Public Policy Brief

Closing the R&D Gap

Evaluating the Sources of R&D Spending

Thomas Karier

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Preface

A good deal of evidence exists for the positive impact of research and development (R&D) investment on productivity growth and competitiveness, and numerous studies have a high sensitivity to this effect. Furthermore, R&D's social returns were found to range from being significant to very significant. Thus, the importance of R&D and its rate of growth mandate that either free markets or public policy or both determine and produce the optimal level of spending. Up to 1986, public policy to stimulate R&D focused mainly on defense procurement spending and the ongoing tax incentives, such as the research and experimentation (R&E) tax credit. Since 1986, however, the pressure to reduce federal outlays for national defense has shifted the focus of government R&D away from defense and toward civilian technology.

The findings by Thomas Karier, a Levy Institute research associate, in this *Public Policy Brief* indicate that the effect of tax incentives, and specifically the R&E credit, on R&D spending has been ambiguous and that imports and defense procurements have had a more significant influence on R&D. These findings, in addition to those of the General Accounting Office indicating that the R&E credit has the potential of becoming too generous for large firms and too restrictive to small firms, suggest that public funds might better be spent on projects that more directly would stimulate private sector R&D. For example, savings from defense downsizing or revenue savings from the R&E credit, should it be allowed to expire, could be shifted to nondefense procurement projects.

The task of restructuring and "modernizing" the research and experimentation tax credit has generated widespread public debate over the appropriate role of the federal government in subsidizing American business. Witnesses at a recent hearing conducted by the Oversight Subcommittee of the House Ways and Means Committee insinuated that in the current environment of fiscal responsibility, even programs that apparently promote America's economic interests—for example, increased R&D—are susceptible to the influence of those determined to balance the federal budget at any cost.

Even though it is difficult to conduct a meaningful cost analysis of the R&E tax credit, the General Accounting Office recently declared that in addition to measuring the credit's direct costs (forgone revenue) and benefits (increased R&D levels) it is important to consider the social impact and spillover effects of the R&E credit. Such effects have yet to be considered in a comprehensive manner, which makes an accurate assessment of the R&E credit difficult.

In the increasingly competitive global economic environment, the firms that will survive and prosper will be those that are able to adapt to changing market conditions through innovation. Arguably, such innovations are often determined by forward-looking programs of research and development; and in this regard many economists, policymakers, and scientists concur and may be alarmed by the fact that R&D spending in the United States has been falling over the recent past. If this, indeed, is the case, we stand to lose ground in our ability to innovate and disseminate technology, which, in turn, could erode our global competitive position.

Dimitri B. Papadimitriou
September 1995

Evaluating the Sources of R&D Spending

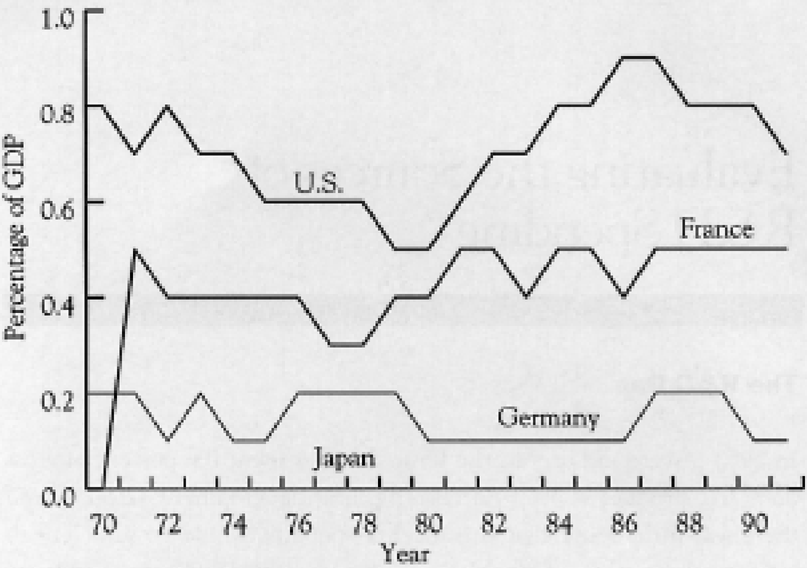
The R&D Gap

In 1953 private industry in the United States spent 0.6 percent of gross domestic product (GDP) on research and development (R&D), and there was little doubt that this level of spending would be sufficient to preserve the country's technological advantage. In 1993 private industry spent considerably more on R&D—1.3 percent of GDP—and yet there was much wider concern that this was not a high enough rate of spending for the United States to compete successfully in international markets. This concern was based on comparisons of U.S. R&D spending with those of Germany and Japan.

It is reassuring, if only momentarily, to note that the United States spends more on total R&D than Germany, Japan, and France combined. Even as a share of GDP, the United States's expenditure of 2.6 percent does not compare adversely to Japan's 3.0 percent, Germany's 2.8 percent, or France's 2.4 percent (National Science Foundation 1993).[1] Furthermore, there is at least one high-technology industry in which the United States enjoys indisputable superiority: weapons manufacturing. This distinction has been achieved only after decades of massive federal outlays for weapons systems and R&D. A comparison of defense R&D relative to GDP, Figure 1, shows that such expenditures by the United States historically have far exceeded those of Japan, Germany, and France.[2]

The U.S. R&D deficiency, however, does not concern national defense. It is generally understood that if U.S. firms are to remain viable in today's markets they must have adequate investment in new technologies which, in turn, depend on investment in research and development. The best

Figure 1 Defense R&D Spending as a Percentage of GDP



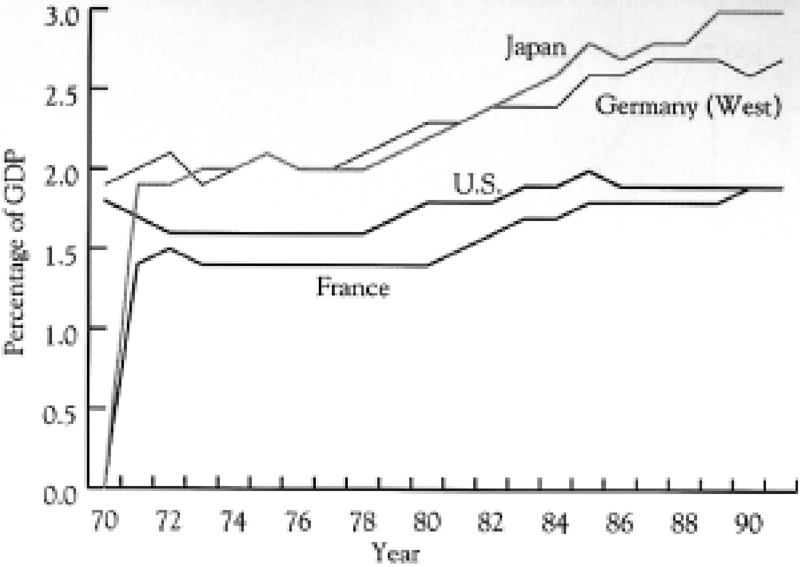
Source: National Science Foundation (1993).

measure of R&D investment is nondefense R&D. In 1991 Japan spent 3.0 percent of its GDP on nondefense R&D and the former West Germany 2.7 percent, compared to a mere 1.9 percent in the United States (U.S. Department of the Treasury 1993). Moreover, there is a possibility that even this figure understates the R&D gap because it may include industry funds for defense.[3]

Not only does the United States fall short of its two major competitors in R&D spending percentages, but the gap has been increasing. Figure 2 shows that in 1970 the United States, Japan, and Germany all spent approximately the same share of GDP on nondefense R&D. Over the past two decades the share changed relatively little in the United States but rose significantly in the other two countries. The recent pattern also shows that the United States now spends almost the same share of GDP on nondefense R&D as France, placing it far below Japan and Germany.

Direct comparisons of nondefense R&D spending in the United States with those of Japan and Germany show the same trend. An index of nondefense R&D spending in the United States relative to those of Japan and Germany was calculated and is reported in Figure 3.[4] Between 1970 and 1991, the United States-to-Germany ratio fell 26 percent,

Figure 2 Nondefense R&D Spending as a Percentage of GDP



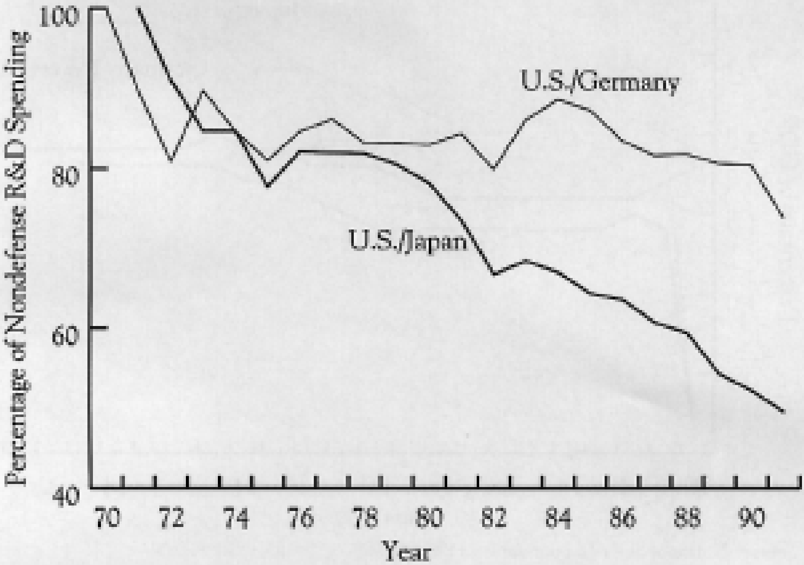
Source: National Science Foundation (1993).

indicating that real R&D spending grew considerably more slowly in the United States than in Germany. The pattern was even more profoundly realized in Japan: Between 1971 and 1991 the United States-to-Japan ratio fell 50 percent as Japanese spending on nondefense R&D accelerated relative to that of the United States.

These measurements were taken by comparing growth rates in real nondefense R&D spending. If exchange rates were taken into account, the picture would look far worse for the United States because during this period the dollar depreciated considerably relative to the yen and to the German mark.

We already may be experiencing one of the effects of the R&D gap. The United States now imports significantly more high-technology commodities than it exports. As illustrated in Figure 4, the U.S. balance of trade on high-technology exports has fallen steadily from a surplus of $16 billion in 1981 to a deficit of $47 billion in 1992.[5] This dismal performance would have been worse if not for the significant trade surplus enjoyed by the aircraft manufacturing industry, one that clearly owes some of its superior performance to its financial ties with the Department of Defense (DOD).

Figure 3 Nondefense R&D Spending in the United States Relative to Japan and Germany

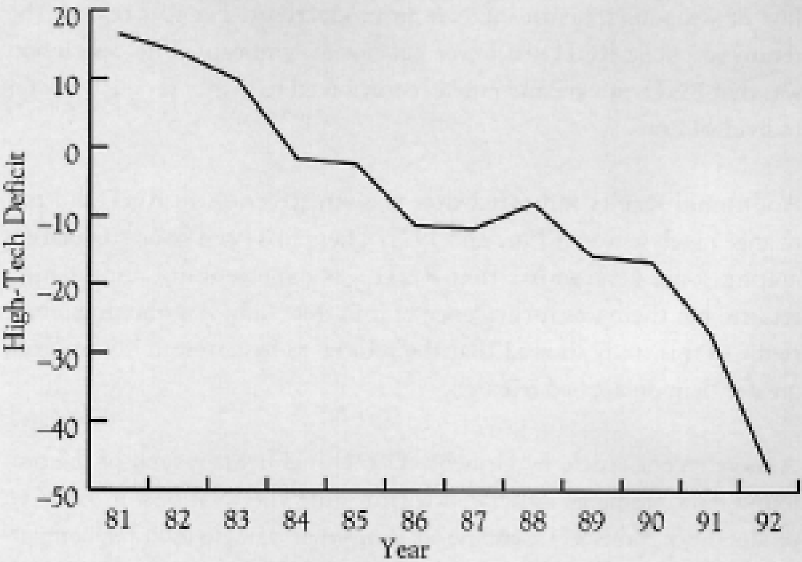


Source: Author's calculations based on data in International Monetary Fund (1994).

From 1978 to 1985 there was reason to hope that the U.S. would close the R&D gap or at least prevent it from widening. An upsurge in real spending pushed private industry R&D from 1.0 percent of GDP in 1978 to 1.4 percent in 1985. The cause of the boom, to be discussed later, appears to have run its course. Private industry expenditures leveled off after 1985 and slipped back to 1.3 percent of GDP by 1993. The current level and composition of R&D expenditures in the United States do not instill great confidence in the future ability of U.S. businesses to compete successfully in world markets.

While there may be considerable debate over the particular form of a national R&D policy, there is remarkably broad agreement that such a policy is needed (Cohen and Noll 1992, Hilper 1991). It is widely recognized that R&D spending is discouraged by the fact that information and know-how can slip easily into the hands of rivals. In economic terms, new products, techniques, and discoveries may have a low level of "appropriability." A patent system provides some protection but is generally agreed to be inadequate for protecting ownership rights to new discoveries, especially for fundamental discoveries with wide-ranging appli-

Figure 4 U.S. Balance of Trade in High-Technology Commodities



Source: National Science Foundation (1993).

cations (Baily and Chakrabarti 1988, 38–39). A private firm likely will underinvest in any activity from which it cannot capture the entire benefit. This fact makes R&D a classic example of market failure and, therefore, one that demands some form of government intervention.

The importance of government-financed R&D in stimulating innovation in private industry has been documented carefully by economists. Perhaps one of the most comprehensive studies was conducted by Nadiri and Mamuneus (1991), who found that higher levels of government R&D spending were associated with significantly lower manufacturing costs and higher productivity. Some of the strongest responses were recorded in durable manufacturing: machinery, electrical equipment, transportation equipment, and scientific instruments. The rates of return on public R&D reported in this study were substantial, ranging from 6.6 to 9.6 percent.

Earlier work by Griliches (1986) found that the return to R&D was extremely high, ranging from 33 to 62 percent. He also distinguished between the returns to private and public R&D. The return to public R&D was found to be lower than the return to private R&D, a fact that Griliches attributed to the relationship between government R&D and procurement. It seems that large expenditures of federal dollars for military research are more likely to be followed by the production of a new line of weapons than an increase in productivity. For this reason, the return to public R&D was lower but not insignificant. The conclusion was that R&D, private and public, contributed to higher productivity for individual firms.

Additional results indicated that the effectiveness of R&D did not change much between 1967 and 1977. There had been some speculation among some economists that R&D was experiencing diminishing returns, but there was no evidence of it in this study. Another important result in this study showed that the returns to basic research were even greater than on applied research.

A more recent article by Griliches (1994) highlights several of the profound data problems associated with testing the relationship between productivity and R&D spending. It seems that a single industry, computers, plays a critical role in many of these studies because it has both high productivity growth and high R&D per dollar of sales. As Griliches demonstrates, this single observation can sway the results of statistical analysis. However, rather than concluding that the computer industry is a "bad" observation, just the opposite may be true. The Bureau of Economic Analysis has invested more effort in developing an accurate measure of real computer output than it has in developing accurate indices for other industries. Consequently, it may be the data for other industries, not computers, that should be questioned.

Another concern about the effectiveness of R&D spending was motivated by the declining rate of patents per dollar of R&D between 1920 and 1992. Once again the specter of diminishing returns was raised. But there is a good possibility that the value and significance of the average patent has been increasing over time. As Griliches (1994) points out, the ratio of patents to R&D fell equally fast in the 1950s as in the 1970s when there was no apparent lack of technological innovation or productivity gains. If anything, this statistic simply may indicate that the number of small, insignificant patents are being weeded out by the rising expense of filing and enforcing a patent.

While there is an abundance of studies demonstrating the positive effect of R&D on productivity, this is probably not the most important function of R&D. Innovations will enhance productivity when they result in new and better ways to produce existing products; but most R&D today is dedicated to producing new and better products, a fact that may have no effect on productivity. Where the results of R&D are more likely to be seen is in changing market shares, raising exports, and enhancing sales and profits. Numerous studies, for example, have documented the fact that high levels of R&D are frequently associated with high rates of profit (Salinger 1982; Griliches 1986; and Hirsch and Connolly 1987). It appears that firms invest in R&D as one of several strategies to compete with rivals.

A recent work on this theme by Scherer (1992) documents the reaction of several American industries to challenges from foreign producers. In some cases U.S. companies were submissive, scaling back their own R&D programs; and in other cases they fought back with more intense spending on R&D. From this study Scherer concluded that domestic firms are more likely to gain an advantage in their industries when they "increase their own R&D in response to intensified innovation efforts by foreign rivals—that is, when they react aggressively . . . " (Scherer 1992, 133). Furthermore, he observed that firms were more likely to respond submissively when they were headed by an executive with an MBA rather than a degree in science or engineering. All of this highlights the important role of R&D in the competition for control of international markets.

With this picture in mind, it is clearly time to evaluate the effectiveness of our national R&D policy. Two of the questions addressed in this report are whether a new R&D policy will contribute to closing the gap as it now exists, and what changes have to be made to our current R&D policy to make it more effective.

R&D Policy and Tax Incentives

The evolution of R&D policy in the United States has been motivated primarily by issues of national defense, not international trade. Consequently, a major focus of R&D spending in this country has been on the development of sophisticated military equipment and weapons. In 1992 federal funds for defense R&D accounted for 29 percent of all R&D expenditures in this country (National Science Foundation 1993, 115). More than one out of every four research dollars was spent on defense. While this figure may appear relatively high, it was once even higher. In 1960, during the middle of the cold war, one out of every two research dollars was spent on defense (U.S. Department of the Treasury 1993; 598, 595).

Other than defense, which accounted for 59 percent of the federal government's R&D budget in 1992, several areas received smaller amounts of public support: spending for health totaled $10.1 billion (14.7 percent of federal R&D); space $6.8 billion (9.9 percent); energy $3.1 billion (4.5 percent); and general science $2.7 billion (3.9 percent). The remaining $5.8 billion (8.4 percent) of the budget was spread over 11 areas, including natural resources and the environment, transportation, agriculture, and education (National Science Foundation 1993, 363).

Direct federal expenditures constitute only the most visible part of the national R&D policy. Less obvious is the fact that government procurement can stimulate *industry* R&D. This occurs when firms compete for valuable government contracts by spending their own funds on research and development. In some cases, firms may be reimbursed for the expense, often defined as *Independent Research and Development* and *Bids and Proposals*. In other cases, firms simply may hope to recover the costs in the profits of future government contracts. As Frank Lichtenberg (1988) concluded in a detailed study of this issue, "Government procurement as a whole has a positive and substantial effect on private R&D investment."

In addition to direct expenditures on R&D and procurement, the federal government has attempted to stimulate private sector expenditures through selective tax incentives. One of these is the full deduction permitted for research and experimentation (R&E) expenditures that dates back to the 1954 tax code. An alternative to full deduction would be to treat R&E like any other long-term investment and spread the cost out for tax purposes over the estimated lifetime of R&E capital, an admittedly intangible asset. By allowing full deduction, a company with current tax liability benefits by not having to postpone (and discount) the deduction (Leydon and Link 1992, 15).

The primary focus of this report, however, is on the effectiveness of the R&E tax credit as included in the Economic Recovery Act of 1981. The possibility of increasing or expanding the credit is one possible way of addressing the increasing R&D gap. Before considering this possibility, however, it is necessary to review the actual credit and evaluate its effectiveness.

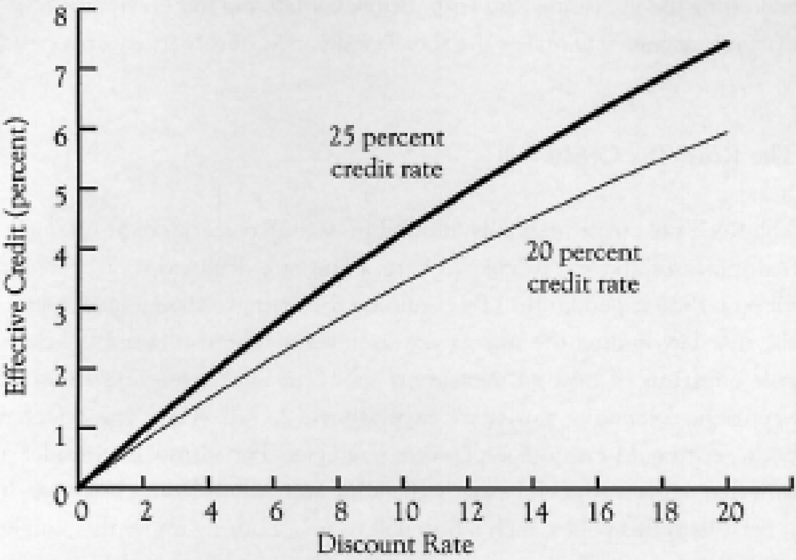
The R&E Tax Credit

The R&E tax credit originally allowed firms a 25 percent credit on qualified increases above a calculated base. (The rate declined to 20 percent for post-1986 expenditures.) By confining the credit to spending increases, the new law limited the impact on tax revenue but also raised the difficult question of how to measure a spending increase. The simplest approach, comparing this year's expenditures to last year's, was rejected because it could encourage perverse strategies. For instance, consider a firm that expects to spend exactly the same amount on R&E every year. If it persists in this policy, such a firm will receive nothing under this simple tax credit because its *increase* in spending is zero every year. If, however, the firm spends twice as much one year and nothing the next, it averages the same expenditure per year but qualifies for a much higher credit.

The new law addressed this issue by calculating the base as an average of R&E expenditures over the previous three years, with special provisions made for the first two years.[6] While this approach tended to limit the rewards for a one-time jump in R&E spending, it created other problems that economists were quick to point out. An additional $1.20 spent today would be rewarded by a 30 cent credit this year ($1.20 multiplied by .25), but it also would cause the credit to be reduced by 10 cents each year for the next three years as a result of increasing the base. The credit is saved from being a complete wash by the fact that firms prefer to have money today rather than tomorrow. The lower the discount rate, however, the lower the effective credit. In the extreme case of a discount rate equal to zero, the effective credit is zero as well. Figure 5 illustrates the effective credit for various discount rates calculated at the pre-1986 statutory credit rate of 25 percent and the post-1986 rate of 20 percent.[7] This built-in disincentive was quite clear to economists; whether it was as clear to businesses is another matter.

The credit had several other features. One feature required that the base be at least 50 percent of current R&E expenditures, which reduced the

Figure 5 Effective R&E Tax Credit and Discount Rates



Source: Author's calculations. See footnote 7 for details of effective rate calculation.

credit for firms with especially fast-growing research budgets. For firms with current expenditures equal to at least twice the base, each additional dollar of R&E expenditures automatically raised the base by 50 cents, thus reducing the value of the credit. This feature of the law was made even more restrictive in the 1989 reform.

For firms lacking both taxable income and the ability to take advantage of the three-year carry-back provision, the value of the credit is further diminished. While the credit can be carried forward up to 15 years, the act of delaying the benefit erodes its value because of discounting and uncertainty. The credit also offers very little incentive for firms that are otherwise planning to reduce R&E expenditures. Before they can begin to take advantage of the credit, they must first increase spending up to the base level. Altogether, the net effect of each of these qualifications is to reduce further the effective credit.

The original credit was extended and modified by the Tax Reform Act of 1986. The most important change to the law was to reduce the statutory credit rate from 25 percent to 20 percent and narrow the definition of qualified research. On the other hand, qualified expenses for basic research paid to colleges and other tax exempt organizations received a 20 percent tax credit (Internal Revenue Service 1986, 100; Senate Committee on Finance 1989, 39).

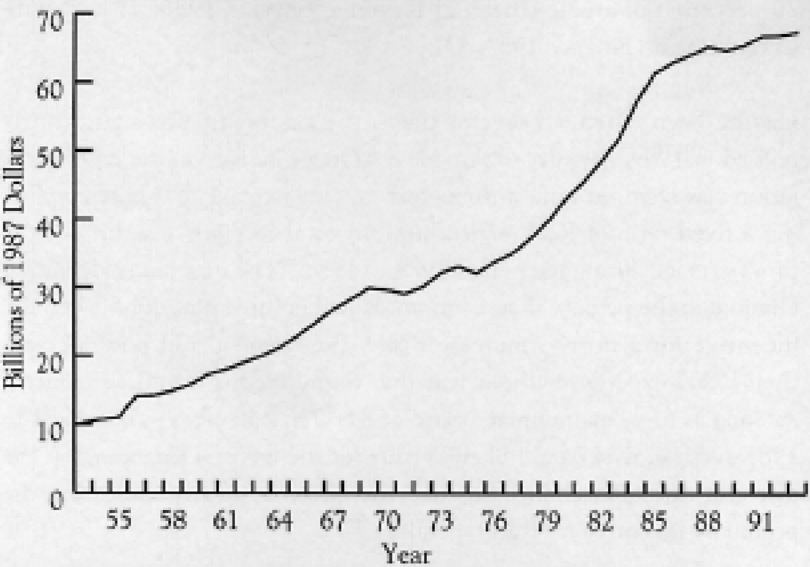
Having been extended several times, the tax credit was significantly revised in 1989. In order to provide a stronger incentive, the base calculation was changed from a three-year moving average to a base employing a fixed ratio of R&E expenditure to total receipts—essentially, the firm's average during the period 1984 to 1988.[8] The new base calculation eliminated the penalty that, economists had pointed out, diminished the incentive for a firm to increase R&D. Businesses could now increase their R&D expenses without fear that future credits would be reduced. As long as firms maintained a ratio of R&D to sales above their 1984 to 1988 average, they would likely qualify for the credit. Depending on the discount rate, this change has had the effect of greatly increasing the pecuniary incentive for R&D spending.[9]

The 1986 law also phased in a progressively higher base limitation that reduced the reward to exceptional growth in R&E. In the original law, only 50 cents of each dollar spent on R&E qualified for the credit once total expenditures exceeded 200 percent of the base. By 1995, only 25 cents of each additional dollar qualified for the credit once expenditures exceeded 125 percent of base.[10] It is this form of the law that was renewed by the Budget Reconciliation Act of 1993 and extended to June 30, 1995 (Joint Committee on Taxation 1993). The new law greatly increased the R&D incentive by eliminating the rolling base but at the same time reduced the relative incentive for very large increases in R&D.

U.S. Industry R&D

At least since 1953, R&D expenditures by private industry have risen faster than both the underlying inflation rate and GDP. As a result, real industry R&D (R&D adjusted for inflation) and industry R&D shares of GDP have increased (see figures 6 and 7). In 1953 industry R&D was only 0.6 percent of GDP compared to 1.4 percent in 1985. Figure 6, however, reveals more than a simple upward trend: after remaining relatively constant during the 1970s, R&D shares rose quite rapidly between 1978 and 1985. During this brief period, R&D boomed in the United

Figure 6 Industry R&D Spending (1987 dollars)



Sources: National Science Foundation (1990a, 1993); *Economic Report of the President* (1994).

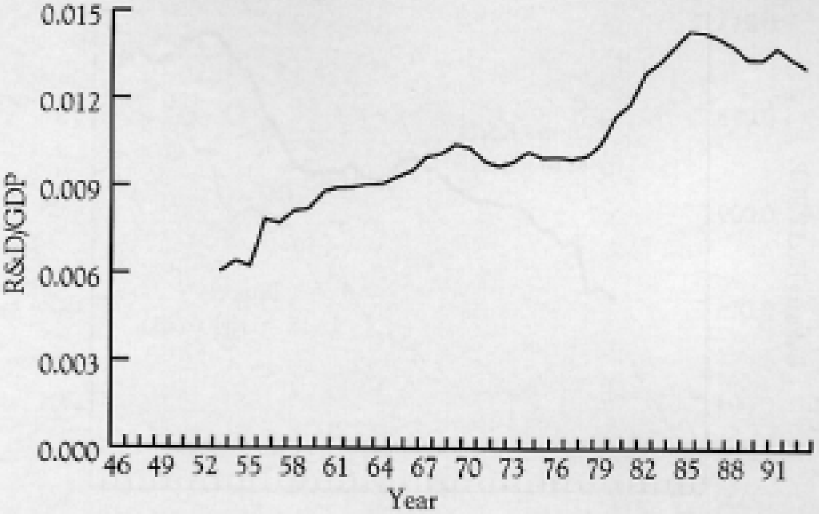
States, coinciding with a similar expansion in Japan and Germany. But spending by U.S. industry peaked in 1985 and thereafter drifted downward, although still remaining above the 1970s levels.

Possible Causes of the R&D Boom

Any national R&D policy should be based on a solid understanding of what determines industry R&D, namely, one that can account for the 1978 to 1985 expansion. There are, as is often the case in economics, a number of competing explanations. The first is the already-mentioned investment tax credit which took effect in June 1981. Second, one could claim that the end of the boom in 1986 was related to that year's tax reform, which reduced the size of the R&E credit and tightened the criteria for qualified research.

There are, however, grounds for skepticism about these explanations. It appears from Figure 6 that the beginning of the R&D expansion can be placed at 1978 or 1979, at least two years before the tax credit was passed. The credit evidently was not the only factor in the R&D increase. It also would be surprising if the relatively small changes made

Figure 7 Ratio of R&D to GDP, 1953–1993



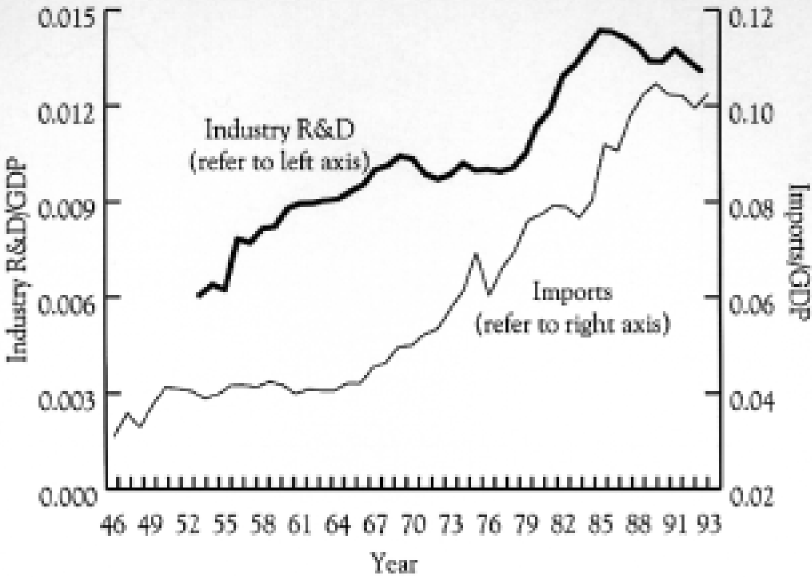
Sources: National Science Foundation (1990s, 1993); *Economic Report of the President* (1994).

to the law in 1986 could alter abruptly the pattern of R&D spending. The credit was only reduced from 25 to 20 percent and was extended to cover funding for university basic research.

Timing is one problem with the credit explanation, magnitude is the other. The R&D expansion in the early 1980s is simply much bigger than could have been expected from the credit alone. For example, suppose we attributed the entire increase in industry R&D shares from 1980 to 1985 to the tax credit. Could the credit have caused a 25.8 percent increase in annual R&D spending?[11] The problem with this figure is that it is about twice the size of even the most optimistic estimate of the credit's impact. In summary, the credit appeared to be too late, persisted too long, and was too small to account for the R&D boom of the early 1980s. This is not the same as saying that the credit had no effect but only that other factors are clearly important.

An alternative explanation is foreign competition. Firms can respond to foreign competition in a number of different ways: they simply can concede market share, they can cut prices, or they can increase expenditures on advertising and R&D in an effort to attract customers. An increase in foreign competition in many areas of the U.S. economy could be one of the factors behind the R&D boom. One indicator of the intensity of for-

Figure 8 Industry R&D and U.S. Nonpetroleum Imports, 1946–1993



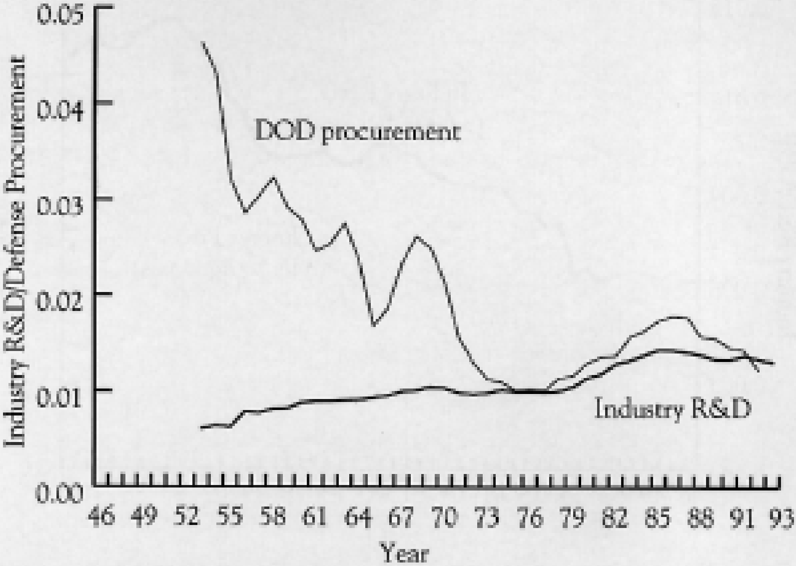
Sources: National Science Foundation (1990a, 1993); *Economic Report of the President* (1994).

eign competition is the level of U.S. nonpetroleum imports. Figure 8 shows the relationship between nonpetroleum import intensity and industry R&D shares. Import intensity rose quite rapidly during two periods: 1975 to 1980 and 1982 to 1988. Except for a brief lapse related to the twin recessions of 1980 and 1982, the rapid influx of imports from 1975 to 1988 parallels the R&D boom from 1978 to 1985. There is a possibility that at least part of the R&D boom was related to increased foreign competition.

Another possible explanation is related to military procurement. The DOD typically will solicit proposals from private businesses for the design of new weapons systems. These "design competitions" require extensive preparation and R&D on the part of participants who are willing to incur such expenses in the hope of being selected as the primary contractor. Although firms may later be reimbursed for these expenditures, they still typically report them as industry R&D, which means that the expenditures are included in the figures relating to the R&D boom.

There was, in fact, a similar expansion in military purchases during this period. As illustrated in Figure 9, DOD procurement rose from approxi-

Figure 9 Industry R&D and Defense Procurement, 1952–1993

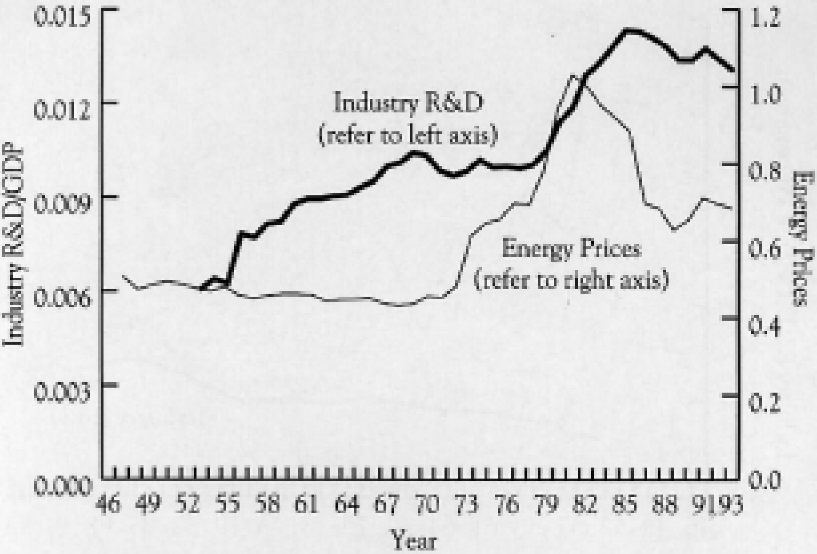


Sources: National Science Foundation (1990a, 1993); *Economic Report of the President* (1994); U.S. Department of the Treasury (various years).

mately 1.0 percent of GDP in 1977 to 1.8 percent in 1986. The slide in procurement after 1986 corresponds closely with a similar pattern in industry R&D. There also is the fact that the military expansion in the 1980s included many high-technology weapons systems such as AWACs, the stealth bomber, and the star wars program.[12]

Another event that could have affected R&D spending in some industries was the energy crisis. Rising energy prices in the 1970s eventually motivated many firms to improve their energy efficiency, which required the development and installation of new equipment and production methods. Figure 10 shows the historic pattern in energy prices relative to industry R&D shares.[13] There is little indication that industry R&D responded to the initial energy crisis in 1974, but the R&D boom does correspond with the second upswing in energy prices in 1979. Energy prices began to subside in 1981, preceding by four years a similar change in R&D. One could construe from this that R&D spending did respond to the energy crisis, but only with a significant lag.

Figure 10 Industry R&D and Energy Prices



Sources: National Science Foundation (1990a, 1993); *Economic Report of the President* (1994); U.S. Department of the Treasury (various years).

Statistical Evidence

We are left with the problem of determining which of the above reasons is primarily responsible for the R&D boom of the early 1980s. If it was the credit, then we have identified an effective policy tool for stimulating industry R&D. If it was military procurement, then we have identified another government action that can affect private R&D. If it was foreign competition or rising energy prices, then we must take that into account in our national R&D policy. The investigation of this question involved three different types of statistical studies (described below), each designed to investigate a particular aspect of the R&D boom.

Time Series Evidence

How much did the R&E tax credit, imports, defense spending, and energy prices contribute to the industry R&D boom? One way to estimate these contributions is by estimating a time series model which analyzes the movement of industry R&D intensity over time. This type of study was conducted using data from 1953 to 1992 and is described in full detail in the appendix. R&D intensity is expected to be a function of the R&E credit (identified by the years the credit was in place), import intensity (U.S. nonpetroleum imports divided by GDP), defense procurement (again divided by GDP), and relative energy prices.

The results show that the complete model explains approximately 95 percent of the variation in R&D intensity. For the entire period, only the credit and imports appeared to have a significantly positive effect on industry R&D as a share of GDP. During the more recent period (1970 to 1992) both of these variables again were statistically significant, as were defense spending and energy prices.

It is instructive to look at the estimated effect of the R&E credit on R&D spending. According to the full model, the ratio of industry R&D to GDP was 0.12 percentage points higher during the period covered by the credit. In 1980, this would have translated into a 10.5 percent increase in R&D spending.[14] This is a large gain, assuming the effective credit was no more than 5 percent, but it is still within the range of earlier studies. These preliminary results suggest that the credit may have had a positive effect on R&D spending.

Industry Evidence

One of the major drawbacks of a simple time series test is that it fails to consider variations within industries. This fault is particularly important in this case because R&D intensity varies so widely among industries, as do DOD procurements and imports. The top five R&D spending industries are office, computing, and accounting machines; motor vehicles and equipment; aircraft and missiles; communication equipment; and drugs (National Science Foundation 1990b). Together, in 1989 these five industries accounted for 52 percent of all industry R&D but only 19 percent of sales in manufacturing. DOD procurement is even more unevenly distributed: the top two industries (aircraft and missiles; communication equipment) received approximately 69 percent of all orders in 1987 (U.S. Department of Commerce, various years a).

If the hypothesis in this report is correct, one would expect to find the largest increases in R&D spending in those industries with the largest increases in DOD procurement and in foreign imports. Regression analysis, described in more detail in the appendix, shows that this is, in fact, the case. The test was based on a sample of 25 industries covering all of manufacturing from 1969 to 1989. R&D intensity, defense procurement, and imports are all divided by industry shipments rather than GDP, but in other respects this test is similar to the time series test.[15] In this study, R&D intensity was consistently higher in those industries with high ratios of imports and DOD procurement to shipments. There was, however, no compelling evidence that R&D was significantly higher during the years when the R&E tax credit was in place. For all industries, the model explained 99 percent of the variation in R&D intensity over this 21-year period.

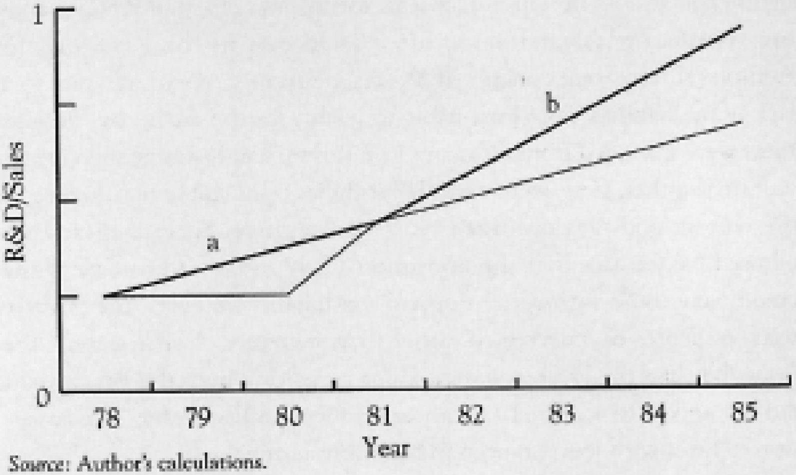
Separate tests were undertaken to investigate the role of these variables in specific industries, namely, those with relatively high R&D expenditures (greater than 1 percent of industry shipments). In these separate regressions, imports had a positive significant effect in six industries (including motor vehicles); DOD procurement had a positive significant effect in five industries (including aircraft and missiles); and the R&E credit had a positive significant effect in only one industry (aircraft and missiles). But even the latter single positive result is questionable because R&D spending in the aircraft and missiles industry is heavily dependent on defense orders.

The results of the industry analysis appear to support the view that military procurement and imports are largely responsible for the R&D boom of the early 1980s. The role of the R&E credit remains in doubt; that is, relative to the other factors it does not appear that the credit had a particularly significant effect on industry R&D spending.

Company Evidence

One specific concern about the R&E credit is that the beginning of the R&D boom actually preceded the implementation of the tax credit by approximately three years. The question has been raised as to whether the increase in R&D intensity following the passage of the credit was, in

Figure 11 Expected Effect of the Research and Experimentation Credit on Industry R&D



Source: Author's calculations.

fact, any larger than the increase that preceded it (Mansfield 1984). In order to answer this question, a sample of 221 firms with R&D spending greater than $25 million from 1978 to 1985 (the duration of the R&D boom) was collected from Standard & Poor's Compustat database.

One of the advantages of company data that has been exploited by other researchers is its detailed information about the financial positions of firms (for example, see Hall 1993, and Swenson 1992). In these data sets it is possible to distinguish between firms that are most likely to benefit from the credit and those that are not. In particular, firms with histories of net losses are less likely to be able to use the credit immediately, especially if they have no current or past tax liability. Here, the company data set was used to test whether R&D spending grew after the credit was put in place and, more specifically, if it was larger for those firms with the most to gain from the credit.

The results of this exercise are described in the appendix. The hypothesis tested was that certain factors contributed to the increase in R&D intensity from 1978 to 1985, an intensity that accelerated from 1981 to 1985 under the R&E credit. The nature of this hypothesis is illustrated in Figure 11. The growth rate in R&D intensity is represented by slope *a*, which increases to *b* as a result of the credit.[16] The analysis in the appendix provides estimates of *b* which, to the extent that the R&E credit was effective, would be expected to be positive and statistically significant. Estimates of *b* using the entire sample are positive but not statistically significant. It does not appear, at least for this sample, that R&D spending significantly accelerated after 1980 due to the R&E credit. Additional tests were conducted to exclude those firms which, due to a lack of tax liability, were least likely to qualify for the credit. In one test, firms were excluded from estimates of *b* if they had losses in the current year. In another, firms were excluded if their accumulated net income in the current and previous three years was negative. Each of these tests allowed for the fact that the firms most likely to take advantage of the credit were those with current or past tax liability. In every one of these tests, estimates of *b* decreased rather than increased. Consequently, the firms that had the greatest potential for benefiting from the R&E credit did not appear to accelerate significantly their R&E spending in comparison to firms with less potential to benefit from the credit.

Tentative Conclusions

The results of this research and others suggest several tentative conclusions (Mansfield 1986, 1984; Eisner 1985, 1984). While part of the period associated with the R&D boom overlaps the R&E credit, the actual relationship is far more complicated. It would be difficult to conclude that the R&E tax credit had a large positive effect on industry R&D. The R&D boom began two to three years before the credit was passed and ended while the credit was still in place. Alternatively, this analysis suggests that the industry R&D boom was linked to a rapid expansion in imports and defense spending and, to a lesser extent, to energy prices.

Some analysts suggested from the start that the reason the R&E credit was not likely to have a large effect was the disincentives built into the rolling base. The effective subsidy for any increases in R&D spending was reduced greatly by including such increases in the calculation of future spending thresholds. What begins as an official 20 to 25 percent credit may shrink to an effective 3 to 5 percent credit depending on the discount rate and other qualifications.

If the credit failed to have a more prominent effect because of this penalty, why didn't R&D pick up after the penalty was eliminated in the

1989 reform? Industry R&D has remained a relatively stable 1.3 percent of GDP since 1989, slightly below its 1985 level. In most economic models, the switch to a fixed ratio in the calculation of the credit should have magnified greatly the incentive to invest. One possible conclusion is that the credit is not especially important in determining R&D spending. Another possibility is that the added incentive of eliminating the rolling base was exactly offset by tightening the base limitation. Recall that the 1989 tax bill limited the full value of the credit to expenditures exceeding the base by 25 percent or less. Beyond 25 percent the credit was reduced by a factor of four. How many firms this might have affected is not at all clear. Even if the R&E credit did stimulate additional R&D, it has been questioned whether the additional spending was as large as the forgone tax revenue. Edwin Mansfield concluded that "The extra R&D stimulated by the tax credit seems to have been considerably less than the revenue lost to the Treasury" (Mansfield 1984). Table 1 provides data on the value of allowed R&E credits for 1981 through 1991.

Table 1 Research and Experimentation Credit, 1981–1991

Year	Allowable R&E Credit (millions)
1981	873
1982	1,641
1983	2,165
1984	2,638
1985	2,780
1986	1,309
1987	1,053
1988	1,276
1989	1,391
1990	1,547
1991	1,656

Source: Internal Revenue Service (1986 and unpublished data).

Mansfield was also one of the first to point out that the tax credit created an incentive for firms to redefine related activities as research and experimentation so that they could qualify for a larger credit. He concluded that a considerable amount of the initial increases in R&E spending was caused by this sleight of hand rather than by real spending increases.

National R&D Policy

This report began by identifying a large and growing gap between non-defense R&D spending in the United States and similar spending in Japan and Germany. If the United States is to look forward to a future that includes solid shares of the world's high-technology markets, it must close this gap. International competition will, in all likelihood, stimulate industry R&D, but there is probably little hope of actually closing the gap without a reorientation of U.S. R&D policy. To this end the government must introduce policies that either stimulate private industry expenditures or expand government funded R&D. How can public policy be reoriented to address these challenges?

While private industry in the United States provides 46.9 percent of total R&D funds, the comparable shares are 59.9 percent in Germany and 72.7 percent in Japan (National Science Foundation 1993). There obviously is room for U.S. firms to increase their share of the nation's R&D effort. But other than the R&E credit, there are few public policies that are even intended to encourage more industry R&D. Given the findings of this report, it is difficult to believe that a stronger credit would do much good. The best argument one could make in its favor, however, is that the credit would have had a positive effect after 1989 if not for the higher base limitation. If the experiment with the credit is to be continued, an obvious improvement would be to reverse the base limitation introduced in the 1989 tax bill. Instead of reducing the effective credit for R&D spending exceeding 25 percent of the base, the credit could be increased.[17]

For such a change to make a difference, it must be demonstrated that substantial numbers of firms would be less likely to increase annual R&D spending by 25 percent or more. The evidence for the 1978–1985 period suggests that this is true for many firms. In fact, approximately 40 percent of all R&D increases during this time originated in firms with individual increases of 25 percent or more.[18] It would appear that a significant number of firms could benefit from the removal of the base limitation penalty.

Before pursuing this policy, at least two objections must be overcome. First, any expansion of the R&E credit is likely to entail lost tax revenue, a problem that was not addressed in the original legislation creating the credit. In fact, one could claim that the R&E credit was initially unfunded, contributing to larger federal budget deficits.[19] In today's environment it is more difficult to justify expanding the R&E credit, or even keeping it, if doing so would mean higher deficits or fewer purchases of public goods.

This raises the important question of who should pay for the credit. Recall that its purpose is to remedy a market failure: the chronic underinvestment in R&D due to uncertainty and lack of appropriability. In theory, firms do not invest sufficiently in R&D because much of the benefit will be captured by other firms. To the extent that the credit causes some firms to increase their R&D funding, others will benefit without paying a cent. Ideally, one would want those corporations benefiting as free riders to pay the cost of providing the incentive. While it probably is impossible to target specific free riders for tax purposes, it would not be inappropriate to finance the R&E credit, or any expansion of the credit, with a slightly higher corporate profit tax.

The second objection to strengthening the R&E credit is more fundamental—it may not work. The results of my research provide few reasons to be optimistic. It is hard to imagine that any change in the credit would spark enough industry R&D to actually close the gap.

There is another way that government can and does stimulate industry R&D. An important lesson of this analysis is that government procurement can stimulate private expenditures.[20] Until now this has been proven primarily through military procurement, which accounted for 87.3 percent of all manufacturing sales to the federal government. Other federal agencies are relatively small consumers of industrial goods. In 1987, NASA was responsible for 2.8 percent of all federal government orders from manufacturing; the Department of Energy's share was 1.1 percent; and all other federal agencies together amounted to an 8.8 percent share (U.S. Department of Commerce 1987). Currently, there is no other federal agency that compares with the DOD in its capacity to issue large contracts for high-technology products.

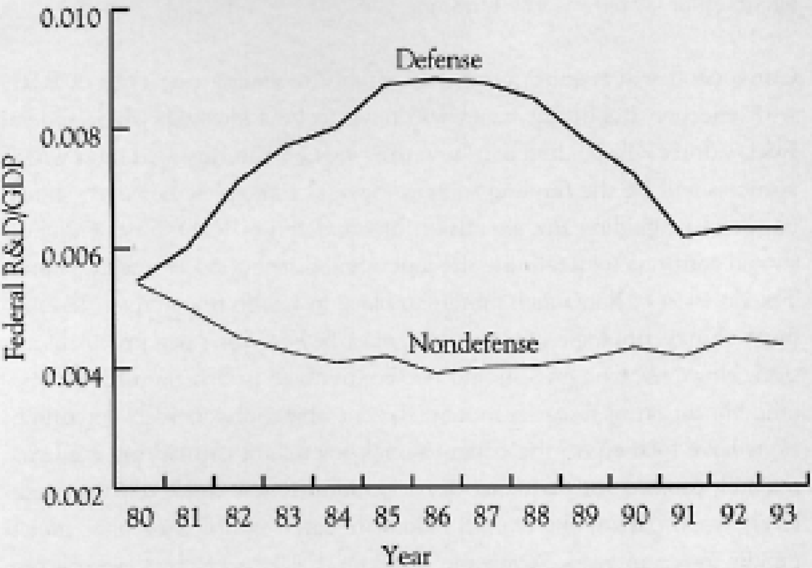
As defense priorities have subsided, there has been a growing need for public goods in other sectors, such as transportation, energy, education, environmental protection, and health care. At least some consideration should be given to expanding the procurement capacity of other agencies for high-technology projects. It is conceivable that an expansion of government procurement awarded on the basis of design competition would stimulate considerable private R&D in each of these nondefense sectors.

The possibilities in these areas are limited by funding, not by a lack of good ideas. The Department of Education may find it useful to purchase high resolution television monitors or computers for schools, the National Institutes of Health may wish to purchase equipment for medical research, the Department of Energy may attempt to develop solar cells and storage batteries for government buildings, or the Department of Transportation may want to assist in the development of modern commuter systems. These purchases would not only contribute to improving the quality of public goods but could replace the impetus for industrial R&D once provided by DOD. These technological alternatives should be given serious consideration as replacements for canceled weapons systems.

Even with an increase in industry R&D, there probably is little hope of closing the gap without an increase in direct government expenditures on nondefense R&D. One part of this reorientation is already under way as military research is converted to other purposes. Some programs, such as the Technology Reinvestment Project (TRP), provide funds for expanding the competitiveness of defense-dependent industries and supporting "dual-use" technologies that benefit both defense and nondefense interests (National Science Foundation 1993, 115). There are also "cross-cutting" R&D initiatives that bring several federal agencies together to coordinate broad areas of research under the Federal Coordinating Council for Science, Engineering, and Technology (National Science Foundation 1993, 108).

The primary problem with recent conversion efforts is that they have been relatively small. Figure 12 shows recent trends in federal contributions to R&D for defense and nondefense purposes. Relative to GDP, R&D for defense has clearly declined since 1987, but there has been no corresponding increase in the nondefense share. If conversion efforts are to contribute to the national R&D effort, federal R&D for nondefense must grow much faster.

Figure 12 Federal R&D Spending for Defense and Nondefense Purposes



Sources: National Science Foundation (1993); *Economic Report of the President* (various years).

A second problem with recent conversion efforts is that several new R&D projects have been retained by the DOD even though they may have little to do with defense. While the department's spending on military R&D has subsided in recent years, civilian research has grown rapidly, reaching $1.9 billion in 1993. Many of these projects, which focus on health, energy, transportation, or manufacturing, would be better placed in the appropriate federal agencies, such as the National Institutes of Health or the Energy, Transportation, or Commerce departments. Included in this list is $100 million for Sematech, the much discussed research joint venture between private businesses and the DOD. This was only one of 35 different projects identified by the G.A.O. that range from medical research on AIDS and breast cancer, $57 million and $210 million respectively, to the national aerospace plane technology program at $141 million (U.S. General Accounting Office 1993).

Some projects undoubtedly will require a coordinated effort among several agencies, requiring a "cross-cut" initiative, but too often such initiatives merely serve to preserve the DOD's dominant role. An advantage of involving more government agencies in this process would be to foster competition for public funds. Each agency would be compelled to demonstrate valuable and constructive results in order to vie with other agencies for Congressional funding.

Conversion will require more than simply replacing one type of R&D with another. Important issues will have to be addressed: where federal R&D efforts will be directed, how they will be administered, and which agencies will be the funding sources. Several principles, however, should be useful in guiding the expansion of nondefense R&D. First, Congress should continue to determine the functional distribution of research funds. The decision of how much money to place in health research versus computer chip technologies, for example, must be based on open public discussion. However, Congress should not be involved in determining the specific allocation of research money. Recent objections to such determinations have focused on the congressional practice of earmarking academic research projects for particular districts. While these funds remain a relatively small part of the overall federal research effort, they have grown rapidly in recent years. Academic R&D funds earmarked by Congress rose from \$247 million in 1990 to \$470 million in 1991, and \$707 million in 1992 (National Science Foundation 1993, 139). It is difficult to defend the merit of R&D dollars that are granted through any process other than design competitions or some form of competitive peer review.

Equally difficult to defend is the current government policy of reimbursing firms for independent R&D conducted primarily by defense contractors. In the modern era it makes little sense for the government to underwrite R&D in which it plays no role in development nor enjoys any control. In testimony before the Senate Armed Services Committee and Joint Economic Committee in 1975, Admiral H.G. Rickover concluded that "The current IR&D [Independent R&D] program does not provide benefits to the Government anywhere near the cost" (Rickover 1975). His proposal to eliminate the practice remains equally appropriate today. Independent R&D reimbursement, which costs the federal government more than \$2 billion a year, should be discontinued (National Science Foundation 1993, 360).

Not only is it important that the process for distributing R&D dollars be defensible, there also must be an impartial assessment of the effectiveness of particular lines of research. It is much easier to distribute funds for R&D than to demonstrate that the funds are well spent. For this purpose, it would be necessary to establish a review process that would do more than determine whether the funds were spent legally; a professional review also should be able to determine whether the research produced any valuable discoveries or innovations. This type of evaluation, which is occasionally conducted by the General Accounting Office, should be incorporated as an integral part of the federal R&D effort.

Finally, it should be noted that all government agencies have experimented with different methods for funding R&D. In some cases, grants are issued to individual academic researchers to conduct specific experiments or research; in others, the government has embarked on joint efforts with private businesses and required specified levels of spending or performance by private firms. An evaluation of one of these joint efforts, Sematech, was recently reported by Irwin and Klenow (1994). In this project, the government allocated approximately $100 million dollars a year to support research by a consortium of U.S. manufacturers of semiconductors. The purpose of the collaboration was to improve U.S. semiconductor production technology. The evidence suggests that the effort has been quite successful. While other industries were reducing their R&D spending intensity after 1987, members of Sematech increased their spending relative to sales from 10.3 percent to 11.6 percent. In addition, profits increased in the industry and U.S. firms regained some of the market share they had lost during the previous six years.

A curious outcome of this joint effort was that R&D intensity by U.S. manufacturing firms who were not members of Sematech increased from 7 percent to 10.6 percent of sales. Some of this increase may have been related to the formation of Sematech; that is, nonmembers may have felt compelled to increase spending on R&D so as not to fall behind Sematech members. Given the choice between contributing to Sematech or increasing their own R&D budgets and hoping for spin-offs from Sematech, nonmembers may have found the latter to be less costly. This raises the possibility that Sematech not only contributed to an increase in R&D intensity among its members but also inspired a significant increase in R&D spending by nonmembers.

Irwin and Klenow (1994) present a considerably different view of these facts. They assumed that Sematech had nothing to do with the increase in R&D spending by nonmembers and attributed the industry's good fortune to "a substantial depreciation in the foreign exchange value of the dollar, a semiconductor trade agreement with Japan that blunted foreign competition, and the declining importance of memory chips compared with microprocessors in the semiconductor market." But rather than test these hypotheses, Irwin and Klenow simply accept them as fact. The depreciation of the dollar may have helped U.S. semiconductor manufacturers, but it also would have helped a whole range of U.S. firms that did not raise R&D spending to any comparable degree. If the trade agreement with Japan was the cause for the turnaround, then it was more effective than most observers would have expected. And if the reason was due to a shift in demand favoring U.S. technology at that time, at least in this instance the government bet on a winner. The question remains whether the industry recovered because of Sematech or because of exchange rates, trade agreements, or demand shifts. One hopes future research on Sematech will address this question.

Whether joint efforts are effective or not remains to be seen. Up to this point, no particular method has proven superior to any other in producing socially useful innovations. It is conceivable that a better system of assessing the results of federally funded research would shed more light on the effectiveness of these various funding alternatives.

Appendix. Accounting for the Industry R&D Boom: 1978-1985

Why did industry R&D increase so rapidly from 1978 to 1985, and how much did the R&E tax credit have to do with it? These questions are addressed in this appendix, utilizing a number of different statistical tests.

Time Series

The first approach is a time series analysis that attempts to model changes in industry R&D as a share of GDP from 1953 to 1992. It is expected that this variable is determined by the level of international competition, the level of defense procurement, energy prices, and the R&E credit. International competition is measured by the ratio of U.S. nonpetroleum imports to GDP (*Economic Report of the President* 1994).

Table A1 Regressions on R&D Intensity (annual data)

	Dependent variable: Industry R&D/GDP			
	1953–1992		1970–1992	
Independent Variable	1	2	3	4
Credit	.062 (.048)	.066* (.053)	.32** (.03)	.12** (.04)
Imports/shipments		5.42** (1.56)		5.12** (.92)
Defense/shipments		-1.72 (2.55)		10.77** (2.89)
Energy prices		.18 (.15)		.141* (.081)
Constant	.99** (.13)	.59** (.15)	1.02** (.02)	.46** (.10)
Adjusted R^2	.95	.95	.90	.95

Notes: Standard errors are in parentheses. All estimates are multiplied by 100.
* Significantly different from zero at the 5 percent level.
** Significantly different from zero at the 1 percent level.

Sources: Author's calculations based on data in *Economic Report of the President* (1994); U.S. Department of the Treasury (various years); National Science Foundation (1993, 333).

The annual level of procurement for the DOD was also divided by GDP to represent changes in intensity over time (U.S. Department of the Treasury, various years). Energy prices were equal to the ratio of the producer price index for fuels, related products, and power to total producer price index (*Economic Report of the President* 1994). The variable for the R&E credit was equal to one in the years that the credit applied (1981 and thereafter) and 0 in the years before 1981. Finally, industry R&D was equal to the annual funds provided by industry for R&D, again divided by GDP (National Science Foundation 1993, 333; U.S. Department of the Treasury, various years).

The results of ordinary least squares regressions for the entire period—1953 to 1992—are reported in Table A1. Because of the presence of strong serial correlation, each of the estimates includes corrections for autocorrelation using the Cochrane-Orcutt method. In the first regression (column 1) the credit variable was not statistically significant. In the second regression (column 2) both the credit and import variables were statistically significant, the former at the 5 percent level and the latter at the 1 percent level. Coefficients on the defense and energy prices variables were not statistically significant.

The results were different, however, when the time frame was limited to the more recent 1970 to 1992 period. The credit variable was highly significant whether it was included alone (column 3) or with additional explanatory variables (column 4). The magnitude of the coefficient also increased in the full model, indicating that the industry R&D-to-GDP ratio was 0.12 percentage points higher during the period of the credit. In this specification, import intensity and defense orders are also highly significant, both at the 1 percent level. The implication is that higher imports or defense purchases tend to increase the level of industry R&D. Energy prices are also significant in this model, at the 5 percent level, suggesting higher R&D during the energy crisis.

Why was defense spending highly significant in the recent period but not in the longer period dating back to 1953? Going back to the earlier period, defense procurement experienced a major reduction following World War II and the Korean War. Much of this reduction was related to the demobilization of a very large standing army, one that was gradually replaced by more sophisticated weapons systems including nuclear missiles. The initial decline in DOD procurement probably coincided with an increase in high-technology procurement and would not have had a depressing effect on industry R&D. On the other hand, much of the military buildup in the 1980s was focused specifically on high technology areas including the Strategic Defense Initiative. Within this context it is not surprising that an expansion of DOD procurement could stimulate industry R&D in the 1980s while a decrease in procurement in the 1950s and 1960s would have no equivalent impact.

The results of this test suggest that the credit did have a significant positive effect on industry R&D spending. There are, however, grounds to be skeptical. The problem is that several of the explanatory variables are highly correlated, even in the period from 1970 to 1992. The correlation between defense spending, energy prices, and R&D spending is high, but it is especially high between imports and R&D spending with a correlation coefficient of 0.82. The close correspondence between imports and the R&E credit makes it particularly difficult to determine the independent contribution of each variable.

Industry Study

Another approach to this question is to study changes in R&D spending in specific industries. For this purpose, data were collected for 25 industries for the 1969 to 1989 period. Industry categories were based on those of the National Science Foundation as contained in their reports on industry R&D spending. Although these industries cover all of manufacturing, they represent an amalgam of two- and three-digit industries based on the Standard Industrial Classification (SIC) coding system.

The credit variable was identical to the one used in the time series study.[21] The ratio of R&D to shipments was measured by the ratio of company funds spent on industrial R&D to industry shipments (National Science Foundation, 1990b, 1981).[22] The imports-to-shipments variable was measured by the ratio of imports from consumption to industry shipments (U.S. Department of Commerce various years b,c).[23] The defense-to-shipments ratio was measured by industry shipments to the DOD divided by total industry shipments (U.S. Department of Commerce, various years a,b).[24] Shipments were total industry shipments (U.S. Department of Commerce, various years a,d).

Other data, for defense spending and imports, were aggregated from the three-digit level to the National Science Foundation (NSF) industry code. Significant revisions were made to the SIC in 1987, requiring some adjustment for later years. Fortunately, the *Census of Manufactures* reported DOD shipments from manufacturing in 1987 according to both the new and old classification system, making it possible to adjust post-1986 data. Furthermore, the Department of Commerce did not report DOD shipments for specific industries after 1987 or for the years 1985 and 1986. The defense data for these years were estimated by interpolation using known estimates of total DOD procurement (U.S. Department of the Treasury 1992, 542) in each year. R&D data were also missing for some industries, especially during the earlier years of the period. These were also estimated by means of interpolation.[25]

Table A2 Regressions on R&D Intensity, Industry Study, 1969–1989

Independent Variable	Dependent Variable: R&D/Shipments			
	1	2	3	4
Credit	.0009 (.0008)	.0011 (.0008)	.0006 (.0008)	.0012 (.0008)
Imports/shipments	.016** (.005)	.016** (.005)		
Defense/shipments	.039** (.009)		.039** (.009)	
Industry variables	x	x	x	x
Adjusted R^2	.99	.99	.99	.99

Notes: Standard errors are in parentheses.
* Significantly different from zero at the 5 percent level.
** Significantly different from zero at the 1 percent level.
Sources: Authors calculations based on data in National Science Foundation (1990b, 1981); U.S. Department of Commerce (various years a, b, c, d).

Estimates of this model for all 25 industries for the 1969 to 1989 period are presented in Table A2. The estimates are from ordinary least squares, corrected for autocorrelation. The full model is presented in column 1. Results show that both imports and defense spending appeared to have had a positive effect on industry R&D spending and were highly significant (at the 1 percent level). The credit variable was positive but not statistically significant. In other regressions, in which various variables are omitted, the credit coefficient remained largely unchanged and insignificant. According to this test, it does not appear that the credit had a strong effect on industry R&D spending.

An alternative to testing the effect of these variables for all industries is to test them individually for each industry. Such tests were conducted for each industry that had a ratio of R&D to shipments greater than or equal to 1 percent. The results, reported in Table A3, indicate that imports were apparently important in some industries while defense procurement was important in others. In only one industry, aircraft and missiles, did the credit appear to have a positive and significant effect. The results for this industry are obviously going to be influenced by the fact

Table A3 Regressions on R&D Intensity, Descriptive Results for Specific Industries, 1969–1989

	Mean R&D/shipments	Standard Industrial Classification
Industries for which imports had a significant positive effect on R&D intensity		
Drugs and other medicines	.094	283
Other chemicals	.015	284, 285, 287-89
Office, computing, and accounting machines	.132	357
Electronic components	.044	367
Motor vehicles and equipment	.031	371
Optical, surgical, photographic, and other instruments	.059	383-87
Industries for which defense spending had a significant positive effect on R&D intensity		
Rubber products	.010	300
Other machinery, except electrical	.013	351-56, 358,359
Electrical components	.044	367
Aircraft and missiles	.052	372, 376
Scientific and mechanical measuring equipment	.051	381,382
Industries for which the R&E tax credit had a significant positive effect on R&D intensity		
Aircraft and missiles	.052	372, 376
Other industries with high R&D intensity (R&D/shipments greater than .01)		
Industrial chemicals	.029	281-82, 286
Petroleum refining	.012	290
Stone, clay, and glass products	.010	320
Radio and tv receiving equipment	.018	365
Communication equipment	.079	366
Other electrical equipment	.021	361-64, 369

Sources: Author's calculations based on data in National Science Foundation (1990b, 1981); U.S. Department of Commerce (various years a,b,c,d).

that it is the largest defense manufacturer. In 1987, this single industry accounted for 44 percent of all shipments to the federal government. The possibility of distinguishing between the effect from the credit and the effect of defense procurement is probably least likely for this industry.

Company Study

Another question that can be addressed using statistical analysis is whether the R&D boom accelerated after 1980 when the R&E credit was introduced. This question can be explored using company data obtained from Standard & Poor's Compustat database. With these data, it is possible to identify particular companies that were most likely to have benefited from the R&E credit. Specifically, firms that had current positive net income or positive net income over the past three years were likely to have benefited the most from the R&E credit. Unfortunately, data that describe the level of import competition or the magnitude of defense procurement are typically lacking at the company level, making it difficult to test a complete model of R&D behavior.

In order to test the possibility that the credit caused the R&D boom to accelerate, a model was estimated using a spline function. In this specification the credit variable essentially measured the change in R&D growth after 1980.[26] The spline function is appropriate in this instance because the question is whether R&D investment accelerated after 1980, and the theory clearly identifies the introduction of the R&E tax credit in 1981 as the pivot point. The model was tested for a sample of 221 firms with annual R&D spending of $25 million or more from 1978 to 1985.

The results of this regression, again corrected for autocorrelation and including company dummy variables, are presented in Table A4. Results in the first column simply confirm that R&D intensity increased significantly during the period. The positive coefficient (.091) on the credit variable in the second column show that R&D spending accelerated after 1980 but that the magnitude of the acceleration was not significant at the 5 percent level. The third and fourth regressions experimented with different specifications for the credit variable. The results in column 3 are for a specification in which the acceleration was tested only for firms with current positive net income. The results in column 4 represent a specification in which the effect of the credit was limited to firms with positive net income over the past three years.[27] By imposing the latter two conditions on the credit variable, the effect of the credit was measured only for those firms with the strongest potential for benefiting from it. The result was rather surprising since the coefficients on the revised credit variables were negative and even statistically significant. One interpretation is

Table A4 Regressions on R&D Intensity According to Company Data, 1978–1985

Independent Variable	Dependent Variable: Company R&D/Sales 1	2	3	4
Time Trend	.190** (.011)	.119** (.045)	.296** (.019)	.196** (.027)
Credit				
All Firms		.091 (.057)		
$[\pi_t>0]$			-.164** (.025)	
$[\pi_t, \pi_{t-1}, \pi_{t-2}>0]$				-.008** (.035)
Company Dummy Var.	x	x	x	x
Adjusted R^2	.94	.94	.94	.94

Notes: Standard errors are in parentheses. All estimates are multiplied by 100.
* Significantly different from zero at the 5 percent level.
** Significantly different from zero at the 1 percent level.
Source: Author's calculations based on data from Standard & Poor's COMPUSTAT database.

that firms with negative net income also experienced declining sales. If these firms did not reduce their R&D spending proportionately with sales, their R&D intensity would have increased. Once these firms are accounted for, R&D showed no sign of accelerating under the credit.

Tests also were conducted that combined industry variables with company observations. Industry data were linked to the company's primary industry, a specification that is not always appropriate, especially for large, diversified companies. It was not clear whether the insignificance of the industry variables in this format captured a real effect or merely was the result of a poor match between industry and company data.

These results indicate that any acceleration in R&D spending after 1980 was most likely to occur among those firms with the least potential for benefiting from the credit, namely, those with negative net income. There is little support here for believing that the R&E credit made much of a contribution to the R&D boom from 1978 to 1985.

Notes

1. All references to Germany refer only to West Germany.

2. Japan's expenditures were less than 0.1 percent of GDP but appear to be zero in the figure due to rounding error.

3. Individual businesses spend some of their own funds on defense, often with the intention of winning government contracts. Some portion of these expenditures is currently reimbursed by the Department of Defense but may not be designated as government R&D funds.

4. Annual growth in a country's R&D spending ($G_{R\&D}$) depends on growth in its share of nondefense R&D spending out of GDP (G_s) and on its growth in GDP (G_y). Specifically,

   $G_{R\&D} = (1+G_s)(1+G_y) - 1$

   These growth rates were then used to calculate changes in the ratios of nondefense spending by the United States and Japan and Germany. GDP figures were obtained from International Monetary Fund (1994).

5. High technology industries include aircraft, computer and office equipment, pharmaceuticals, communication equipment, electrical machinery, and instruments (National Science Foundation 1993, 440).

6. In effect the base was equal to

   $\frac{1}{3}\sum_{i=-1}^{-3} RE_i$ for 1983, $\frac{1}{2}\sum_{i=-1}^{-2} RE_i$ for 1982,

   and

   $\frac{1}{2}RE_{-1}$ for 1981

   (with the last component applying to only half the year). RE_i = research and experimentation expenditures in year i.

7. The effective credit rate (k) depends on the stated credit rate (K) and the discount rate according to the following formula:

   $k = K - K[\frac{1}{3}\frac{1}{(1+r)^1} + \frac{1}{3}\frac{1}{(1+r)^2} + \frac{1}{3}\frac{1}{(1+r)^3}]$

8. The fixed ratio is equal to the firm's historical ratio of R&D expenditures to sales from 1984 to 1988. The base is then calculated as the product of this ratio and average receipts over the four preceding years. The ratio was set at 3 percent for start-up companies, and special provisions were made to develop a fixed ratio for these firms and for those without sufficient records of R&E expenses or receipts in the 1980s.

9. For example, assuming a discount rate of 10 percent, the effective credit on an additional dollar of R&D spending increases from 3.4 percent to 20 percent. This is approximately a six-fold increase in the effective credit.

10. Where the base was required to be at least 50 percent of current qualified R&E expenditures up to 1990, the minimum was gradually raised to 75 percent by 1995 (Senate Committee on Finance 1989).

11. This is based on a 0.29 percentage point change in the R&D share of GDP from 1980 to 1985. This ratio, multiplied by 1980 GDP ($2,708 billion) and divided by total industry R&D spending in 1980 ($30.9 billion), yields an increase of 25.8 percent. If the effective credit is assumed to have been approximately 5 percent, the implied long-run elasticity with respect to R&D prices is 5.2, far greater than the range of 2.0 to 2.7 estimated by Hall (1993).

12. If rising DOD procurement in the early 1980s stimulated private R&D, why didn't falling DOD procurement during the 1950s and 1960s cause the reverse to occur? During this time, the United States was simultaneously demobilizing from the Korean War and World War II and mobilizing for the cold war. It is quite possible that, although DOD procurement was being cut at this time, a greater emphasis was being placed on sophisticated weapons systems produced by private industry. Some of the early reduction in procurement was related to the shift from personnel to weapons systems. There were, in fact, nearly one million fewer military employees in 1975 than in 1955 (U.S. Department of Treasury 1979, 353).

13. Energy prices are represented by the ratio of the producer price index for fuels, power, and related products to the overall producer price index.

14. Multiplying .0012 by 1980 GDP ($2,708 billion) and dividing this by industry R&D spending in 1980 ($30.9 billion) yields 10.5 percent. Assuming a 5 percent effective credit, the elasticity estimated in this test is 2.1, which falls within Hall's estimated range of 2.0 to 2.7 (Hall 1993).

15. The energy price variable was omitted because it was not particularly important in the time series data and because there was no cross-sectional dimension to it.

16. The model is a spline function of the form:

    $$R\&D/Sales = a_0 + aY_t + b(Y_t - Y_c)C_t + e.$$

    In this model, R&D intensity is a function of time (Y_t). The variable C_t is equal to one when the credit was in force (1981 and on), and Y_c is equal to 1980. R&D intensity increases at the rate of *a* per year until 1981, when it accelerates (or decelerates) by an amount proportional to *b*.

17. A very similar problem existed with the old utility price structure called *declining block rates*. With lower prices at higher levels of consumption, this policy encouraged consumption rather than conservation. Modern price structures are more likely to contain *increasing block rates*, which encourage conservation.

18. This is based on a sample averaging 525 firms from 1978 to 1985. In this sample, 60 percent of all increases in R&D were from firms with 0 to 25 percent R&D growth rates, 37 percent from firms with 25 to 100 percent growth rates, and 3 percent from firms with more than 100 percent growth rates. (Source: Standard & Poor's Compustat database).

19. The discussion here treats the tax credit as a microeconomic policy intended to correct a case of market failure. If the purpose is to stimulate the macroeconomy through deficit spending, then the issue of funding is irrelevant.

20. As Lichtenberg (1988) has demonstrated, government procurement stimulates private R&D spending primarily through design and technical competitions in which firms compete with each other for the purpose of winning production contracts. His results, however, apply only to competitive contracts. Noncompetitive contracts, often issued as a follow-on to existing contracts, actually had the opposite effect—reducing industry R&D. Since competitive procurement had a relatively stronger impact, the overall effect of government procurement on R&D remained positive.

21. The credit variable had mean and standard deviation of 0.429 and 0.034 respectively.

22. The mean and standard deviation of the R&D-to-shipments ratio were 0.028 and 0.034 respectively.

23. The mean and standard deviation of the imports-to-shipments ratio were 0.112 and 0.151 respectively.

24. The mean and standard deviation of the defense-to-shipments ratio were 0.059 and 0.130 respectively.

25. In this case, interpolation was based on the industry's share of R&D spending.

26. This is based on a spline function, described in footnote 16.

27. In column 4, for example, the credit variable is equal to one only if the year is 1981 or later and the sum of current net profits and net profits of the previous three years is greater than zero.

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About the Author

Thomas Karier is a Research Associate of The Jerome Levy Economics Institute of Bard College and professor of economics at Eastern Washington University in Spokane, Washington. Karier is the author of *Beyond Competition: The Economics of Mergers and Monopoly Power* (Sharpe, 1993); he is finishing a book on the history of macroeconomic policy in the 1980s. Karier is the author of Public Policy Brief No. 13, *Investment Tax Credit Reconsidered*.

Besides working on his forthcoming book, Karier is doing research in the area of recalculating profits for nonfinancial corporations. Karier contends that adjustments in the National Income and Product Accounts (NIPA) leave misleading deficiencies in corporate profits data (for example, they fail to include interest on debt and fail to incorporate the effect of inflation on debt). He therefore proposes to calculate a new profit series that makes two adjustments to the NIPA data. The first is the addition of interest payments to total profits, and the second is the adjustment of corporate debt for inflation in a manner analogous to the adjustment of capital consumption changes. His recent publications include "U.S. Foreign Production and Unions," in *Industrial Relations* (forthcoming); and "Competitiveness and American Enterprise" and "The Heresies of John Kenneth Galbraith" in the January–February 1994 and July–August 1993 issues, respectively, of *Challenge: The Magazine of Economic Affairs*. Dr. Karier received his Ph.D. from the University of California at Berkeley.