of equipment; purchase or construction of new facilities or improvement or modernization; purchase of land including buildings.
3. Cost sharing incentives to assist goods and services suppliers to enter new export markets or expand activities. Includes costs of: participation in capital projects abroad, market identification or adjustment visits, trade fair participation outside Canada, and group marketing efforts through export consortia.
4. Federal financial assistance including loans, loan guarantees, equity financing, leasing for new and existing businesses which cannot obtain other financing on reasonable terms.

Tax Incentives
1. Tax credits (5 to 10 percent) for regional development area new manufacturing or processing facilities, or new product expansions, modernization or volume expansions.
2. Remission of duty on certain imported machinery and equipment used by secondary industry.
3. Excise tax exemptions for manufacturers and producers on partly manufactured goods changing hands for further processing; production equipment; pollution control equipment; certain processing materials; and plans, drawings and specifications for use in manufacture or production of goods or control of pollutants.
4. Customs incentives including reductions in duty and duty-free entry of articles and materials for manufacture of certain merchandise.

UNITED STATES[10]

Research and Development, Innovation and Productivity Incentives
1. Full deduction of certain R&D expenditures in year incurred. Includes costs representing R&D in experimental or laboratory sense.

Industrial Development Grants, Loans, Guarantees and Other Financial Assistance
1. State industrial financing programs that provide guarantees or loans for acquisition, construction, repair or improvement of industrial and manufacturing facilities, and purchase of machinery and equipment.
2. Federal loans and loan guarantees under the Defense Production Act to assist private enterprises in fulfilling defense production contracts.
3. Federal grants, loans and loan guarantees are available through numerous departments. Some key industry stimulus programs are administered through the following:
   - **Economic Development Administration, Department of Commerce**
     Public works grants and loans; economic adjustment assistance grants; business loans for industrial and

[9] *Doing Business in Canada–Federal Incentives to Industry* (Ottawa: Department of Industry, Trade and Commerce, 1978).

[10] *Federal Credit Activities: An Analysis of the President's Credit Budget for 1981*, The Congress of the United States, Congressional Budget Office, (February, 1980).

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commercial facilities (65 percent of cost; 15 percent supplied by applicant) and for working capital (90 percent). Guarantees (90 percent) of unpaid balance of leases for private industry and private loans for industrial and commercial facilities and working capital. Technical, planning and research assistance for development areas.

- **Export-Import Bank of the United States**
  Assists in financing exports of U.S. goods and services including direct loans, guarantees, and insurance. Direct lending limited to larger sales of U.S. products and services. Guarantees, insurance and discount programs to assist exporters in smaller sales of products and services. Long-term direct credits to foreign borrowers in connection with sales abroad of capital goods.

- **Farmers Home Administration, Department of Agriculture**
  Rural industrialization loans (to 85 percent of project) and loan guarantees (90 percent) to improve, develop or finance business, industry and employment in rural areas and cities below 50,000 population. Some grants for water, waste disposal, and industrial site facilities improvement.

- **Federal Aviation Administration**
  Guarantees 90 percent of principal and 100 percent of interest on loans up to $100 million for commuter air carriers for the purchase of aircraft and equipment. Also grants-in-aid for airport development.

- **National Science Foundation**
  Grants, contracts and awards, largely for basic research, to universities, nonprofit and other research corporations and sponsorship of projects involving industry-research group interface. Funds in 1981 Budget earmarked for cooperative projects with industry to facilitate innovation in American industry.

- **Overseas Private Investment Corporation**
  Encourages U.S. investment overseas through programs of political risk insurance against losses and investment financing through direct loans and loan guarantees (to 75 percent of the principal). Has an investment fund for direct loans.

- **Small Business Administration**
  Loan guarantees (90 percent) and direct (100 percent) or immediate participation (75 percent) loans to finance plant construction, conversion, or expansion and acquire equipment, facilities, machinery, supplies or materials. Provides working capital. Makes, participates in, or guarantees economic opportunity loans. Interest rates relate to cost of money to the government. Guarantees small business surety bonds, lease contracts and pollution control equipment contracts. Loans to state and local development companies assisting small business concerns.

Tax Incentives

1. Corporate income tax reduced from 48 to 46 percent (Revenue Act of 1978) to stimulate capital investment.
2. Investment tax credit (10 percent). Credit can be used to offset 90 percent of other taxes.
3. Accelerated depreciation for plant and equipment (can select asset life 20 percent shorter than IRS guideline life).
4. Provision of loss offsets through treatment of corporation with 15 or fewer shareholders as partnerships, for tax purposes. Provisions permitting individual investors to deduct losses from investments in small business from ordinary income.
5. Maximum corporate capital gains tax reduced from 49.1 to 28 percent (Rev. Act of 1978). Capital gains taxes lowered for investors in all income brackets (60 rather than 50 percent excluded from taxable income).
6. Alternative tax rate on corporate capital gains reduced from 30 to 28 percent (Rev. Act. of 1978).
7. Credit for investment (10 percent) in specified energy property.
8. Exclusion of interest on state and local government debt issued to finance pollution control facilities and industrial development from income subject to tax.

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