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99

THE "TECHNOLOGY GAP" AND NATIONAL SCIENCE POLICY

Richard R. Nelson

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The "Technology Gap" and National Science Policy*

Richard R. Nelson

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During the last decade the notion of "technological gap" between the United States and Europe has played an important role, on both sides of the Atlantic, in thinking about policy regarding science and technology. Europeans have pointed with alarm to the alleged gap, have credited (or blamed) the gap on massive support of "big science and technology" by the United States government, and have proposed that the remedy is for European governments to do likewise. At the same time various aspects of American policy have been rationalized by arguments that they are necessary if the United States is not to lose its technological lead. Yet the very concept of a "technological gap" is a somewhat slippery one; many people have argued that there is no such thing. And certainly the connection between the existence or non-existence of a gap and specific science policies is far from obvious.

In this paper I will argue three points. First, the technological gap is a meaningful concept, and the phenomenon probably is real. Second, it is nothing new; something like a technological gap between the United

* This paper is based partially on research undertaken under the sponsorship of the Twentieth Century Fund and the Agnelli Foundation.

States and Europe has existed for upwards of one hundred years. Third, keying science and technology policy to "eliminating" or "preserving" the gap (depending on which side of the Atlantic one resides) provides an unfruitful, and often pernicious, direction and structuring to policy.

I. THE MEANING OF A TECHNOLOGICAL GAP

By a technological gap I think most people have in mind phenomena that transcend the consequences of differences across countries in factor endowments, either innate, or as developed through past investment. Thus, differences in income levels due to difference in output per worker across countries is not direct evidence that a technological gap exists between the high and lower income countries. The productivity differences could be the result of different amounts of resources invested, over the years, in machinery and equipment, education, training, and other intangibles per worker. Various studies of cross country productivity differences indicate strongly that differences in investment indeed are a good part of the story. Both physical capital per worker, and various measures of educational attainment, are systematically related to output per worker. But various other studies indicate quite strongly that there is more to it than this.*

It has been known for some time that if one looks at growth over time within a country, increases in capital per worker (even including education and other forms of human capital) are incapable of fully explaining growth

* For a review and critique see Richard R. Nelson, "A Diffusion Model of International Productivity Difference" American Economic Review, December, 1969.

of productivity, and obviously cannot come to grips with the phenomena even more impressive than productivity growth--the tremendous enrichment and improvement in the kinds of final products produced.* Recent research by Keasing, Vernon, Hufbauer, and others, has been concerned with the effect of technology and technological change on trade patterns.** Their well-known results are that, to a considerable extent, U.S. manufacturing exports are in new products that other countries have not yet begun to produce in quantity. Vernon and Hufbauer go on to show that, with a lag, other manufacturing nations pick up and employ U.S. technology and gradually cut the United States out of export markets.

By putting these threads together one comes up with an explanation of international differences in productivity that involves but transcends differences in capital. The main engine of manufacturing development is the creation of new technological knowledge, and its application, above all in the United States, and to a more limited extent in Europe and Japan. With a lag, the other major manufacturing countries pick up the new technology and learn to use it effectively. With a much greater lag, the less developed countries do. Under this view, one would expect to find differences across countries in productivity and composition and manufacturing activity that transcend differences in capital and other inputs per worker directly engaged in production.

* For a review of the literature See Richard R. Nelson, Merton J. Peck, and Edward D. Kalachek, Technology, Economic Growth, and Public Policy, The Brookings Institution, Washington, D.C., 1967.

** Donald Keasing, "The Impact of Research and Development on U.S. Trade", Journal of Political Economy, February, 1967; Raymond Vernon, "International Investment and International Trade in Product Cycles", Quarterly Journal of Economics, June 1966; G.C. Hufbauer, Synthetic Materials and the Theory of International Trade, Gerald Duckworth, 1966.

A technological gap between countries, in the above sense, should show up in three ways. The first is differences in general or total factor productivity, which probably should be associated with differences in output per worker but transcends it. Second, one should observe that the leading country is a major exporter in technically progressive industries. Third, the lagging countries should be adopters of technology rather than innovators.

It would appear probable that a technological gap, in the above sense, does exist between the United States and Europe, at least in many industries. The trade and adoption aspects of the phenomenon are, of course, well documented.* It is far harder to document the total factor productivity differential. Denison has concluded that, under his assumptions, differences in productivity between the U.S. and Europe cannot be fully explained by differences in capital-labor ratios, educational attainments or other differences in relative quantities and qualities of factors of production.** One cannot prove the existence of a "gap", but it appears quite likely.

II. THE TECHNOLOGICAL GAP AS A LONG-STANDING PHENOMENON

The recent discussion of the technological gap not only asserts that it exists, but that it is something new. Some of the more careful students of the phenomenon have pointed out that it isn't all that new,

* See the reference above and a series of recent articles by Christopher Freeman and associates in the National Institute Economic Review.

** Edward Denison (assisted by Jean-Pierre Poulhier), Why Economic Growth Rates Differ, The Brookings Institution, 1967.

citing the various comparative productivity studies made just after World War II that showed that a "gap" existed then. But I want to suggest that the phenomenon is of far longer standing than that.*

As long ago as 1835 de Tocqueville noted regarding shipping:

It is difficult to say for what reason the Americans can navigate at a lower rate than other nations; one is at first led to attribute this superiority to the physical advantages that nature given them; but it is not so...I am of the opinion that the true cause of their superiority must not be sought for in physical advantages, but that it is wholly attributable to moral and intellectual qualities.**

And not just in shipping,

The United States of America has only been emancipated for half a century from the state of colonial dependence in which it stood to Great Britain; the number of large fortunes there is small and capital is still scarce. Yet no people in the world have made such rapid progress in trade and manufactures as the Americans...***

Habakkuk opens his excellent recent work on American and British Technology in the Nineteenth Century by confirming and reinforcing de Tocqueville's judgment.

There is a substantial body of comment, by English visitors to America in the first half of the nineteenth century, which suggests that, in a number of industries, American equipment was, in some sense, superior to the English even at this period. As early as 1835 Cobden had noted, in the machine shop of a woolen mill at Lowell, "a number of machines and contrivances

* John Diebold also has noted this. See his "Is the Gap Technological?" Foreign Affairs,

** Alexis de Tocqueville, Democracy in America, Vintage Books, New York, 1955, Vol. I, p. 441.

*** Ibid., 1954, Vol. II, pp. 165-166.

for abridging labour greater than at Sharp and Robers." He thought agricultural implements in New England exhibited "remarkable evidences of ingenuity...for aiding and abridging human as well as brute labour," and gave several other instances. And the two groups of English technicians who visited America in the 1850's reported that the Americans produced by more highly mechanized and more standardised methods a wide range of products including doors, furniture and other woodwork; boots and shoes; ploughs and mowing-machines, wood screws, files and nails; biscuits, locks, clocks, small arms, nuts and bolts.*

The evidence of a technological gap in many fields prior to 1850 essentially is the record of scattered non-quantitative impressions of sophisticated and knowledgeable visitors. After 1850 we have access to more quantitative evidence. All three facets were present; higher total factor productivity, a strong export position in technically progressive industries, and foreign (European) adoption of the U.S. practices.

It is very clear that by the 1860's and 1870's real per capita income was significantly higher in the United States than in the United Kingdom or Western Europe. Kuznet's data show that, if anything, the percentage difference between the United States and France and Germany was greater in the mid-nineteenth century than today, and the relative gap between the United States and England was only slightly smaller then than now. ** In part this was due to the high productivity of American agriculture. But value added per worker almost certainly was higher in American manufacturing industry.

* H.J. Habakkuk, American and British Technology in the Nineteenth Century, Cambridge University Press, 1962, pp. 4-5.

** Simon Kuznets, Modern Economic Growth, Yale University Press, 1966, pp. 64-65.

It was higher for at least two reasons. Even by that time a large number of industries in the United States probably were operating at a higher capital-labor ratio than their English or European counterparts. This is both explained by and explains the significantly higher wage rate in the U.S. industry. High American wages go back at least as far as 1830, and scattered evidence suggests that by the 1870's U.S. wages may have averaged perhaps twice that in the United Kingdom (and even more, relative to France and Germany). But this cannot be the full explanation. If it were simply greater capital intensity, but the same total factor productivity, the rate of return on capital should have been significantly lower in the United States.* The limited evidence suggests, rather, that it was higher. Over the second half of the nineteenth century the yield on British consols never got above 3.5 percent; the yield on the best American railway bonds (to be sure somewhat more risky) never sunk that low and tended to be over 5.0 percent.** Relatedly, this was a period when capital was flowing from the United Kingdom to the United States, not the other way around.

Between 1880 and 1910 the growth of U.S. finished manufactured exports increased more than six fold; imports less than tripled. The United States, which ought to have and clearly did have a great comparative advantage and large net export position in foodstuffs (which made exchange available for manufactured imports) nonetheless was a net exporter of

* A well known implication of economic theory is that wage rates rise, but rates of return on capital fall, as the capital-labor ratio increases, if technology is constant.

** William Fellner, Trends and Cycles in Economic Activity, Henry Holt and Company, 1956, pp. 396-397.

manufactured products by 1900. A good share of the surge was in "technically progressive" industries. By 1899 about one-third of t U.S. manufactured exports were in machinery, chemicals, or vehicles.* For Germany and the United Kingdom the figure was about one-fifth. The value of U.S. machinery exports increased ten-fold between the mid-1880's and 1905-1906. It would appear that around the turn of the century the United States dominated trade in typewriters, for example.**

This evidence suggests a significant "technological lead", not surprisingly, for the last half of the nineteenth century was indeed the well-known great age of American invention. It was also the era in which the system of interchangeable parts was rapidly coming into play in industry after industry in the United States. In many fields Europeans and Englishmen were busy picking up American technique with a lag, just as today. Of course, it was not a one way street. The Americans did not lead in all fields, and in many fields the lead changed hands. Sometime during the nineteenth century the U.S. lost its lead in shipping. The English and Europeans developed, and then lost to the Americans, the lead in steel technology. But that on the average in some sense, the Americans were the technological leaders in manufacturing industry seems clear.

* All data cited for U.S. exports during the late nineteenth and early twentieth centuries are from The Historical Statistics of the United States, U.S. Department of Commerce, 1960.

** See the paper by Richard N. Cooper, In Technology and World Trade, U.S. Department of Commerce, 1967.

Then, as today, there is evidence of considerable concern on the part of some Europeans. Viner presents the following quote from an 1897 letter circulated by Count Goluchowski, the Austrian Foreign Minister:*

Europe has apparently reached the turning-point in her development. The solving of the great problem of the material well-being of nations, which becomes more pressing from year to year, is no longer a distant Utopia. It is near at hand. The disastrous competition which, in all domains of human activity, we have to submit to from over the seas, and which we will also have to encounter in the future, must be resisted if the vital interests of Europe are not to suffer, and if Europe is not to fall into gradual decay. Shoulder to shoulder we must ward off the danger that is at our doors, and in order to prepare for this we must draw upon all the reserves that stand at our disposal...

...the twentieth century will be a century of struggle for existence in the domain of economics. The nations of Europe must unite in order to defend their very means of existence. May that be understood by all, and may we make use of those days of peaceful development to which we look forward with confidence, to unite our best energies.

Then, as today, some Americans were concerned about the prospects of losing the lead for it was recognized by at least some observers that the reason why U.S. industry was able to pay such high wages, still earn such a high rate of return, and yet remain competitive in world markets, lay in its technological lead. In 1915 Taussig commented as follows on the rapid diffusion of American technology in automatic machinery:

The more machinery becomes automatic, the more readily can it be transplanted. Is there not a likelihood that apparatus which is almost self-acting will be carried off to countries of low wages, and there used for producing articles at lower price than is possible in the country of high wages where the apparatus has originated? In hearings before our congressional

* From Jacob Viner, The Customs Union Issue, Anderson Kramer Associates, 1961, pp. 22-24.

committees a fear is often expressed that American investors and tool-makers will find themselves in such a plight. An American firm, it is said, will devise a new machine, and an export of the machine itself or of its products will set in. Then some German will buy a specimen and reproduce the machine, in his own country (the Germans have been usually complained of as the arch plagiarists; very recently the Japanese also are held up in terrorem). Soon not only will the exports cease, but the machine itself will be operated in Germany by low-paid labor, and the articles made by its aid will be sent back to the United States. Shoe machinery and knitting machinery have been cited in illustration.*

It is striking how the dialogue today echoes the earlier voices of alarm, both European and American. This is not to argue that nothing is new. Many things are, and three in particular would appear to be of major importance in recent policy thinking. First, there has been the rise of the very large corporation to economic prominence in many industries, the evolution of beliefs that size and technological progressivity are closely correlated (with the causation running from size to progressivity) and recently the phenomenon of massive direct investment in Europe by the large American companies. Second, there has occurred a profound change in the bases of military strength with a large and effective military R and D effort now a pre-requisite for strategic power. These two factors have played an extremely important role in molding the Europeans' preception of the "technology gap", in particular in intensifying the feeling, embryonic in the quote from Count Goluchowski, that the gap is a threat to national sovereignty. Americans also have associated general technological leadership with military security, if not control of economic self destiny.

* F.W. Taussig, Selected Readings in International Trade and Tariff Problems, Ginn & Co., Boston, 1921, p. 138; reprinted from Chapter 3 of Some Aspects of the Tariff Question, 1915.

A third development has been the rise to prominence of large scale organized industrial R and D. Only recently has organized R and D been recognized as an important factor generating technological advance. Years ago the focus was on "inventiveness" and "ingenuity" and "energy"; the new focus on R and D provided a policy handle that was not there when the sources of progressivity were viewed in terms of personal attributes. During the 1960's data collection progressed to a point where it was possible to compare national R and D efforts.* The Europeans began to point with alarm to the American R and D lead, the Americans to the European closing of the gap, and both to "doing something about it".

In the following section I shall be concerned with this last aspect-- the evolving conception of a national R and D policy and the influence of "gap" thinking upon that conception. Unfortunately in many discussions on both sides of the Atlantic, all three of the prominent and visible aspects mentioned above, and the more traditional phenomena associated with a "technology gap", are all snarled together.** An overly simplistic characterization of the point of view is that in today's world military and space R and D are the key sources of almost all important technological progress, and that the efficient way to get that R and D done is through

* A useful reference is C. Freeman and A. Young, "The Research and Development Effort in Western Europe, North America, and the Soviet Union," OECD, 1965.

** As an obvious example see J.J. Servan Schrieber, The American Challenge, Althenian Press, 1968.

Governmental R and D contracts with large industrial concerns. Suffice it to say here that this point of view cannot be squared with evidence that "spillover" from defense and space is impressive in only a narrow range of product fields, that it is far from clear that "size" and "efficiency" or progressivity are strongly correlated once one gets beyond some kind of a minimal size threshold, and, as we shall discuss later, growing perception of deep troubles with the mechanism of contracted R and D, in the U.S. defense industries.*

In the more recent policy deliberations these aspects have been kept more separated than earlier. As a consequence the idea of a "civilian" R and D policy has emerged, more or less apart from discussions of national security policy and industrial rationalization or organization. However, as we shall see, there still remains certain perceived and real interconnections. Let us turn to this set of evolving policy ideas.

III. THE NEW POLICY DEPARTURE: GOVERNMENT SUBSIDY OF LARGE SCALE R AND D ON NON-MILITARY PRODUCTS

It now seems conventional wisdom that, on the one hand, science and technology policy is an important element determining a nation's economic growth performance, and on the other, that the objective of fostering economic progress somehow should enter prominently in determining a nation's policies regarding science and technology. ** To a considerable

⁸ For a general discussion and review of the evidence see Nelson, Peck, and Kalachek, Ibid.

** See for example OECD Report, Science, Economic Growth, and Government Policy, Paris 1964.

extent the suggested new policy departures really amount to doing "more" and "better" what governments have done for some time; in particular supporting basic science and engineering research and education. Yet the concept of a "gap", calling attention as it does to particular product fields and industries also naturally has pointed policy deliberation in the direction of subsidizing or financing the development of products for production and sale by private companies through the market to the general public (prominently including the export public). This would represent a significant new policy departure for the United States, as well as the European nations. The supersonic transport program of the Department of Transportation, and the civilian power reactors programs of the Atomic Energy Commission mark the first major steps down this road. It is this new direction that I want to discuss here.

Of course, for many years the Federal Government has played a vital role in influencing the nation's efforts in science and technology, and since the Korean War has accounted for a large share of total R and D spending. However, the purposes of public R and D programs, while numerous and diverse, can for the most part be placed in two categories. The first is the development of new technology for the public sector. The dominant programs here, of course, traditionally have been defense related but Government also undertakes or supports R and D to improve the ability of public agencies to protect the public health, guard against dangerous drugs, support construction of public facilities like airports and roads, improve air safety, etc. In all of these cases the Government is charged with performing a particular function and the R and D is undertaken to permit it to perform more efficiently. The second is to advance basic

knowledge or knowledge of highly diverse interest or use. Here the basic research support programs of NSF and NIH are clear examples. Recently NASA has been a dramatic new departure in Government sponsorship of a scientific and technological venture that was deemed both fundamental and of general diffuse benefit. As Price and others have documented governmental spending for both of these purposes has traditions that go back far into American history.* The Constitutional responsibility for setting and maintaining standards for weights and measures soon lead to a small research effort in the Treasury Department. The army arsenals performed R and D on a variety of weapons. Coast and Inland Surveys and explorations were undertaken and financed to enable the Army and the Navy to protect the country better and because it was believed that the knowledge would be of widespread interest and utility to the citizens.

But by and large the Federal Government has steered shy of supporting and undertaking R and D aimed specifically at improving a particular class of products and services whose normal channel of distribution is through the market. Where this has been done the product in question has had strong claim to being a merit good, the quality of which "ought" to be improved or cost reduced (like those connected with better health) or large fraction of the society was concerned with their production (as the early rationale for public support of agricultural research) or the product was closely linked with defense (like aviation). There are also

* Don Price, Science and Government, New York University, 1954.

a few examples of R and D support in particular industries (like coal) believed to be "in distress". But by and large in all of these cases public funds tended to go into basic and applied research, and experimental development, with development of commercial products being left to private initiative and funding.

The pre-1960 public support of research relevant to civil aviation is directly relevant. In 1912 the National Advisory Committee on Aeronautics (NACA) was created to spur and facilitate the development of American aviation. During its heyday during the 1920's and 1930's, NACA pioneered in the development and operation of R and D facilities for general use--for example, wind tunnels--in information collection and dissemination and in basic research and exploratory development. It undertook major work on aircraft streamlining, design of engine parts, properties of fuels, structural aspects of aircraft design, building and testing a variety of experimental hardware. But NACA did not directly support the development of particular commercial airplanes.

Until the 1960's the programs of Atomic Energy Commission in support of civilian power reactors were similar in spirit to the NACA support of aircraft technology. Indeed the amended Atomic Energy Act of 1954 established a more or less explicit division of responsibility between the AEC and private enterprise, with the Government's role being limited to the undertaking of support of research, the building of experimental reactors, operating facilities for testing, information dissemination, etc. Private enterprise clearly was left the job of bringing the technology to practice on its own initiative.

In the past decade the complexion of these two programs changed significantly. With the advent of the SST program the Government came into the business not just of supporting personnel, research and experimentation in civil aviation but of committing itself to the development of a particular aircraft. Similarly the power reactor program began to plan and subsidize R and D through final product development.

A close look at certain characteristics of the technical change process the United States has experienced in civilian industry, and at certain characteristics of the Government financed development programs in defense raise some warning flags. Technological progress in most American industries has been marked by considerable diversity of the sources, and unpredictability (at least in fine structure) of the advances. New products, processes, inputs, and equipment for an industry have come from established firms in the industry, from suppliers, purchasers, new entrants to the industry, individual investors.* Many developments that seemed to be promising did not pan out. Many important breakthroughs were relatively unpredicted and were not supported by the recognized experts in the field. While detailed case studies are not plentiful, one has the impression that in most technically progressive industries most of the bad bets were rather quickly abandoned particularly if someone else was coming up with a better solution. And good ideas generally had a variety of paths to get their case heard.

* Two interesting case studies are Merton J. Peck "Inventions in the Post War Aluminum Industry" and John Enos "Invention and Innovation in the Petroleum Refining Industry" both in The Rate and Direction of Inventive Activity, Princeton University Press, 1962.

In contrast, since the Korean War the United States has attempted to plan technological developments in defense. A natural concomitant of planned development financed by the Government has been a narrowing down of the sources of technological advance. The firms in the defense industry have become, in effect, chosen instruments. The likelihood is remote that a firm without a contract could, by using its own funds, ultimately beat out the firm with R and D contract. Thus as Government R and D financing and planning has intensified independent industry initiative has dried up. There is no question but that the advances in performance that have been achieved under the system are fantastic. Yet the waste and sheer mistakes are equally impressive. The percentage of developments that achieved anything like the performance originally promised at anything near the anticipated costs, has, of course, been dismal. It is not clear that the early bets on promising designs in defense have been any worse than in civilian industry. But there has been a tendency to stick with the game plan in the face of mounting evidence that it was not a good one, that appears only in exceptional cases in areas where R and D is more decentralized and competitive. The case of Convair throwing good money after bad on the 880 development rightly is regarded as an aberration, and the fact that General Dynamics learned its style in military R and D undoubtedly was a contributing factor.* But this kind of thing is the rule, not the exception, in military R and D.

Why the high cost and apparent waste? Largely because of the pace of advance sought. The nature of the arms race imposes a high cost on not having equipment at least as good as the potential enemies', or at least this is the perception that

*For the story see Richard Smith, Corporations in Crisis, Anchor Press, 1966.

has guided defense R and D planning (I will not stress here that in many cases this notion is simply wrong). Thus each R and D project reaches as far as it can. Costs are high both because it is costly to stretch, and because there are many stumbles. It would seem that we ought to be able to achieve our defense capabilities with less cost and fewer stumbles than we have. But to a considerable extent the costs and stumbles seem inherent in force feeding a technology. (Popular impressions aside there was much the same syndrome of cost overruns and failures in Project Apollo). And if force feeding is felt to be important, it would seem that Governmental subsidy and a considerable extent of central planning, with chosen instruments, blocked competition, and the rest, is the only way to do it.

Over the past decade the defense and space R and D style has begun to be viewed as extendible to civilian industries, and as remarked above, has been extended to the development of supersonic transport, and civilian nuclear power reactors. This has occurred both in the United States and Europe; here I shall focus largely on the U.S. experience. In both cases the defense R and D syndrome is emerging. Boeing is without competition in SST development; with the extent of Governmental funds provided to Boeing what other company would hazard its own funds? A duopoly is emerging regarding production of power reactors. The batting averages in these programs thus far do not appear good. The signals are clear enough that the present SST design is in trouble (the first one had to be abandoned after considerable expense) and only momentum and lack of an alternative carry the project forward. Similarly throughout the history of the power reactor program there have been complaints that the AEC was persisting in

R and D on designs long after evidence had accumulated that this was not an attractive route, and conversely that AEC has been sticky about initiating work on new concepts.*

As in defense, the syndrome is largely the result of an attempt to force feed the technologies. The articulated reason for the force feeding also is similar to defense--the objective of staying ahead of (for the European's catching up or leapfrogging) other countries. These programs are the natural consequence of "technology gap" type thinking. While there exist some plausible arguments for some kind of Governmental assistance to development of advanced civil aircraft, and there are quite persuasive arguments for Governmental assistance in power reactor development, the rate of Government funding and, more importantly, the extent of involvement in final product design and development that has developed over the past decade is justified only if American leadership, per se, is assigned very high value. And indeed preservation of American leadership is an explicit objective in both programs.**

The programs above are much more "technology" than science. But the same kind of rhetoric and rationalization is sneaking into justification and advocacy of science programs. Thus prominent among the distress noises being directed by American science community to policy makers and the public is that, as a result of cut backs in funding of various

* For a good discussion see Philip Mullenbach, Civilian Nuclear Power, Twentieth Century Fund, 1963.

** See the relevant legislation.

areas of science, the United States lead is being jeopardized.* As in product field or technological areas, the "leadership" rationale in science policy amounts to keying policy to what other people are doing so as to stay ahead of them.

I maintain that the objective of maintaining or achieving across the board technological leadership is not a viable one much less a desirable guide to U.S. policy. And while there may be certain fields where such an objective is in the public interest, this does not seem the case for the SST and power reactors. Similarly across the board "leadership" does not seem to be a viable and certainly is not a desirable objective for "science" policy. The broad objective of maintaining general technological and scientific progressiveness does seem viable, and probably does provide a useful guide to U.S. policy. But the kinds of policies that seem relevant are quite different from the ones we are employing in fields that have been infected by the objective of preserving the gap.

Maintaining across the board technological leadership is, on its face, an arrogant ambition for the United States. Only the post World War II prostration of the other major industrial powers permitted the temporary manifestation of such a phenomenon. The United States long has lived by being ahead on average, but except for the temporary post war aberration always has been a "follower" in many fields, and seems to have survived all right. With the rebirth of Western Europe and Japan, across the board leadership simply is not a viable objective. We do not have the

* For a sample see "The NSF Budget: House Group Reacts to Data on the Flight of Science" Science, 3 April 1970.

resources to push into any technological area where another country appears to be pulling ahead. Even if we could it seems senseless. Surely there are better criteria for guiding resource allocation than that someone else is "ahead" or threatens to be.

It has been argued that civil aviation and power reactors are cases where we not only can but obviously should try to stay ahead. But the arguments do not seem persuasive to me. Surely there is no near term crisis of conventional fuels and energy sources.* Various studies have reached quite sanguine conclusions regarding the energy picture in the short and medium run. While nuclear energy certainly is in our future (given the past fifteen years of AEC spending it is in our present) there certainly is no urgency about the matter. And the available cost benefit studies suggest that the intensive program planned by the AEC for the next 15 years is a poor investment at this time. Similarly there certainly is no pressing need for a SST and this is reflected in its poor performance on a benefit cost test.**

This is not to say that a slower paced more exploratory and sequential program would not be worthwhile. Such a program would yield payoff later, but certainly at much lower costs. As in defense it is the rush that is causing the high costs and, incidentally, requiring Governmental participation in the final product development stage as well as in research and exploratory

* Even the governmental study which has need to justify the program showed this. See Energy R and D and National Progress, USGPO, 1966.

** The semi official cost benefit studies are Atomic Energy Commission Cost Benefit Analysis of the U.S. Breeder Reactor Program, April 1969, and Federal Aviation Administration Summary of Current Economic Studies of the United States Supersonic Transport, September, 1969.

development stage. But why rush? Is the rush justified by the fear that if we don't rush someone will get there before us? The British achieved a jet transport aircraft before us, but, as the present Concord, the Comet was a premature aircraft and the U.S. had no trouble catching up. It is hard to believe that the long run U.S. position will be jeopardized if we do not push through our present SST design, which, while better than the Concord, certainly is a more costly and less efficient aircraft than one we will be able to build five years from now. That we will be in long run trouble if a foreign power beats us out in certain reactor designs simply is not believable.

National policy makers might agree with the economic argument but argue that from the point of broadly defined national interest, if not economic well being, slipping behind in fields like civil aviation and computers is dangerous. This obviously is relevant in fields relating to military technology. But there is more to it than this; as suggested earlier, not being behind technologically in the most revolutionary fields has been, or is becoming, an aspect of national sovereignty. Thus many Europeans who do not believe, or will not profess, that a European strategic capability is needed now, will argue that the option to build one is important in alliance negotiation, and to guard against a change in the world environment. Many Europeans who would agree that in principle, if "reasonable" terms could be assured, it would be far cheaper to buy aircraft, or computers, from the United States than to invest vast sums in R and D, will argue that having the technological capability to produce aircraft and computers given important bargaining leverage to assure reasonable terms,

and guards against future adverse developments. In the United States there is a heavy element of "prestige" on the scales. The notion that best civil aircraft, or computers, are European or Japanese, sticks in the throat of national pride.

But given the rapid increase in technological prowess of Europe and Japan, the objective of across the board technological leadership simply is unattainable. Striving for such an objective would be increasingly costly even if it could be attained, but it cannot. What can be attained, and what makes sense to try to achieve, is general economic, technological, and scientific progressiveness. If experience be a guide, the road to this objective involves assuring a steady flow of well-educated scientists and engineers into the labor force, and broad support of basic science. Certain new departures like Governmental assistance of experimental development also would seem in order. The incredibly successful programs in support of agricultural research, the old NACA model and the earlier more related AEC programs seem promising prototypes. But it would seem very important not to let the defense and recent reactor and SST aberrations set precedence and provide the model for the future.

Now would it seem wise for the scientific and educational communities to latch on to the "gap" arguments, as they appear to have in the past year or so. It is more likely that these arguments can be turned against basic research and education than that these arguments can sustain long run steady support of the necessary kind. Neither "Hindsight" nor "Traces" nor many of the other studies of the relationship between basic science and technological advance provide much support for the argument that a

nation's ability to advance technology in the short and medium run depends much on today's basic scientific efforts. They certainly do not support assertions of the importance of the scientific efforts of nationals.* Indeed so to argue cuts at the very roots of the traditional rationale for public support: That payoffs are long run, unpredictable in terms of specific application, and difficult to "capture". Arguments keyed tightly to technological leadership are far more likely to lead to such programs as the SST than to more support of basic research and education. To the extent that a nation's R and D budget is viewed as a whole (which seems to be a thrust of recent "gap" thinking) a Gresham's law may well exist that Development tends to drive out Research. A softer form of the law is that to the extent research is justified by applicability to particular technological fields where leadership is perceived as threatened, the argument for long run steady support is drowned out by inherently fluctuating and capricious concerns about the gap problem as a whole and the nature of the threatened fields.

Most certainly this is not to argue that support of basic science should be separated totally from interest in solving certain technological problems or opening up certain opportunities. The support of mission oriented Government agencies (and business firms) for basic research in fields and on topics that they regard as feeding into their technological problem-solving ability will and should continue to provide a major share of basic research funding, and will and should play an important role

* First Interim Report on Project HINDSIGHT, Office of the Secretary of Defense, 1966; Technology in Retrospect and Critical Events in Science, NSF 1968; Derek de Sola Price, The Difference Between Science and Technology, Address, Dallas, February 10, 1968.

in determining allocation across fields and projects. But basic research support related to particular technological fields and problems must be justified by the long run importance of the field or problem; a rationale posed in term of crisis management will not have long run credibility. Nor am I arguing that the quality of the nation's efforts and accomplishments in basic science should not be a matter of national pride. But pride in national accomplishments in science cannot be permitted to degenerate into a field by field comparison with the Russians or Europeans or Japanese. Science can stand neither the degree of politization nor the periodic sharp shifts in emphasis that would be the natural implications. Basic science for science's sake, and on the faith, based on solid long run experience, that the applied benefits as well as the uplift to human understanding are considerable, cannot carry the full weight of the argument for strong and steady national support. But these arguments must carry a considerable portion of the weight. It is essential that these traditional arguments not get abandoned and replaced by others that cannot maintain long run credibility.