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THE CHALLENGE TO U.S. LEADERSHIP IN HIGH-TECHNOLOGY INDUSTRIES (CAN THE UNITED STATES MAINTAIN ITS LEAD? SHOULD IT TRY?)

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ABSTRACT

The United States emerged from World War II as the acknowledged global leader in basic science and its industrial application. While U.S. science has been able to maintain that preeminence in most areas, the nation's technological lead has met increasingly formidable challenges from abroad. Although the evidence on recent U.S. performance is mixed, other nations, and especially Japan, have clearly gained ground in high-technology production and trade. The future of U.S. high-technology production has thus emerged as a major focus of public policy. This paper reviews the recent performance of U.S. high-techology industries, examines possible motives underlying government policies to promote high-technology production, and offers some guidelines for evaluating the outcomes of alternative policy regimes.

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THE CHALLENGE TO U.S. LEADERSHIP IN HIGH-TECHNOLOGY INDUSTRIES (CAN THE UNITED STATES MAINTAIN ITS LEAD? SHOULD IT TRY?)

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At the close of World War II, the United States emerged as the acknowledged global leader in both science and its industrial application. While U.S. science has been able to maintain that preeminence in most areas, the nation's technological lead has met increasingly formidable challenges from abroad. Today, a number of U.S. high-technology industries have already lost their accustomed positions in world markets; a growing share of the commercial benefits from major U.S. scientific advances are now captured by foreign rather than American producers.

In the postwar period, U.S. excellence in science and technology has been vital not only to the dramatic rise in living standard enjoyed by most Americans, but also to national security and the central role of the United States in the western alliance. The erosion of the nation's technological superiority therefore calls into question the ability of the United States to sustain its leadership role in global institutions. Competitors abroad, understandably proud of their recent gains at the expense of a once-invincible economic and military rival, are at the same time uneasy about the wider implications for international stability of waning U.S. hegemony.

The future of U.S. high-technology industries has thus emerged as a major focus of public policy. This paper examines the recent performance of U.S. high-technology industries and policy options for maintaining or improving that performance. Section I reviews postwar trends in U.S. performance relative to major competitors abroad and the implications of these trends for U.S. trade. Section II analyzes the distinctive economic features of high-technology industries and evaluates the potential costs and benefits from policies to promote high-technology production. Section III presents an approach for evaluating policy alternatives. Section IV sums up implications of a diminished U.S. lead in science and technology for U.S. international competitiveness and national well-being.

I. Trends in U.S. performance

Three decades have passed since the Soviet Union shocked complacent Americans with the successful launch of Sputnik. The Soviet triumph touched off a prolonged wave of national soul-searching but also stimulated coherent national action. Moving quickly from collective humiliation to new levels of resource commitment, Americans became the first people to walk on the face of the moon.

Until the 1980s, the commercial challenges to U.S. technological supremacy were less dramatic. Although other U.S. manufacturing industries gradually lost their share of foreign and even domestic markets to competitors abroad, high-technology production appeared to be largely immune.[1] The U.S. trade balance on other manufactured goods had already moved into deficit by 1970, but the overall balance on trade in high-technology products continued to grow.

The balance of trade in high-technology products

Despite some significant losses on particular goods, the U.S. trade surplus in high-technology manufactured products rose from $6.1 billion in 1970 to $26.6 billion in 1980. Net trade in other manufacturing followed an opposite trend, with the deficit on U.S. trade in non-high-technology products growing from $3.8

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[1] High-technology industries are usually defined either in terms of the proportion of "professional, technical, and kindred" workers in total employment or the ratio of research and development expenditures to total sales.

billion in 1970 to $9.2 billion by 1980 (Table 1).

But 1980 proved to be a turning point for U.S. performance in high-technology trade. The surplus generated by high-technology products narrowed in each subsequent year, falling to $3.6 billion by 1985. The deterioration was less marked than in other manufacturing industries, where by 1985 the deficit had reached an astonishing level of $111 billion. However, the pattern was similar, with deterioration of U.S. performance in almost every product category and in almost every major trading relationship.

For both high-technology and non-high-technology trade, the declining balances have reflected primarily surging U.S. imports rather than falling U.S. exports. In high-technology trade, the value of U.S. exports nearly doubled between 1978 and 1985 -- but imports more than tripled over the same period. For non-high-technology manufactures, the contrast between export and import growth was even more dramatic, with the value of exports rising from $66.6 billion in 1978 to $93.5 billion in 1985 while imports soared from $90.6 billion to $204.6 billion.

The relatively minor reduction in the U.S. high-technology trade surplus in comparison to the marked decline in performance of mature industries is a reflection of continuing U.S. leadership in many high-technology sectors. Producers in the United States operate at a substantial labor-cost disadvantage relative to most trading partners, and the impact of this cost disadvantage on U.S. sales is greatest where comparable goods are available from a number of sources worldwide. The U.S. cost disadvantage was exacerbated in the first half of the 1980s by the rising international value of the dollar.

But in the high-technology field, the United States remains the sole source of many leading-edge goods (and services). For these products, labor costs and exchange rates therefore play a smaller role in determining U.S. trade performance. Even so, high costs of U.S. production can influence the decision of U.S. firms to establish subsidiaries abroad. The main "foreign" competition for U.S. high-technology products often comes from affiliates of U.S. companies.

The U.S. share in world exports

U.S. shares in world production or world exports likewise confirm a decline in the U.S. relative position. This is true both in manufacturing overall and in high-technology manufacturing. Part of this decline can be attributed to the influence of "temporary" macroeconomic factors, especially the huge U.S. budget deficit. However, it also reflects a process that can be expected to continue and even to accelerate: an increase in the number of nations with the knowledge base and the industrial capacity to quickly absorb and apply new technologies.

In 1950, the United States accounted for more than 40 percent of total world output and about 17 percent of world exports. By 1980, the U.S. share in global output had dwindled to 22 percent and its exports to 11 percent. These data are used by Bhagwati and Irwin (1987) to establish a striking parallel between the postwar decline in U.S. global dominence and the relative decline of Britain in the nineteenth century.

However, the use of 1950 as a base year for the comparison may exaggerate the decline in relative economic strength of the United States. As Baldwin (1984) points out, the period immediately after World War II was itself atypical. The United States had emerged from the war with greatly expanded productive capacity, while its erstwhile adversaries and allies alike had sustained extensive losses of capital and manpower. Every U.S. manufacturing industry was able to show a trade surplus, a situation that masked the relative weakness of some. U.S. shares of world activity just after the war were significantly above the corresponding measures for the period just before the war. The U.S. share of total exports of the ten most important industrial countries was 35 percent as late as 1952, while it had been only 26 percent in 1938 and 28 percent in 1928.

Looking specifically at national shares in total world exports of high-technology products, the U.S. share has actually risen in recent years and by 1984 was less than two percentage points below its 1965 level (25.2 percent versus 27.5 percent; see Table 2). The dramatic change in the global market has been the increase in the Japanese share, which rose from 7.3 percent in 1965 to 20.2 percent in 1984. However, the Japanese gains have come primarily at the expense of other nations, notably the United Kingdom, rather than the United States. Table 3 shows that in 1984 the United States retained relative strength in most technology-intensive product groups but had declined to a minor presence in radio and TV receiving equipment, a category dominated by the Japanese with almost 80 percent of total world exports. These trends indicate that the major change in patterns of global competition in high-technology products has been less the decline of the United States than the rise of Japan.

Declining U.S. competitiveness?

Moreover, because the usual indicators of U.S. market losses take no account of the concomitant rise in U.S.-controlled production abroad, these indicators may overstate the decline of the United States as an economic power.[2] The U.S. share of world manufactured exports fell from over 17 percent in 1966 to less than 14 percent by 1983. However, the global share of U.S. multinational firms remained unchanged over almost two decades, with gains in exports of majority-owned foreign affiliates compensating for declines in exports from parents (Lipsey and Kravis, 1985, 1986). Thus, while U.S. manufactured exports are indeed losing their share of world markets, to a great degree they are losing it not to foreign competitors but to themselves, i.e., to foreign subsidiaries of U.S. companies.[3]

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[2] Similar arguments apply in the case of the United Kingdom and other European nations with extensive direct investments abroad.

[3] Of course some U.S. sectors did better than the average while others lost ground to foreign competitors. The largest loss of export-market share both for U.S. production and for U.S.

This evidence suggests that much of the current discussion of declining U.S. competitiveness does not fit the facts. In particular, analyses that focus on failings of U.S. management and innovation are inconsistent with the sustained market shares of U.S. firms. Rather, the data show that the United States has lost ground as primarily as a locus of production. Differences in costs are presumably the main factor underlying the shift abroad by multinational corporations of production activities. Effective policies to improve U.S. competitiveness must address the determinants of these costs in order to upgrade the United States as a site for production.

Implications of the closing gap

While the postwar scientific and technological advances of Europe and Asia were undeniably impressive, these gains were made possible in large part by the existence of a technology gap between the United States and other industrial nations. Even in those cases where considerations of national security prompted the United States to limit foreign access to its advanced technology, scientists abroad were usually able to duplicate U.S. results at a small fraction of the original cost. Thus, as other nations achieve parity with the United States in scientific and technological endeavors, global patterns of innovation and

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multinationals came in motor vehicles, not a high-technology industry by the usual definitions. The largest gain over the period was in chemicals and allied products, a high-technology sector.

dissemination will undergo corresponding changes.

Like other nations, the United States has always derived substantial benefits from imported scientific and technological knowledge. In the postwar period, however, the significant U.S. lead in most areas meant that this source of advance was of only secondary importance. While catch-up abroad entails painful adjustments for the U.S. economy, it also means a potential increase in U.S. gains from technological imports. Although the specter of other nations closing the technology gap is evidently distasteful to some nationalistic Americans, over the long term it offers the opportunity for mutual gains through expanded two-way trade in new knowledge. Other consequences include greater U.S. participation in international cooperative research projects and commercial joint ventures, trends already well underway.

Investments in science and technology

The rapidity with which other industrial nations have achieved parity with the United States in many scientific and technological areas raises the question whether one of these nations (Japan in particular) might soon displace the United States as the global leader in science and technology. Such predictions of future national performance are often based on comparisons of current aggregate spending for R&D. However, interpretation of these statistics is complicated by at least four factors: the huge size of the American economy, the importance of defense-related expenditures in the U.S. total, differences in types of support used by the United States and its major rivals, and the growing R&D activities abroad of U.S. companies.

Critics of U.S. policy argue that the United States has fallen behind in research and development, relative both to other major nations today and to its own past efforts. This assessment is based largely on comparisons of R&D spending as a share of gross national product (GNP), a measure that shows other nations catching up to or even surpassing the United States (see Table 4). Yet the United States still spends far more in total than any other OECD nation, a reflection of the nation's much larger size. (The Soviet Union, not an OECD member, is estimated to allocate an amount comparable to that of the United States.)

While R&D spending as a fraction of GNP varies surprisingly little across the major industrial nations, there are significant differences in the allocation of funds among alternative uses. In relation to its major commercial rivals, the United States skews its R&D resources toward defense projects. In 1984, defense accounted for two-thirds of total U.S. spending for research and development, with civil space research taking another five percent of the total.[4]

Among the major nations, West Germany and Japan devote the highest proportion of GNP to nondefense R&D spending (Table 5). The United States is alone among major nations in its extensive

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[4] As a writer for Fortune magazine recently put it, U.S. research and development is getting too much bang for the buck.

support of basic research and its almost negligible direct support of commercial R&D projects. These funding patterns help to explain why the United States has been able to maintain its lead in most areas of military technology and basic science but has lost ground to other nations, particularly Japan, in translating U.S. scientific advances into commercial gains.

As with production trends, the activities of multinational corporations blur the distinction between U.S. and foreign R&D. A significant share of "foreign" R&D is actually performed by subsidiaries abroad of U.S. firms. One striking example is the breakthough in superconductivity research that earned the Nobel prize for two IBM scientists working in the firm's Swiss laboratories. A similar phenomenon exists for European and Japanese firms operating in the United States. As foreign companies establish U.S. subsidiaries, these firms are also increasing their local R&D activities.[5]

The Role of Domestic R&D

Recommendations intended to restore the U.S. competitive edge in high-technology production almost always include measures to spur domestic R&D. This prescription reflects two implicit

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[5] In the past, multinationals typically centralized most research activities in a single domestic location, undertaking R&D at locations abroad primarily to tailor products and processes to local needs. The recent increase in research undertaken abroad stems in part from cost considerations, especially labor costs. However, tax and incentive policies of host governments have become an increasingly important factor in determining the location of corporate research activities.

assumptions: first, that more R&D means more innovation and productivity growth; and second, that these assumed results of U.S. R&D activity influence mainly domestic productivity growth and thereby boost U.S. international competitiveness. Yet there is scant empirical evidence to justify this critical assumed link between a nation's aggregate R&D and productivity gains relative to competitors abroad.

In the past, lack of ability to absorb and apply new knowledge was the major factor preventing foreign firms from sharing equally in the commercial benefits from U.S. research and development. Today, however, new technical knowledge is quickly transmitted abroad and applied by foreign as well as domestic firms. In particular, subsidiaries abroad of U.S. multinationals can be expected to enjoy a level of technological advancement similar to that of the U.S. parent.

Absorptive capacity, rather than national boundaries, is the key to determining the implications of U.S. research and development for the international competitiveness of American producers. On the other hand, U.S. firms can now benefit from new knowledge resulting from foreign R&D activity. Narrowing of the technology gap between the United States and other industrial nations thus means expanded opportunities for two-way trade in knowledge as well as products. And the recent growth in offshore research activities of multinational firms further calls into question the significance of comparisons between U.S. and "foreign" R&D spending.

II. Motives for promoting high-technology production

The United States is one among many nations currently seeking to promote domestic high-technology industries. This goal of government trade and industrial policies has become commonplace not only for most of the industrialized nations but also for many less-developed countries. In some cases, the cost as conventionally measured of maintaining the sectors in question appears to be staggering (although perhaps less than for the ubiquitously sheltered agricultural sectors of industrial nations). And notwithstanding large expenditures, many such attempts are ultimately unsuccessful in creating an economically viable domestic industry. Thus, it is important to identify the broader objectives the United States and other nations seek to foster through support of high-technology production.

Policies to raise national income

Economists' theoretical analyses of trade policy usually assume as a starting point the goal of maximizing national income (or, more precisely, its present discounted value). On this basis, there are two fundamental justifications of departures from laissez-faire, both resting on an assumed divergence of social and private benefits. The first justification, which entails gains for one country at the expense of its trading partners, is the optimum tariff argument. A country that is large relative to the world market can improve its terms of trade (the price of its exports relative to that of its imports) by restricting the volume of trade; the optimum tariff sets the level of trade restriction to balance these terms-of-trade gains against the accompanying reduction in trade volume.

However, the same logic suggests that large suppliers should shun export subsidies (which would increase industry profits but lower national income). Since subsidies to production and export are endemic in high-technology industries, it is safe to conclude that maximization of national income through terms-of-trade manipulation is not the relevant consideration underlying support of these industries.

A recent variant of this reasoning views trade and industrial policies as means by which a nation can increase its share of worldwide economic profits ("rents") in oligopolistic industries.[6] As in the case of terms-of-trade manipulation, one country's gain from such a strategy is likely to mean corresponding losses abroad. However, the implications for global efficiency are ambiguous, since the starting point is not (as in the standard optimal-tariff analysis) a Pareto optimum. I return to this point in Section III below.

<u>Externalities</u>

The second theoretical justification of government intervention to increase national income requires that a productive activity generate benefits not fully captured by the

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[6] For a helpful review of the issues and literature, see Grossman and Richardson (1985).

producing firm. Under these conditions, the market-determined level of the activity may be too low relative to its value to society, and there is a case on narrow efficiency grounds for a subsidy to production. However, direct production subsidies are rarely employed, or even proposed. Rather, the alleged spillover becomes the basis of an argument for import restrictions or export incentives. These policies do provide an implicit subsidy to domestic production, but also an implicit tax on domestic consumption. Their use can therefore be justified on second-best grounds if the social benefit from the production subsidy outweighs the social loss from the consumption tax.

Assumed spillovers or externalities from high-technology production are frequently cited as the main rationale for policies to promote these industries (and, recently, more broadly, to promote any "complex production"). Appeals based on learning curves, forward linkages, strategic activities, and maintenance of an industrial base are all updated versions of the traditional infant-industry argument for protection and subject to the same qualifications.[7]

Two important qualifications must be met for protection to be justified along these lines. First, there must actually <u>be</u> an externality. In particular, this means that the mere existence of learning-by-doing is not enough; it must be impossible for firms to fully capture these benefits. This could be true because of problems of technological appropriability or because

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[7] The papers in Krugman (1986) offer numerous examples.

private capital markets are "imperfect" in their ability to finance large, risky, long-range projects.

In addition, the size of the expected benefit must be sufficiently great to offset, in present-value terms, the cost of the policies to produce the benefit. This condition is more likely to be met if the productive activity can be encouraged directly rather than through trade intervention, since the latter entails additional cost. The additional cost is still greater, and the case for intervention correspondingly weaker, if the facilitating policy is maintained after the infant has matured.

The externalities argument does seem at least potentially relevant to the case for government support of high-technology industries. In particular, the fruits of research and development may not be captured fully by the innovating firm, especially in industries such as electronics where the market is served by a large number of small firms. On the other hand, there is no clear evidence that, as a consequence of appropriability problems, firms do in fact engage in a suboptimal aggregate level of research and development; rivalry among firms may induce duplicative R&D efforts.

Furthermore, as in any efficiency argument for government intervention, the potential for a welfare gain from an optimal policy does not ensure that the actual policies adopted with this motive will be socially beneficial. And, since the affected domestic industry almost always benefits from preferential policies regardless of whether the broader national interest is served, an activist trade or industrial policy is likely to divert substantial industry resources into lobbying. A final consideration is that policies that promote the growth of particular high-technology sectors (targeting) or of high-technology industries as a group will, except in the very long run, drive up the costs to all users of specialized inputs, e.g., the salaries of scientists and engineers.[8]

Other policy goals

A more basic question concerns the appropriateness of the assumed ultimate goal used in most economic analyses: maximization of national income. It is clear that national policies are shaped by other criteria also, including the distribution of earned income and the composition of domestic production. With respect to the former, U.S. policy to a large extent aims to maintain the status quo, i.e., to slow the process by which changes in competitive conditions worldwide (whatever their cause) are translated into corresponding changes in U.S. earnings or employment patterns.

The second criterion, composition of domestic production, also figures prominently in national policy making, although it is rarely stated in this way. Arguments about American deindustrialization and about the strategic role of particular industries usually reflect implicit assumptions about the

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[8] For a theoretical analysis of this point, see Dixit (1985). The same issue is raised by the justification of U.S. defense and space R&D in terms of commercial spin-offs.

desirable composition of the nation's output. The national debate about causes and consequences of "loss of international competitiveness" has at its heart the question of how the composition of employment or production ought to be determined. Also important is that issues of distribution and of industrial composition are intimately related; an accelerated shift away from the manufacturing industries (or from mature industries to newer ones) entails important redistributive consequences by region, sex, race, education, and union status.

Why promote high-technology industries?

The high-technology manufacturing sector consists of individual industries, each with its own distinctive economic features and policy concerns. The common defining feature is the high share of research and development activities relative to sales, or of "professional, technical, and kindred" employment relative to total employment. However, efforts to promote specifically these industries raise several issues that are much more important than for other types of industrial policy.

First, these are the industries in which the United States has had its clear competitive advantage in recent decades and which together account for the lion's share of U.S. manufactured exports. Access to superior technology has allowed American producers to remain internationally competitive despite labor compensation far higher than in other nations. Thus, there is a strong belief, both in the United States and elsewhere, that high-technology production has been the main cause of the nation's economic and military strength, and that loss of U.S. competitiveness in these industries must mean a corresponding reduction in both the U.S. standard of living and the nation's military might.

Second, for many high-technology products, R&D expenditures constitute a substantial fraction of total cost. These large costs of research and development in turn create significant economies of scale. Aircraft is an extreme case of this, in which it is estimated that the total market worldwide can sustain only two, or perhaps three, profitable firms. Furthermore, once the R&D costs associated with a given product or process have been incurred, a private or government-controlled firm may find it optimal to sell at a price that is well below full average cost per unit. If firms or nations price in this way, resulting financial losses to rivals tend to drive some from the industry and thus curtail future competition and innovation.

Third, both technological barriers to entry (proprietary technology in the form of patents, copyrights, and trade secrets, but also absorptive capacity) and pervasive scale economies tend to restrict the number of competitors worldwide at any given time. This means economic profits need not be forced to zero through competition among firms. An additional implication of limited entry is that, from a social point of view, production may be too low, i.e., the cost of additional output from the industry would be more than justified by its value to potential consumers.

Finally, these industries are perceived as having important links to the nation's defense capabilities. In aircraft as well as semiconductors and computers, past U.S. defense and space expenditures are credited with an important role in facilitating the subsequent commercial dominance of the domestic industry in world markets. But for aircraft, that dominance is threatened today by the success of the European Airbus consortium, while in semiconductors and computers, the Japanese have become an increasingly formidable presence.

Moreover, the implications for the United States of increased R&D activity abroad are more complicated in industries with clear links to defense. The economic benefits from one nation's superior products or processes are typically shared worldwide through trade, so that the United States is likely to benefit not only from its own research and development efforts but also those of other nations. In contrast, the military value of new products and processes depends critically on their superiority to what is available elsewhere. From the point of view of defense, a rival nation's gains must always come at the expense of the United States.

Although each of these considerations appears to play some role in shaping national policies toward high-technology industries, it seems that the last one, broadly conceived, offers the best explanation for the evident willingness of many nations to promote these industries even at considerable expense in terms of foregone national income. In these industries, world ranking makes an important difference. For the United States, moving from first to second means a fundamental adverse shift in the world strategic balance. For the major economic rivals of the United States, the challenge to U.S. worldwide preeminance in high-technology production implies a challenge to U.S. political and military hegemony as well as to established commercial interests.

For minor industrial nations (e.g., Sweden, which has its own national aircraft producer) or for less-developed countries (e.g., Brazil, which has supported a domestic industry in both aircraft and computers), it is evident that the motivation must be somewhat different. Again, however, part of the explanation may hinge on the implications for the nation's political and strategic relationship with the United States and other superpowers. Having a viable domestic industry in, say, aircraft or computers, elevates a nation from the dependent status of technological followership, even though the twin goal of leadership may be, at least for the present, unattainable except in relation to other minor nations.

In those industries such as aircraft where sellers are few worldwide, buyers' fears of economic or political exploitation may be justified. However, in light of the strong incentives for sellers to supply their products at a price below full average costs, political costs of dependency seem far more likely than economic ones. This is particularly true when the United States is the relevant external supplier, given the nation's extensive use of temporary trade embargoes and the very broad definition of "strategic" importance used in licensing exports with potential military applications (Jacobsen, 1987).

The economics of high-technology production

Arguments for special treatment of high-technology industries are usually based in part on the distinctive economic features of these industries' productive processes and cost structure. The key role of research and development in these industries has at least three important implications for the role of policy.

First, extensive research and development often means a relatively long period of time between the decision to market a new product and the first sales of that product, and an even longer time until the new product "breaks even." In the case of aircraft, it is estimated that the first positive net cash-flow associated with a new model occurs five to ten years after the start of development. In pharmaceuticals, legally mandated product testing almost always means significant delays in bringing a new product to market.

A related characteristic of high-technology production is potentially higher risk than in mature industries. This great risk entails both technological uncertainty with respect to the feasibility of producing the planned product and uncertainty concerning market conditions at the relatively remote date when the product is ready for sale. In the case of aircraft, sales have been affected by unforeseen changes in fuel costs and real interest rates, noise-abatement policies, and deregulation of the U.S. industry. For nuclear power, falling energy prices and conservation have reduced demand, while regulatory difficulties have led to costs several times greater than originally projected.

Both the long period until profits are realized and the greater financial risk suggest that, even where the dynamic benefits could potentially be captured entirely by the innovating firm, private capital markets may be unwilling to provide the required financing for major development projects.

Finally, because research and development expenses represent fixed costs that do not depend on the total volume of output produced and because of learning curve effects, there are typically strong economies of scale in production -- the cost of each <u>additional</u> unit produced of a given model will be much lower than the average cost per unit (which will itself be a decreasing function of the length of the production run). The firm's profits will thus depend on its ability to spread fixed costs over a sufficiently large volume of output. Another consequence of this cost structure is the incentive to sell products below full average cost, especially in the early stages of a production run. This practice may cause special problems when a profit-motivated firm must compete with government-supported enterprises abroad.

<u>The problem of interface</u>

Competition between profit-motivated U.S. firms and enterprises owned or heavily subsidized by foreign governments is not a problem unique to high-technology industries. Steel and ship-building are examples of mature industries in which governments worldwide have chosen to participate actively, attempting to mitigate the domestic consequences of secularly declining demand and global excess capacity. However, the particular characteristics of high-technology industries make the problem of interface between a basically market-oriented domestic industry and competitors underwritten by foreign governments even more complicated than for other manufacturing activities.

As already noted, foreign governments may see special reasons for market-share protection of their high-technology industries. Furthermore, the cost structure of these industries presents particular problems in maintaining a competitive market. In light of pervasive scale economies, there are strong economic incentives for import restrictions, dumping, and export or production subsidies. As U.S. firms view the situation, the key economic question is not how many suppliers are needed to meet world demand for a particular product, but, rather, how many different manufacturing entities, each competing for a favorable share of a finite market, can the world industry support?

United States reliance on the market as the major mechanism for allocating productive resources entails a belief that investors should be rewarded for risk-taking through higher-than-average anticipated profits. In particular, this means the possibility of losses as well as profits from any given undertaking. However, high-technology industries pose special problems because profits earned by U.S. firms are likely to depend more on actions of governments (both foreign and U.S.) than on the conventional ingredients of industrial competitiveness. While as a society we may be comfortable with lower profits for an entrepreneur who guesses wrong about tastes, technology, or costs, it is quite different to say the same about losses caused primarily by actions of foreign governments. The long-term survival of the U.S. market-based system may be threatened if domestic firms must compete on equal terms with enterprises bankrolled by foreign treasuries.

From the foreign perspective, however, that support may be deemed necessary in order to avoid economic and political domination by the United States. In aircraft, computers, and semiconductors, foreign governments point to the influence of U.S. military procurement in maintaining the profitability of U.S. firms. Thus, there are really two aspects of interface: between profit-oriented and government-underwritten suppliers, and between defense-related and civilian sales.

III. Alternative policy regimes

A wide variety of policy measures may be used to enhance the competitive performance of high-technology industries. Because these industries are often characterized by oligopolistic rather than highly competitive markets, because of the important role of governments both as consumers and as producers, and because multiple criteria (economic, political, and strategic) are used in evaluating outcomes, economic theory can offer few firm guidelines concerning the potential costs and benefits of policies to promote high-technology production or to protect national shares in global markets for specific products.[9]

Rather than attempting here to catalog every possible outcome -- in any case, an impossible task -- it may be helpful to enumerate the most important dimensions along which the outcomes of alternative policy regimes may be measured. Specifically, policy outcomes may be judged on the basis of their effects on market competition (number of firms worldwide and in a specific market), cost of production, product "variety" available to consumers, and national share of global economic profits for the industry.

The last of these is easiest to evaluate. The industries in question are ones in which positive economic profits (supernormal profits) may be sustained indefinitely. Therefore, other things

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[9] See, however, Grossman and Richardson (1985) for an excellent account of the ambiguous economic considerations and references to the relevant technical literature. Dixit and Kyle (1985) analyze the many possible outcomes in a very simple case of two countries and two firms.

equal, a country will benefit from increasing its share of the market and, thereby, its share of the (relatively fixed) pool of global profits. Although these gains will arise in the form of higher profits of the relevant national firms, they will normally be shared more broadly through factor payments and taxes. However, one nation's gain in this dimension is necessarily another nation's loss.

Competition among nations for the fixed total can only reduce world welfare and may well reduce welfare also for each competing nation (the latter is not assured, even when all nations retaliate optimally to their competitors' profit-grabbing tactics). Because of the certainty of global losses and the likelihood of national losses from competition of this type, there is a clear case for international agreements to limit at least the most obvious forms of it.

Again holding other considerations constant, more firms serving a given market means more competition and greater economic efficiency. In this case, however, the gains come in the form of benefits to consumers from a larger volume of production and lower price. Economic profits are expected to decline as the number of competing firms increases, although the possibility of exit ensures an adequate expected return.

For industries in which the number of firms has no important relationship to cost per unit or to product variety, more competing firms will always be economically beneficial. This suggests that market-share protection has greater expected benefits (or lower social costs) when it increases national firms' share in an integrated global market than when it reserves a particular segment of the market for its own firms. By this logic, the Airbus market-competition strategy is preferable from an efficiency point of view to a restricted-market approach (along the lines of the U.S.-Japan semiconductor agreement) that achieved the same sales volumes for Airbus and Boeing.

This analysis of competing suppliers would be sufficient in an industry in which costs were unrelated to the level of output (constant returns to scale) or tended to increase with the level of output, and each firm supplied an identical product. For the high-technology industries, however, neither situation is typical. Choice among a greater range of related products is clearly an additional advantage from policies that increase the number of firms competing to serve a given market. Unfortunately, the issue of cost per unit tends to cut in the opposite direction.

With strong static and dynamic economies of scale, a larger number of firms means higher cost per unit. Ignoring for a moment the issue of variety, the social optimum would be achieved with a single producer selling its product at marginal cost. However, this arrangement requires a subsidy to that firm in excess of the full cost of research and development. The distributional and political issues raised by this solution of the natural-monopoly problem are well known. One possible compromise is average-cost pricing, typical in public utilities.

In mature industries, a major problem associated with regulation of natural monopoly is lack of incentive for cost minimization and an associated incentive for over-capitalization. Implementation of either regulatory approach in high-technology sectors is even more problematic. Complete underwriting by government of fixed costs uncertain in both size and technological outcome dilutes the incentives to produce marketable results at minimum cost. This is true whether the actual R&D is undertaken by a profit-oriented firm or by a government agency. Furthermore, government bureaucrats are thereby placed in the position of making technological and business judgments about which projects ought to be undertaken. The history of the U.S. government's role in innovation suggests that this arrangement virtually guarantees failure (Nelson, 1983).

On the other hand, complete reliance on the market is also likely to be unsatisfactory, for several reasons. As already noted, both appropriability and capital-market problems may prevent the private sector from undertaking some worthwhile projects. One workable compromise for the United States is to encourage cooperative ventures in which government support plays a role, particularly in the "generic" research where appropriability problems are likely to be greatest, but profit-oriented enterprises are encouraged to prticipate actively. A related approach already used in the United States is to encourage industry R&D indirectly via support for university research activities (see Nelson, 1986).

Even these mixed strategies have disadvantages, at least from a static perspective. One is the high probability of duplicative R&D effort unless the government limits its support to just one firm or group per project. But since such limits would eliminate some of the benefits from fostering private-government cooperation, this would presumably be the appropriate choice only where capital costs are very large. Furthermore, to the extent that the reward to successful innovators comes through control over eventual output and price, there will still be the usual incentives to supply a volume of output below the social optimum. If the quid pro quo for government participation were some form of mandatory licensing, this problem would be reduced but not eliminated.

At the international level, exactly the same economic problem of natural monopoly arises, except that is further complicated by implications for the national distribution of super-normal profits already mentioned. In terms of trade regimes, global productive efficiency is best served (ignoring the issue of variety) by concentrating production in a single firm. Efficiencies of scale make market-share protection an economically rational strategy for any individual country that has a potentially competitive supplier. But, again, competing efforts to achieve these economies of scale will actually result in the opposite: high-cost production from an excessively large number of competing suppliers worldwide. Here the case is even stronger for international rules limiting policies to capture scale economies for national producers.

Furthermore, there are potential efficiency gains from measures that encourage international cooperative ventures among firms serving a given national market. As long as national policies toward trade allow the world to remain in effect a single integrated market, possible losses from a reduced number of competitors are likely to be more than offset by supply-side savings. This suggests that market-segmentation strategies implemented by tariffs, quotas, voluntary exports restraints, or other bilateral agreements are inferior on efficiency grounds to production or export subsidies that have the same effect on the number of surviving competitors.

IV. U.S. prospects and options

The evidence on recent U.S. performance in high-technology industries is mixed. Some alleged U.S. problems simply reflect the postwar recovery and technological catch-up of other nations, i.e., a return to normal conditions from highly atypical ones. But if the nation's competititiveness problems have been exaggerated, it is nonetheless clear that the era of unquestioned U.S. economic hegemony is over. Today, Japan and the European Community rival the United States in important dimensions of economic achievement. Yet the United States remains the acknowledged leader of the western alliance in both economic and security matters. One possible reason is the apparent reluctance of other economically powerful nations, specifically Japan and West Germany, to assume the burdens and costs of an active leadership role. That reluctance may be another legacy of the unique circumstances that propelled the United States into its postwar hegemonic role.

The decline of the U.S. technological lead entails important changes in the economic relationship between the United States and its major trading partners. As these nations become more similar in terms of technology base, abundance of capital and skilled labor, and per capita income, intra-industry trade is likely to grow. In particular, two-way trade in technology and in technology-based services should become increasingly important as other nations move from adaptation into innovation. And in the mature industries and even some that are now considered "high-technology" sectors, all the industrial market economies will be squeezed by a new tier of competitors in Asia and elsewhere.

Likewise, for all the industrial economies, problems of sectoral adjustment will continue to generate strong pressures for import protection and other forms of assistance to industries losing ground to newcomers. Contrasting national approaches to the nurturing of high-technology production will remain a major source of sectoral trade conflict between the United States and its trading partners.

Simple policy prescriptions are unlikely to emerge from any analysis that captures the important features of high-technology production and international competition. Nonetheless, some broad guidelines for policy do emerge. The key distinguishing features of alternative policy regimes are the number of competing firms in a given market or worldwide, cost efficiency, product variety, and national distribution of economic profits.

These considerations suggest the utility of international agreements that limit counterproductive efforts to increase any one nation's share of world production in a specific industry, whether to get a larger share of economic profits or to capture greater economies of scale. They also imply that market-share protection is more likely to be deleterious to world and national welfare when it segments the international market. Import barriers or explicit turf agreements are thus less desirable than production or export subsidies. This is a particularly interesting conclusion in light of current GATT rules, which allow import barriers and at least tacitly accept turf agreement but actively discourage the use of subsidies. Similarly, U.S. trade law contains explicit provision for countervailing any foreign subsidy but has been less successful in combatting the greater damage resulting from foreign barriers to imports.[10]

Finally, it is evident that potential world and national gains are greatest from policies that encourage international cooperation in high-technology ventures while limiting the potential harm from reduced competition among suppliers by maintenance of an integrated world market.

Can the United States maintain its lead? Should it try?

Many Americans are reluctant to accept a future in which the United States is but one among several leaders in the high-technology industries. By redoubling its efforts, could the United States return to its one-time position of unquestioned technological preeminence? Even with vastly increased resources allocated to research and development, this kind of advantage probably can no longer be sustained -- by the United States or any other country -- in a world that has become highly interdependent, and in which many nations command the physical

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[10] "Reciprocity" trade legislation now under consideration in the United States has never, to my knowledge, been justified in terms of its potential contribution to maintaining integrated world markets. Of course, bilateral, product-by-product reciprocity would probably lead to market-share agreements rather than open markets.

and human resources necessary to participate in research and production at the technological frontiers. The advantage gained by being first in any innovation, whether for a firm or for a nation, is likely to be short-lived, thanks to the greatly increased speed with which new technical knowledge now becomes available to potential competitors all over the globe.

But even if it cannot succeed, the U.S. effort to maintain technological leadership is likely to have important positive consequences, not only for the United States but for its trading partners as well. Research and development and the resulting scientific and technological advances will continue to provide the primary basis for economic growth and a rising standard of living. Vigorous competition, whether among firms or among nations, can quicken the pace of technological advance worldwide and thus enhance economic prospects both at home and abroad.

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Table 1.

U.S. TRADE BALANCE IN HIGH-TECHNOLOGY AND NON-HIGH-TECHNOLOGY MANUFACTURED PRODUCT GROUPS, 1970-1985

(billions of dollars)

	High-technology products			Non-high-technology products		
Year	Exports	Imports	Balance	Exports	Imports	Balance
1970	10.3	4.2	6.1	19.0	22.8	-3.8
1971	11.4	4.9	6.5	19.0	27.4	-8.4
1972	11.9	6.3	5.6	21.8	33.7	11.9
1973	15.9	7.9	8.0	28.8	39.8	11.0
1974	21.5	9.8	11.7	42.0	49.7	-7.7
1975	22.9	9.5	13.4	48.1	45.5	2.6
1976	25.6	13.2	12.4	51.6	56.4	-4.8
1977	27.3	15.3	12.0	52.9	66.6	-13.7
1978	34.5	20.1	14.4	59.5	86.7	-27.2
1979	43.1	22.5	20.6	77.9	96.3	-18.4
1980	54.2	27.7	26.6	95.0	104.2	-9.2
1981	59.9	33.5	26.6	100.7	115.7	-15.0
1982	57.6	34.1	23.4	89.8	116.5	-26.7
1983	59.7	40.9	18.8	79.9	129.9	-59.0
1984	65.0	58.7	16.2	86.2	173.2	-87.0
1985	68.4	64.8	3.6	93.5	204.6	-111.0

Note: Based on U.S. Department of Commerce DOC-3 definition of high-technology products. Data for 1970-1977 are estimates.

Sources: National Science Foundation (1986, p. 54); U.S. Department of Commerce (1986, p. 131).

Table 2.

WORLD EXPORT SHARES OF TECHNOLOGY-INTENSIVE PRODUCTS, 1965-1984

(percent)

Country	1965	1970	1975	1980	1981	1982	1982	1984
United States	27.5	27.0	24.5	22.9	23.0	24.7	25.1	25.2
Japan	7.3	10.9	11.6	14.3	17.4	16.2	17.8	20.2
France	7.3	7.1	8.4	8.5	7.9	8.3	7.7	7.7
West Germany	16.9	16.8	16.8	16.3	14.8	15.5	15.0	14.5
United Kingdom	12.0	9.8	9.6	10.8	9.0	9.4	8.7	8.5

Note: Technology-intensive products defined as those for which R&D expenditures exceed 2.36 percent of value-added (DOC-2/OECD definition).

Source: National Science Foundation (1986, p. 58).

Table 3.

WORLD EXPORT SHARES OF TECHNOLOGY-INTENSIVE PRODUCTS, 1984

(percent)

Product field	United States	Japan	West Germany	France	United Kingdom
Aircraft & parts	45.1	0.5	15.2	11.8	14.5
Industrial inorganic chemicals	23.9	4.3	15.0	11.5	12.2
Radio & TV receiving equipment	0.5	79.5	8.2	1.0	2.2
Office & computing machines	35.5	19.1	9.2	5.6	9.5
Electrical machinery & equipment	23.9	19.3	17.3	8.2	9.2
Communications equipment	26.5	35.5	10.4	6.1	6.4
Professional & scientific instruments	13.7	31.2	15.3	5.7	7.4
Drugs	19.6	2.6	15.8	10.7	11.9
Plastic materials, synthetics	14.4	10.1	21.4	9.5	6.9
Engines & turbines	29.0	17.4	16.4	1.9	8.7
Agricultural chemicals	33.7	4.1	13.0	7.2	7.2

Note: Technology-intensive products defined as those for which R&D expenditure exceeds 2.36 percent of value-added (DOC-2/OECD definition).

Source: National Science Foundation (1986, p. 60).

Table 4.

NATIONAL R&D EXPENDITURES AS A SHARE OF GNP, 1961-1985

(percent)

Year	France	West Germany	Japan	United Kingdom	United States	U.S.S.R.
1961	1.4	NA	1.4	2.5	2.7	NA
1962	1.5	1.2	1.5	NA	2.7	2.6
1963	1.6	1.4	1.4	NA	2.8	2.8
1964	1.8	1.6	1.5	2.3	2.9	2.9
1965	2.0	1.7	1.5	NA	2.8	2.9
1966	2.1	1.8	1.5	2.3	2.8	2.9
1967	2.1	2.0	1.5	2.3	2.8	2.9
1968	2.1	2.0	1.6	2.3	2.8	NA
1969	1.9	1.8	1.6	2.3	2.7	3.0
1970	1.9	2.1	1.9	NA	2.6	3.3
1971	1.9	2.2	1.9	NA	2.4	3.5
1972	1.9	2.2	1.9	2.1	2.3	3.7
1973	1.8	2.1	1.9	NA	2.3	3.8
1974	1.8	2.1	2.0	NA	2.2	3.7
1975	1.8	2.2	2.0	2.2	2.2	3.8
1976	1.8	2.2	1.9	NA	2.2	3.6
1977	1.8	2.1	1.9	NA	2.1	3.5
1978	1.8	2.2	2.0	2.2	2.1	3.5
1979	1.8	2.4	2.1	NA	2.2	3.6
1980	1.8	2.5	2.2	NA	2.3	3.8
1981	2.0	2.5	2.4	2.4	2.4	3.7
1982	2.1	2.6	2.5	NA	2.5	3.7
1983	2.2	2.5	2.6	2.2	2.6	3.8
1984	2.2	2.5	2.6	NA	2.6	3.9
1985	2.3	2.6	NA	NA	2.7	NA

Note: Data for 1983 and 1984 are preliminary; data for 1985 are estimates.

Source: National Science Foundation (1986, p. 4)

Table 5.

NONDEFENSE R&D EXPENDITURES AS A SHARE OF GNP, 1971-1985

(percent)

Year	France	West Germany	Japan	United Kingdom	United States
1971	1.5	2.0	1.8	NA	1.6
1972	1.5	2.1	1.8	1.5	1.6
1973	1.4	1.9	1.9	NA	1.6
1974	1.5	2.0	2.0	NA	1.6
1975	1.5	2.1	1.9	1.4	1.6
1976	1.4	2.0	1.9	NA	1.6
1977	1.4	2.0	1.9	NA	1.6
1978	1.3	2.1	2.0	1.5	1.6
1979	1.4	2.3	2.1	NA	1.7
1980	1.4	2.3	2.2	NA	1.8
1981	1.5	2.4	2.4	1.7	1.8
1982	1.6	2.5	2.5	NA	1.9
1983	1.7	2.4	2.6	1.6	1.9
1984	1.8	2.4	2.6	NA	1.8
1985	1.8	2.5	NA	NA	1.9

Note: Data for 1983 and 1984 are preliminary; data for 1985 are estimates.

Source: National Science Foundation (1986, p. 6)