NOT FOR QUOTATION
WITHOUT PERMISSION
OF THE AUTHOR

HIGH TECHNOLOGY AND INDUSTRIAL POLICY

M.J. Peck

February 1986
CP-86-6

Collaborative Papers report work which has not been performed solely at the International Institute for Applied Systems Analysis and which has received only limited review. Views or opinions expressed herein do not necessarily represent those of the Institute, its National Member Organizations, or other organizations supporting the work.

INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS
A-2361 Laxenburg, Austria

PREFACE

Former economic research at IIASA focused on comparative studies of structural changes in developed countries. The intensity of these changes has serious, and sometimes severe social implications. One area of current concern throughout the world is the diffusion of new technologies with a high potential in substituting labor in manufacturing and services, as well as drastically changing the existing patterns of international trade.

In the process of formulating an agenda for the research within the Technology-Economy-Society (TES) Program, IIASA organized an expert meeting on "Socio-Economic Impacts of New Technologies", which was held in Warsaw, Poland, from 18 to 20 November 1985. Twenty-six participants from eleven countries and four international organizations discussed possible IIASA research in this field and came to an understanding that IIASA can and must contribute to the development of a conceptual framework for analyzing and forecasting the impact of high technology (e.g. robotics).

M.J. Peck, an outstanding scholar contributing greatly to this issue, helped us structure the discussions during the meeting, in particular as a chairman of the final session.

Prof. Peck was a Chairman of the Department of Economics of Yale University and also served as a Member of the Council of Economic Advisors. He worked at IIASA as a Research Scholar within the "Minerals Trade and Markets" Project in 1983 and has been one of the very helpful IIASA alumni in the last years.

This paper, which was presented at the meeting, stimulated the discussions on the macroeconomic problems of High Technology and the final conclusions. We hope that it will also stimulate IIASA staff and other scholars in their thoughts about the very complex problem of industrial policy at a time of high technology diffusion on the industrial sector.

Anatoli Smyshlyaev

HIGH TECHNOLOGY AND INDUSTRIAL POLICY

M.J. Peck*

Contribution to the IIASA Task Force Meeting on
"Socio-Economic Impacts of New Technologies"
Warsaw, November 18-20, 1985

* Merton J. Peck is Professor of Economics at Yale University, New Haven, Connecticut 06520, USA.

INTRODUCTION

My assigned title is so broad that it does not trouble my conscience to limit the topic. One limitation is geographic. I will deal only with five countries - the United States, Japan, the Federal Republic of Germany, the United Kingdom, and France. They are countries I know a bit more about than others, but a more scholarly justification is that these five countries account for 85 percent of the R&D in the 21 OECD countries. Among these 21, the five also are the most R&D intensive as measured by the ratio of R&D expenditures to GNP with the exception of Sweden, Switzerland, and the Netherlands. I look forward to the discussions at this conference to bring out information about R&D in other countries, particularly those that are more centrally planned than the OECD nations.

I. DEFINITIONS AND THE R&D EXPENDITURES

I define the high technology industries as what the OECD calls the engineering and chemical groups. The group titles are not very descriptive; It is more informative to simply list the industries in the two groups. In the engineering group are aerospace, electronics, electrical products, instruments, machinery, computers, motor vehicles, and shipbuilding; in the chemical group are chemicals, pharmaceuticals, and petroleum refining (see Table 1). Surely this is a diverse list, but the industries have in common a high ratio of R&D expenditures to value added compared to other industries. High technology is a good journalistic phrase but the more accurate term would be the research intensive industries.

While it is obvious that R&D expenditures are concentrated in the research intensive industries, it is striking how great is the concentration. Table 2 tells the story: the research intensive industries account for

TABLE 1

The Research Intensive Industries

Engineering Group

- Aerospace
- Electronics
- Electrical products
- Instruments
- Machinery
- Computers
- Motor Vehicles
- Shipbuilding

Chemical Group

- Chemicals
- Pharmaceuticals
- Petroleum refining

Source: OECD Science and Technology Indicators, (OECD, Paris, 1984)

TABLE 2

Percent of Total R&D Expenditures
in Research Intensive Industries, 1979

	Percent of Research Expenditure	Percent of Value Added
U.S.	62.0	16.2
Japan	47.2	11.0
F.R. Germany	62.3	26.7
U.K.	54.6	20.4
France	58.8	18.0

Source: Calculated from data in OECD Science and Technology Indicators (OECD, Paris 1984)

47 to 62 percent of the total R&D expenditures in each of these five nations. I should underline total R&D expenditures which includes expenditures of universities, government laboratories, and separate research institutions. Note also that the concentration vastly exceeds the share of research intensive industries in GNP. These nations are betting much of their R&D on a relatively small part of their economy.

The bets are even more concentrated than Table 2 reveals. Despite all the talk in the United States about the small R&D firms strung along Route 128 outside Boston or the "brain companies" in Japan, R&D in these countries is concentrated in a few firms. In the United States, the twenty largest firms in terms of R&D spending account for 44.2 percent of the nation's R&D expenditures, in the United Kingdom 43 percent, and in Japan 19.7 percent. Indeed, the biggest R&D spenders pay out a staggering amount. General Motors is the biggest R&D spender in the United States (apart from the Pentagon). If General Motors were a nation, its R&D expenditures would rank it ninth among the 21 OECD nations, just behind the Netherlands and ahead of Sweden. The Japanese electronics firm Hitachi would rank with Finland, and the Swiss pharmaceutical firm Giba-Geigy would rank just after Finland. R&D then is concentrated in the large firms in the research intensive industries.

One further concentration deserves mention, though I am not sure how to evaluate its significance. The United States accounts for 55 percent of the total R&D effort of the five nations. But that concentration is simply a reflection of the size of the U.S. economy. If the comparison is by the percent of GNP devoted to R&D, the United States ranks after the Federal Republic of Germany among the five nations; if the comparison is limited to civil R&D expenditures as percent of GNP, the United States ranks after both Germany and Japan.

My talk requires one more comparison. Up to this point I have focused on R&D expenditures, but that is not the same thing as who pays for the research. Table 3 reports who pays for the research conducted by business enterprises. Unfortunately, data is unavailable to show how R&D is financed in the research intensive industries, but these industries are such a large part of all industrial R&D that the results in Table 3 would be a fair representation of the situation for the research intensive industries.

In all five nations clearly two-thirds or more of industrial research is financed by industry from the revenue realized in the market place. The United States stands at one extreme as the nation with the most industrial R&D financed by the government; Japan is at the other extreme with very little so financed. That is in contradiction to the popular stereotype that Japan does much to help its research intensive industries and the United States does little.

The important factor in explaining the differing role of government funding of research in industry is not industrial but defense policy. U.S. defense and space R&D accounts for 78 percent of Federal R&D funds flowing to industry. This explains,in turn, why about 56 percent of Federal R&D funds are spent in the aerospace industry,and Federal funds account for roughly 90 percent of the total R&D expenditures in this industry. A somewhat similar pattern prevails in the United Kingdom. Defense R&D is largely related to specific projects; there is dispute as to how much economic benefit is derived from R&D defense contracts.

If we set aside the special cases of defense, the research intensive industries largely finance their R&D by the revenues they realize in the market. To say more, then, requires looking at how market forces influence R&D. There should also be an analysis of decision-making within the large firm. Economists, however are notoriously reluctant to examine what goes

TABLE 3

Financing of Industrial Research
(Percent)

	Industry	Government	Abroad
United States	67	33	-
Japan	98	2	-
F.R. Germany	80	18	2
France	71	22	7
United Kingdom	62	29	9

Source: Calculated from data in OECD Science and Technology Indicators (OECD, Paris 1984)

on with the firm, preferring instead to rely on the simple assumption of profit maximization on the part of the firm. I will follow that tradition, partly because of ignorance of what goes on within the firm and partly because the operation of the market on R&D itself presents more than enough issues for this talk. In the first part of my talk then I will concentrate on the market and R&D.

But what of industrial policy? And you also have noticed I left that term undefined. Industrial policy is defined here as government actions that influence the high technology industries in these five nations. Even though markets are the important part of the story, industrial policy has its influence largely by affecting the operation of the markets of the R&D intensive industries. If we regard market forces as a stew, then industrial policy is its pepper. The pepper is a small part of the dish, but it can surely influence its taste. The second part of my talk will deal with industrial policy.

II. THE MARKET AND R&D

Economists have tried to explain R&D by using supply and demand framework. Certainly that can be done, but I prefer to stress two other factors: (1) technological opportunity and (2)appropriability.

Technological Opportunity is the ability to use R&D to devise new products that gain great market acceptance and new processes that significantly reduce costs. Technological opportunity exists to some extent for all industries; the question is one of degree. There is some controversy as to whether technological opportunity is endogenous or exogenous to an industry. Clearly it is endogenous in that industry's past R&D efforts create its current technological opportunities. But if we are interested in explaining why some industries are research intensive and others are not, past R&D itself needs to be explained.

It must be then that it is the exogenous factors that give more technological opportunity to one industry than another. We can visualize all industries as starting equal, but some are receiving more free inputs of technology than others.

The current R&D intensive industries have had that status for a considerable length of time and so one single free input, a dramatic scientific breakthrough, cannot be the explanation for their research intensity. Rather these industries must be receiving a continuing stream of greater technological opportunities that keeps them research intensive over many decades. The literature suggest three sources for the free inputs: (1) basic science which is created in universities and research institutes; (2) research from government laboratories; and (3) R&D carried out by users of the industries products. All of these are free goods to the firm. I would stress that these three sources do not provide finished knowledge that can be utilized as an input to further R&D by the industry. Rather they are inputs for the R&D process itself and raise the productivity of R&D expenditures compared to other industries receiving less of the free inputs. Higher profitability, in turn, leads to more R&D spending.

These free inputs are to be distinguished from other sources of productivity increasing inputs from outside the industry; namely, equipment and material innovations that are made by suppliers outside the industry. These, however, are in finished form and so require little or no R&D by the receiving industry. Textiles is an example. Equipment innovations, such as the shuttleless loom, and material innovations, such as synthetic fibers, have raised the productivity of the textile industry without much R&D in the textile industry itself. The distinction is that basic science raises the productivity of R&D in an industry, whereas new equipment and materials raises the productivity of the industry's production.

Appropriability is the ability of the innovating organization to realize the gains of innovation in terms of increased profits. Ever since Kenneth Arrow's pioneering article in 1961, economists have stressed the special role of appropriability in the production of new knowledge. The initial view emphasized the public good character of new knowledge and the related idea of its inappropriability. Innovators would place their new products on the market at prices that would include a return on their investment in R&D. Competitors would observe the new product and imitate them. The resulting competition between the innovators and imitators would drive down the price of the new product and in the process destroy the profits of innovation.

Of course, there would be some returns to innovation arising from the time lag between innovation and imitation. And patents could protect the monopoly position of the innovator. But the point is that generally there is a wedge or difference in the social returns and the private returns from innovation. Competition passes on part of the social returns to consumers, leaving only part to be realized by the innovator. The division between social and private returns, however, will vary between industries,and the research intensive industries presumably will be the ones in which appropriability is the highest.

Empirical Testing would take the form of whether appropriability and technological opportunity can explain the existence of differing research intensities across industries. Both technological opportunity and appropriability, however, are not directly observable. Nor have there been obvious proxies for either technological opportunity or appropriability that can be used to test the role of these two factors in explaining differing R&D intensities.

A team of economists at Yale has created a set of data to represent both technological opportunity and appropriability. The work of Levin and his associates is, I think, important and not as widely known as it should be.

Levin used the survey approach; a method that is uncommon among economists. The essence of the survey approach is to ask economic agents their views rather than to rely on the data generated by economic transactions, which is the more common approach. Good surveys are an art itself; I only list the major characteristics of the Levin survey:

1. The unit of observation was a line of business as defined by the Federal Trade Commission. A line of business generally corresponds to the 400 some 4 digit industries in the U.S. Census

of Manufacturers, and so they are narrower than the industry categories that are used by the OECD.

2. The survey was limited to 688 publicly traded firms, which is a nearly comprehensive list of significant R&D performing firms in the U.S. economy.

3.The respondents were senior R&D executives in a particular line of business,and they were treated as observers of the R&D process in their line of business rather than reporters of the activities of their firm. They were asked to rank their answers to various questions on a scale of one to seven.

The survey scores were used in a multiple regression to explain the dependent variable of research intensity; that is, the ratio of R&D expenditures to sales in a particular line of business. The independent variables were the scores reported by respondents as to the importance of various factors in their lines of business. Table 4 lists the variables that were significant in all the various specifications of the model.

The three significant variables are science base, government laboratories, and the proportion of recently installed plant and equipment in the line of business. Science base was measured by the respondent's rating of the importance of any one of eleven basic science fields to technical progress in his or her line of business. The higher the average score in any of these fields, the higher the value assigned to science base. A similar procedure was used to represent the contribution of government laboratories.

One would expect that greater importance of science base and government laboratories would increase R&D intensity. They are the free inputs into the research process discussed earlier and they serve to make an industry's R&D more profitable. The Levin results then confirm the simple hypothesis of the importance of free inputs.

TABLE 4

Determinants of R&D Intensity
(R&D Expenditures/Sales)

Significant

SCIENCE BASE

GOVERNMENT TECHNOLOGY

NEW PLANT

Insignificant

MATERIAL TECHNOLOGY

EQUIPMENT TECHNOLOGY

USER TECHNOLOGY

APPROPRIABILITY

IMITATION LAG

CONCENTRATION

Source: Adapted from Levin et al, "R&D Appropriability, Opportunity and Market Structure: New Evidence on Some Schumpeterian Hypotheses." American Economic Review, May 1985

It is more difficult to explain the role of investment, defined here as the percent of the line of business investment in property, plant, and equipment installed since 1976. More R&D spending may lead to a higher rate of investment and obsolescence,or alternatively, industries with a high rate of turnover in their capital stock may be better able to capitalize on their current R&D. Still another interpretation is that high R&D leads to more new products and an expansion of sales that in turn requires more investment.

Perhaps of equal interest are the variables that turn out to be insignificant. Three of these are other sources of technological knowledge external to the industry - namely suppliers of materials, equipment,and users of the product. But except for user information, none of these require large R&D expenditures by firms in the industry. Appropriability measures (including patents, lead time, secrecy, marketing advantages) turn out to be insignificant. This is somewhat surprising considering the importance assigned to appropriability in the economic literature. There may well be scaling problems in this variable.

Finally, concentration - the share of sales of the four largest firms - is not significant; a result that tends to contradict previous findings. If only concentration is regressed against R&D intensity, then concentration is significant. But once the measures of technological opportunity are introduced concentration becomes insignificant.

To sum up, research intensive industries are those that have a strong science base, large government contributions to technological knowledge, and a high rate of investment in plant and equipment. Hardly surprising results, but it is well to have them confirmed quantitatively. What remains to be explained is why some industries have a strong science base and others do not. That takes us into the logic and history of science, a subject that remains mysterious to an economist.

Some Other Concepts deserve mention even though they have not been empirically tested,nor do they fit neatly into the explanation of the existence and persistence of the research intensive industries.

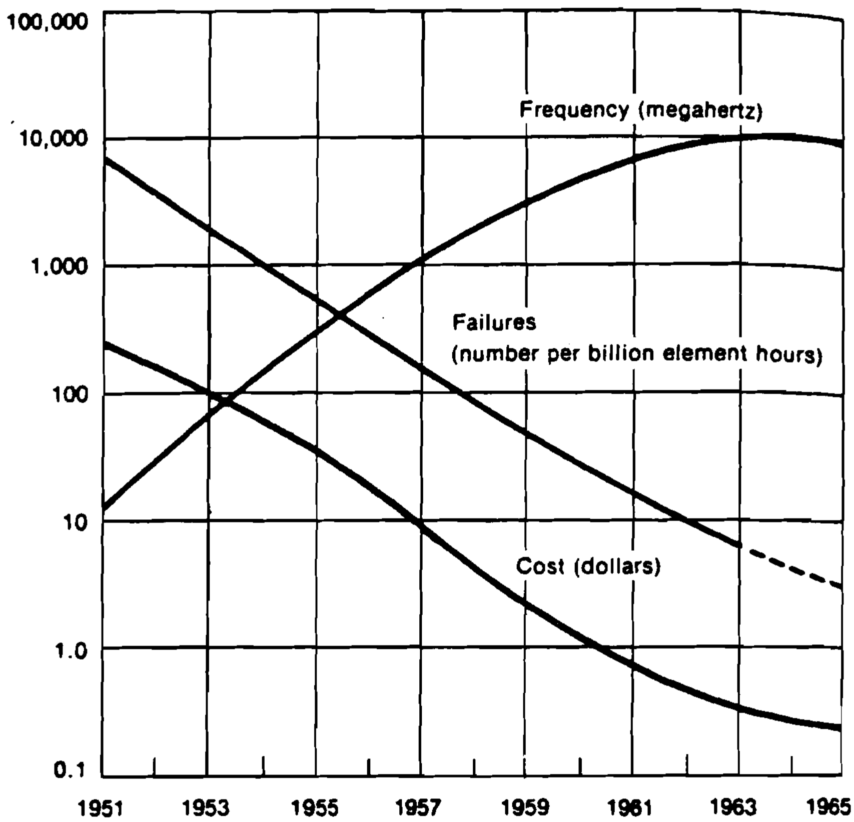
The first of these is a technological trajectory defined as technological progress which proceeds along certain dimensions that, at least in retrospect, appear fairly smooth. Technological knowledge seems to follow a certain path, with one innovation proceeding apparently logically from the preceding invention and building on the knowledge obtained in that innovation. An example would be random access memories in which the trajectory is an increasing capacity of a single chip - from 4K to 16K to 64K and now 256K.

There can be breaks in the technological trajectory; that is, the successive introduction of innovations suddenly begins to follow a different course. An example would be the shift from vacuum tubes to semiconductors in electronics, or the shift from piston to jet engines in aviation. These breaks in technological trajectories make the accumulated knowledge of less value in making further innovations. Perhaps as a result, breaks in the technological trajectories are often accompanied by the entry of new firms. Thus the introduction of jet engines was accompanied by the entry of General Electric and Westinghouse into the manufacture of aviation engines,and the introduction of semiconductors was accompanied by the rise of new firms such as Texas Instruments.

A second concept is that of a dominant product. Economists consider that a product has various attributes valued by consumers. Some products are dominant in some attributes; others in still another set of attributes. A dominant new product is one that is superior to existing ones in every attribute. Table 5 illustrates the evolution of the transistor as a dominant product. The valued attributes are lower cost,

TABLE 5

Transistor Performance



Source: Burton H. Klein, <u>Dynamic Economics</u> (Cambridge, Mass: Harvard University Press, 1977), p.130

fewer failures and higher frequency. Note that the successive transistors gave a better product in all three dimensions. There was no necessity for a trade-off between, say, costs and rate of failure. It is not surprising then that new products supplanted the old ones.

In examining the history of the research intensive industries, it appears that they are characterized by a technolgical trajectory that generates dominant products. I offer this as a hypothesis that may bear further examination.

A third concept is that of adaptive R&D. Such R&D is that required to adapt and incorporate innovations that come from outside the firm or country. The concept of appropriability sketched out previously assumes imitation is costless. But even when the general concepts are known and the product on the market, considerable R&D may be required for a firm to produce a comparable product. Indeed, in Levin's survey, respondents estimate that an imitator's cost for introducing a product is 50 to 75 percent the cost of the innovator. Expenditures on imitative R&D would mean that in industries which have significant innovations there are two types of R&D - that of innovators and that of imitators struggling to keep up with their adaptive R&D. Once innovation occurs, the need for adaptive R&D by imitators might well explain the high research intensity of what has come to be called the high technology industries.

III. INDUSTRIAL POLICY

I will confine my remarks to industrial policy in three of the five countries - The United States, Japan, and the United Kingdom - because I am unfamiliar with the details of industrial policy in France and Germany.

The Gap Between Social and Private Returns.

Economists have contributed only one idea to the discussion of technology policy - the private marginal returns to innovation are lower than the marginal social returns, because the innovator cannot appropriate all the marginal returns of the innovation. The gap between marginal social returns and private marginal returns has a clear policy implication. Firms will spend too little on R&D from the viewpoint of society since their decisions are guided by private returns, whereas the social optimum level of R&D spending is set by social returns.

The pioneering work of Edwin Mansfield of the University of Pennsylvania has provided estimates of the gap between private and social rates of returns for particular innovations. His results, along with those of Tewksbury, are shown in Table 6. Social returns exceed private returns as one would expect. The surprising feature of the empirical work is that social returns are on average three times the private return. Around this average there is a very large variance including those cases in which social returns are negative. The wide range reflects the great uncertainty that characterizes R&S activity.

That uncertainty means that the gap between social and private returns cannot justify a subsidy to R&D generally. The calculations in Table 6 are expost; in advance the policy maker does not know whether the innovation would be like industrial process U, in which there is in fact no gap, or like industrial process T, in which there is a large gap. Policy makers might rely simply on the average to find R&D underspending and hence to

TABLE 6

SOCIAL AND PRIVATE RATES OF RETURN FROM

INVESTMENT IN 30 INNOVATIONS

Innovations	Rate of return in percent		Innovation	Rate of return in Percent	
	Social	Private		Social	Private
Primary metals innovation	17%	18%	Industrial product A	62%	31%
Machine tool innovation	83	35	Industrial product B	negative	negative
Component for control system	29	7	Industrial Product C	116	55
Construction material	96	9	Industrial product D	23	0
Drilling material	54	16	Industrial product E	37	9
Drafting innovation	92	47	Industrial product F	161	40
Paper innovation	82	42	Industrial product G	123	24
Thread innovation	307	27	Industrial product H	104	negative
Door-control innovation	27	37	Industrial product I	113	12
New electronic device	negative	negative	Industrial product J	95	40
Chemical product	71	9	Industrial product K	472	127
Chemical process A	32	25	Industrial product L	negative	13
Chemical process B	13	4	Industrial process R	103	55
Major Chemical process	56	31	Industrial process S	29	25
			Industrial process T	198	69
			Industrial process U	20	20

	Social	Private
Median rates of return	71.0%	24.5%

Source: Column (1): Mansfield (et al) "Social and Private Rates of Return from Industrial Innovations" QJE March 1977
Column (2): Tewksbury (et al) "Measuring the Societal Benefits of Innovation" Science 8/8/80

Note: Both articles used identical estimations and data collection techniques.

justify a general policy of subsidy for all R&D spending. In the three countries R&D has a modest favorable tax treatment, but there has been no granting of general subsidies to R&D.

Civilian Public R&D Spending

Instead, governments have chosen to be selective in the disbursement of public funds to subsidize R&D. Table 7 shows how such spending has been disbursed among various policy objectives. Note that the Table deals only with the spending for civilian purposes. In both the United States and the United Kingdom about two-thirds of government R&D spending is for defense and aerospace. In Japan the corresponding percentage is sixteen percent. Since I wish to focus on the role of government in industrial policy the Table is limited to the distribution of government R&D spending among civilian objectives. That distribution is perhaps a good indicator of how the three governments perceive their roles as promoters of R&D.

All three governments put money in the same set of objectives, but the emphasis varies. Agriculture R&D has a long tradition of government support in most countries, reflecting a view that individual farms are too small to carry out R&D to improve their productivity. One surprise is how much the Japanese government spends on agriculture, but Japan has 10 percent of its labor force in agriculture, about three times the percentage in the United States and the United Kingdom.

Energy research has increased sharply in all three countries since the two oil shocks of 1973 and 1979, but in all three the government was already involved in energy production. Health is also a traditional government concern. The proportion of government spending going to health is noticeably high in the United States, perhaps reflecting the preoccupation of the American public with their health.

TABLE 7

Government R&D Spending by Socio-Economic Objective
Percentage Distribution

	United States	Japan	United Kingdom
Advancement of knowledge	8.5	19.3	36.5
Energy and other intrastructure	40.1	29.8	28.7
Health and Environment	42.9	10.4	11.0
Agriculture	7.6	23.1	12.8
Industry	0.9	17.4	10.8
	100.0	100.0	100.0

Source: Calculated from data in OECD Science and Technology Indicators

All but two of the items listed on Table 7 occur in sectors that have a long history of government involvement as both a regulator and provider of services apart from R&D support. The decision process is not one which searched the entire economy to find where government R&D support would be most productive. Rather, the R&D spending occurred in sectors in which the governments were already involved. R&D support was simply one more measure to promote or improve particular sectors in which the government has long made a general commitment.

The exceptions are research spending for the advancement of knowledge and the promotion of industry. Advancement of knowledge is defined as the support of basic research unconnected with a mission agency. Each country has an agency charged with the general support of scientific knowledge rather than a particular mission, such as health. In the United States, the National Science Foundation, in Japan, the Science and Technology Agency, and in the United Kingdom, the Research Councils are such agencies. Of course other agencies support basic research. Thus in the United States considerable basic research in biology and biochemistry is supported by the health agencies. But the two types of agencies use different criteria to allocate their funds. The science agencies make their decisions by the importance of the research to advancement of science, the mission agencies by whether the research is important for performing a mission objective such as better health or more productive agriculture.

The three governments recognize that the advancement of science is important for technological progress. That view is confirmed by the empirical research cited earlier. Furthermore it is recognized that general scientific progress is not well served by a market system. Appropriability has the most uncertainty and is the longest term as compared to applied research and development. The result is that the industry performs less than a fifth of all the basic research in these three countries.

Instead about sixty percent of all the basic research is performed in universities in all three countries with government laboratories ranking next. And in the universities most of its formal research is supported by the government.

Basic research is most often a joint product with education at the advanced levels, and in that sense universities may be regarded as having a comparative advantage in basic research. Universities by tradition are not engaged in the business of marketing their research; rather they encourage publication of research as fast and furiously as they can. The phrase publish or perish well describes life in what used to be tranquil academic cloisters.

Table 7 shows one peculiar feature about advancement of knowledge: the United Kingdom spends a high proportion of its public R&D spending in this category compared to the United States and Japan. The result may be an artifact of the data. Basic R&D expenditures shown in Table 7 should exclude general university support, that is government spending primarily for teaching. It is easier to make that division in the United States and Japan - countries with a significant role for private universities. In the United Kingdom university support is largely from public funds.

Government R&D to promote industry is the other exception. This objective is used to describe government R&D support with an economic objective to advance technology in the manufacturing industries as opposed to such sectors as agriculture. Table 7 shows the United States is at one extreme of little public funding for such R&D and Japan at the other. The U.S. government takes the position that industry R&D should be carried out and financed by the private sector. Indeed, its reply to an OECD study states, "It is against the fundamental principles of United States policy to give direct aid to industrial technicological development." The small positive entry in Table 7 reflects a few old programs tucked away in odd corners of the Federal government.

Japan represents the opposite tradition. The Ministry of International Trade and Industry (MITI) supports R&D with commercial objectives in both its own laboratories and in industry. Table 7, which shows a large role for the Japanese government and a small role for the United States, seems at first glance inconsistent with Table 2, where the U.S. government has a large share in the financing of industrial R&D and Japan has a small share. The difference is explained by the fact that Table 2 reflects defense spending; Table 7 does not. One other matter; Table 7 is stated in percentage terms,and the U.S. government spending, apart from defense, is eight billion dollars; the Japanese government spending is about five billion dollars. The difference then is not that large in absolute terms. More specifically, the Japanese government spends about 450 million dollars on the promotion of general industry R&D; the U.S. spends about 92 million dollars.

Still it is important to recall that the Japanese government expenditures are only about four percent of all Japanese industrial R&D. The small percentage still may give the Japanese government considerable influence over the general direction of R&D. This influence may be reflected in the publication which MITI plans, <u>Visions</u> of future R&D priorities. The current <u>Vision for the Eighties</u>, foresees Japan as a "technology based nation." MITI R&D support is now and will be even more so focussed on three broad fields:(1) materials, (2) biotechnology, and (3) information processing, including computers and integrated circuits.

Japan represents the opposite tradition. The Ministry of International Trade and Industry (MITI) does support R&D with commercial objectives in both its own laboratories and in industry. MITI has published the Vision of the Eighties, which foresees Japan as a "technology based nation." MITI R&D support is now and will be even more so focussed on three broad fields: (1) materials, (2) biotechnology, and (3) information processing, including computers and integrated circuits.

Information processing is the one field in which MITI has been active for some time. Its best known program is the Very Large Scale Integrated Circuit program (VLSI), which existed from 1975 to 1979. Its principle features illustrate the distinctive Japanese approach to government support of R&D. These are (1) the organization of a research association composed of five large Japanese manufacturers of integrated circuits. The research association holds patents derived from the project, distributes the research results, and plays a key role in the governance of the project. By its ability to grant and withhold subsidies, MITI has a veto over association decisions. (2) The research itself is generic, that is, to solve common problems in designing and producing very large scale integrated circuits. The development of specific products is left to the research organizations of the companies and is company financed. (3) The funding for the research done under the project itself comes partly from the government and partly from the companies. (4) The project research is done largely in two group laboratories and by researchers assigned by the companies from their staffs. At the end of the four year project researchers return to their companies, and in this way facilitates the transfer of technology.

Such an R&D organization is a blending of private and public R&D in its financing and a blending of individual company and joint R&D. The VLSI program is considered to have a good record of research achievement.

Its success has attracted considerable attention in the United States, and has raised questions as to whether such organizations would be valuable in the U.S. context. While a novel organization, the VLSI program took place in the context of a semiconductor industry that was simultaneously carrying on a high volume of privately financed R&D. Even at the height of the VLSI program about 85 percent of the R&D was privately financed outside of the VLSI program. The Japanese production and export of integrated circuits has increased notably since 1976. It is difficult, however, to distribute the gain between contributions of the VLSI and similar programs and the privately financed R&D.

Does Industrial Policy Matter?

There is debate as to whether the explicit measures of industrial policy directed at R&D matter all that much for the technical advance of an economy. One factor that may count for more is educational policy. Japan has recently been highly successful with its high technology industries, particularly in integrated circuits and computers. At the same time Japan has increased significantly its supply of electrical engineers. In the mid sixties both the United States and Japan had 80 electrical engineers per million of population. By 1977, Japan had 185 electrical engineers per million of population and the United States had 66. From 1969 to 1977 the number of Japanese electrical engineers who graduated annually doubled; the absolute number in the United States stayed constant. If one takes the view that engineers are the footsoldiers of technological advance, the educational policy that generated more engineers is a distinct asset to technical progress, perhaps of more importance than the measures MITI has adopted.

Let me return to the point that I made at the outset - that most R&D in the five countries is by private companies with their own funds.

As a result, the technical change these companies generate is influenced primarily by market conditions rather than government policy directed at either technical change or the specific industries. Again we must make an exception for sectors in which government involvement is extensive: aerospace, agriculture, health, and energy.

For the remaining sectors, the importance of markets does not mean that government policy is unimportant, but that government policy works through its impact on markets. The policy measures that matter, however, may not be those of industrial policy, but those of general economic policy. Under this heading belongs fiscal and monetary policy, trade policy, tax policy, and antitrust policy, and even labor relations. These policies are set largely by objectives that are far from the promotion of R&D or the high technology industries. Yet they have a major impact on those industries. High technology industries seem to thrive only in a thriving economy. Japan's success in the high technology industries may owe more to the fact that its economy has done much better than other OECD economies than it does to specific MITI policies. And the United Kingdom's relative failure in the same industries may be laid more at the door of its macropolicy makers than at the door of its Ministry of Technology.

This is a speculative conclusion. I began my talk with the stew and pepper analogy. What we still do not know is whether industrial policy represents just a pinch of pepper in a bland stew or the teaspoon of pepper in a pepper pot stew in which pepper is the dominant ingredient.

REFERENCES

This paper is based in large part on my previous publications, which are admittedly dated. For the United States see Richard Nelson, Merton J. Peck, Edward Kalachek, Technology, Economic Growth and Public Policy (The Brookings Institution, 1967); for the United Kingdom, Merton J. Peck "Science and Technology in Britain's Economic Prospects, (Richard Caves, ed., The Brookings Institution, 1968); for Japan, Merton J. Peck with Shuji Tamura, "Technology" in Asia's New Giant, How the Japanese Economy Works (Hugh Patrick and Henry Rosovsky, eds, The Brookings Institution, 1976) and Merton J. Peck and Akira Goto, "Technology and Economic Growth: The Case of Japan," Research Policy, October 1981

The data in this paper are largely from the Organization for Economic Cooperation and Development, OECD Science and Technology Indicators: Resources Devoted to R&D, (OECD, Paris 1985). The statistics are usually for the years 1979 and 1980. Comparisons of R&D expenditures among countries have been made with the use of purchasing power parity exchange rates.

The survey by Levin and associates is described in Richard Levin, Alvin Klevorick, Richard Nelson and Sidney Winter, "Survey Research on R&D Appropriability and Technological Opportunity" Working Paper, Yale University, July 1984. The regression results used in this paper are reported in Richard Levin, Wesley Cohen, and David Mowery, "R&D Appropriability, Opportunity and Market Structure: New Evidence on Some Schumpeterian Hypotheses," American Economic Review, May 1985.

Finally for a more complete discussion of public policy in all five countries, I recommend Richard Nelson, High Technology Policies: A Five Nation Comparison (American Enterprise Institute, 1984)