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IMPRESSIONS, OBSERVATIONS AND COMMENTS ON SCIENCE & TECHNOLOGY IN JAPAN

by

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Introduction:

This paper reports my recent experience as a Fulbright research scholar affiliated with the Department of General Systems Studies, University of Tokyo, between September 1986 and May 1987.

The Fulbright program in Japan is administered by the Japan-U.S. Educational Commission. In 1986, twelve non-academic professionals were supported from the U.S., as part of their cultural exchange activities which recently celebrated its 40th anniversary year. Since 1982, some 36 Americans have been supported by local funds contributed by Japanese Fulbright alumni. I was fortunate to have received one of the awards.

In September 1986, I began a nine-month leave from NSF, as a professional developmment assignment, to undertake an original research project in Japan. The investigation inolved a comparative study of Japanese and U.S. high-technology transfer policies, particularly regarding the utilization of university research in three fields: robotics, biotechnology, and advanced ceramic materials.

I had read that former attitudes about technology transfer were beginning to shift; that in some applied fields, like robotics and ceramics, the Japanese were now beginning to innovate and to export their latest technology.

Beside the specific aim of studying Japanese technology transfer processes, I found this period of time in Japan to be very rewarding. For years I admired the Japanese people. From centuries of isolation, through the Meiji reformation period and the post-war occupation, the Japanese have a long history of adopting and improving upon ideas from the West. But it is only recently that they have become a major world economic power. The so-called "Japanese miracle", I was to learn, has many dimensions including some unique economic and cultural factors, which are described below.

The investigation in Japan also provided me a unique opportunity to witness a larger dynamic; how Japanese society works and how Japanese people think. In daily life, I was exposed to countless situations where the traditional culture and modern ways coexist without conflict. And in my work, I also saw how some of leading companies develop their new technology, while being allowed personal interviews with key researchers to trace through some of their research networks.

This experience was a revelation; it provided an eye-level view of how modern Japanese society works, how its technology policies are carried out, and some of the different institutional arrangements used to produce highly effective research collaboration within Japan.

I hope to use this experience, not only to help interpret Japanese science and technology policies in a more timely and realistic fashion, but also to add some appreciation for the unique qualities of the Japanese people, their society, cultural traditions, and the broader aspects of Japan's growing international role.

Initial Observations

During the nine-months in Japan, I kept asking myself just what makes the Japanese so effective at doing some things, what are the things they do so well, and why do they do things differently from the way it is done in the U.S.

When interpreting the differences between the U.S. and Japan, I believe it important to view Japanese policies, instituions, and behavior from a cultural perspective. This is so one can understand that what works well in the Japanese context may not be so effective in ours. I realize, too, that some of what I observed may not be news to other people, but may nevertheless be interesting and hopefully useful in confirming their own impressions.

Science & Technology in Japan

The distinction between "science" and "technology" in Japan is not as clear as in the United States. It is hard to differentiate "applied research" from "new-technology development" in Japan. My impression is that most of the "basic research" comes from foreign sources, that academic science in Japan is primarily for teaching graduate students, and the "research", per se, which is performed by university professors is far removed from current industrial interest.

I also observed that research done in industrial companies is typically user-driven rather than investigator-inspired. Research in new technologies is performed by multi-disciplinary teams, rather than by single discipline groups, like only electronics or mechanical engineers. And the same research team seems to take the new product further through the development process.

In contrast to the kinds of scientific research performed in the U.S., most of the research I observed in Japanese universities can more accurately be described as "fundamental engineering sciences." This usually is done in groups, rather than by individual investigators, and consists mainly of experimental verification work. However, there are a few senior professors doing some good theoretical work at the more basic end of the research process.

My Research Activities in Japan

For my first month in Japan, I was fortunate to be invited by Prof. Fumio Kodama to stay at the Graduate School for Policy Science at Saitama University, one hour's ride from Tokyo. There I learned of three conferences, which later I attended. The first was a European science policy group on the structure of basic technology research, the second was the joint I.R.I./JATES (Japanese Association of Techno-Economic Societies) meeting which included site visits to three industrial research laboratories and several discussions with senior R&D executives. The third was the annual meeting of the Japan Society for Science Policy and Research Management. This recently formed, 500-member organization of academic, industrial, and govenment R&D policy people was extremely helpful for obtaining personal introductions during my subsequent affiliation with the University of Tokyo.

The high-technology areas which I investigated while in Japan are more closely related to engineering in the United States than to basic scientific discovery. The researchers interviewed at the universities were mainly from the engineering faculty, while the industrial researchers were working in what they term, "basic technologies" or "advanced research."

My research work involved an survey of Japanese university and industrial researchers who were currently working in the fields of robotics, biotechnology, and advanced ceramic materials. Interviews were arranged for and conducted at twelve universities, nine companies, and at six government organizations. The questions focused on the role of the individual researcher in the technology transfer process and the actual way the work was performed. The object was to identify the specific linkages between each researcher and his professional colleagues at universities or in other R&D organizations within Japan or abroad.

A preview of my findings shows that, for the three fields surveyed, there is a remarkably high degree of technical communication and collboration going on between researchers at the leading Japanese universities and their colleagues who work in competitive companies. Moreover, a majority (65%) of those who were interviewed said they had spent a year or more abroad at either a U.S. or a European university. Nearly sixty percent reported presenting papers at some international conferences during the past two years, while about half (58%) had applied for patents within the same period. I was also struck by the keen awareness that most Japanese researchers have about the work of leading people in their fields.

Regarding patents, there is a remarkable increase in the amount of university patent activity since 1980, reported to the Japan Society for Promotion of Science (JSPS). Although the numbers are smaller than those for U.S. universities, the JSPS data shows an 80% increase in the number of patents issued to universities between 1981 and 1986, and nearly a three-fold increase in the licensing of them during the same period. This increase appears to reflect the recent shift in the patent policy of both countries (between 1978 and 1980) which authorized universities and research laboratories to promote inventions resulting from government-funded projects. Both Japan and the U.S. now have programs inplace to assist university professors transfer their inventions to commercial use.

During the next several months, I hope to be able to analyze my research findings and also to make a short comparative survey of researchers at several leading U.S. universities and industrial organizations. The purpose is to trace the primary transfer paths within the same three high-technology fields in order to compare the effectivness of U.S. and Japanese research networks in utilizing the results of university research for industrial use.

Physical and Economic Environment

One of the first things that struck me was the relative size of the country. Japan consists of a 2000-mile chain of islands, with much of its population concentrated in one megalopolis on the largest island, Honshu. The latitude of this chain is equivalent to the stretch between Vancouver and Los Angeles. The climate is cold and dry, in the winter, and hot and muggy during the summer. But the fall and spring weather is very comfortable.

The area of Japan is less than the size of Montana; the total population is about 120 million, or half that of the United States. However, some 75% of that area is either uninhabitable or non-arable, so that a population half the size of that of the United States is crowded into an area about 25% of the state of Montana. This gives some idea how closely packed together are the people who live and work in Japan.

In comparing Japan's economic productivity to that of other industrialized nations, in terms of GNP per area of arable land (OECD data, 1979), Japan comes out ahead; with West Germany only half that of Japan, and the U.S. about one-twentieth (.05) the productivity/per sq. km. of arable land, as does Japan.

The dominating factors in Japan's economy are: 1) its lack of natural resources, 2) its determination to compete in international markets with high value goods, and 3) its utilization of technologies obtained from the West.

Japan must import all its raw materials and more than 85% of its energy. Thus, Japan mainly manufactures end items which are of higher value than the imports, and exports these finished goods to world markets. It is no wonder that Japan has totally embraced advanced technology, and is now making some efforts to achieve world leadership in some of the high-technology areas.

Areas of Excellence*

What do the Japanese do differently? First, they are good at reliable manufacturing at low prices. They are good in converting raw materials such as imported coal and iron ore into steel, much of which is exported. And they do not hesitate to build more modern plants before older plants have reached their service life, when efficiency or manpower savings can be attained.

There are at least two reasons why Japanese manufacture has good quality, is reasonably priced, and delivers a reliable product. One has been implied; that is, automation in the manufacturing process. When one visits the Nissan Company's Kurihama manufacturing plant, hardly a dozen people are on the floor of the plant. Contrast this with the mass of humanity in the usual assembly plant in the United States. Moreover, my experience in observing how people build automobiles in Japan indicates how far the automated production process actually extends. The assembly line is computerized to provide for all models with all the options (in terms of color, upholstery, and equipment) so that any order can be punched into the computer.

An additional wrinkle is that the computer controlling the assembly line is so programmed as to allow for automobile variations that are required by the laws of individual countries, and in our country, the individual states. For example, if one orders a car to be driven in California, not only does the computer-controlled assembly line place the steering wheel on the left-hand side, but it also supplies the car with a catalytic converter.

Another characteristic of Japanese manufacture is extensive and complete product testing. One thing said about Japanese mentality is that it is unable, unwilling, or inexperienced in dealing with the ideas of statistical sampling. A concept, such as "95% safe" or "3-sigma confidence level," does not seem to covey the same meaning to the Japanese as they do to us. To them, a product is either 100% fit for consumption or use, or it is not. And in that case, it is not sold.

The same attitude in dealing with statistics carries over into the use of sampling for product testing. In the U.S., we are in the habit of taking every tenth or hundredth product off the line and testing it, assuming that if every hundredth product tests out all right, then the asembly line must be operating well and each of the intermendiate products is fit for sale.

Spot checking is not done in Japan where every product coming off the line is tested. Such absolutism my seem strange to us, but it fits well within the Japanese character. Moreover, as we have seen, it results in a more reliable product for the marketplace and has led to much of the success the Japanese have attained commercially.

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* Rudolph J. Marcus, ONR Bulletin, (March 1984).

R&D Planning and Funding

In observing what the Japanese do differently, I first mentioned reliable manufacture at good prices. A second item is that the Japanese do industrial R&D planning and funding differently than we do it. In the U.S. it is usual for one kind of individual, the basic researcher, to do the fundamental work and to publish his or her findings in the open literature or as a patent. From those publications in the primary literature, the applied research community picks up new knowledge and basic ideas which it considers to be promising, carries them through the applied research, and again publishes the results either in the journal literature, as a company report, or as a patent.

From the pool of new technology, the industrial development community picks out its most promising projects, and so forth; each type of R&D work being done by a different kind of scientists or engineer, with some kind of intermediate publication point. This step-by-step R&D process also makes it easier to track the kinds and amount of basic research, applied research, and product development work being done in our country.

By contrast, the Japanese usually have one team of researchers carrying through a particular project, from the initial research, through development, prototyping, and even on to production. It makes it hard to track the process of technolgy development in Japan, because there are no intermediate publication points. On the other hand, being so closely associated with one particular item or development project gives the Japanese researcher a tremendous sense of pride and attachement to the final product, which is highly motivational.

What does the Japanese journal literature consist of, if there are fewer intermediate publication points between research and the final manufactured product? And what is presented at meetings of the Robotics Society of Japan or at the Japanese Chemical Society?

The Japanese journal editors do not appear to insist on publishing only original work. There are many progress reports as well as reports on setting up and testing methods of experimentation which may have been published elsewhere. This is related in part to Japanese feelings about originality, which are quite differernt from ours, and in part, to Japanese research funding practices, particulaly in universities.

The fundamental research unit in a university is the "koza", or chair. It consists of one professor, an associate or assistant professor, one or two research assistants at the doctoral level, and two or three graduate students. With a minimal proposal each year, each koza is granted sufficient money to buy moderate supplies, but not much else. Travel money for international travel must be obtained separately, most often from industrial sources. Research equipment is usually home-built; otherwise funding for equipment also needs to be obtained separately.

Thus, much of a graduate student's time is spent building and calibrating test apparatus, much of it jerry-rigged from odds and ends. The quality of the results obtained in this manner, as well as the ingenuity and persistance shown in constructing the apparatus is truly remarkable. Exceptions to this situation are found in the four national research institutes, north of Kyoto, which are showplaces and have modern equipment. Another exception is the University of Tsukuba, about 40 miles from Tokyo, where the government has created a "science city" and has relocated many of its national laboratories.

The ties between universities, industry, and government are very strong, although often informal. For example, many career government employees in technical fields are offered high-ranking industry positions after an early retirement from government service. Similarly, there seems to be frequent changes between positions in industry and in the private universities by professors, deans, and directors of research. A very recent policy change now permits national universities also to participate in such R&D management exchanges.

Antitrust laws in the U.S. have required each competitive firm to carry on its own industrial research. Technical cooperation is not only limited, but actually forbidden by law. Things seem to be different in Japanese industrial research, where often the government promotes the formation of research consortia between the four of five leading companies in a particular field for purposes of developing new advanced technologies. Patents resulting from this arrangement go into a patent pool for all participating companies to use.

This system of national research projects has been widely used in Japan, particularly for promoting the semiconductor and the computer industries. By organizing research consortia, government direction and support is given to stimulate industrial R&D outside the usual project grant route. (Just imagine what such government-sponsored civilian research collaboration could do for some of our industries where individual company resouces are not large enough for a really large-scale R&D project).

Research Disciplines

Thirdly, what kinds of research are the Japanese good at? In chemistry, the Japanese seem to be good at organic synthesis, particularly for polymers and pharmaceuticals. They are also very innovative in non-stochiometric materials such as those used for ceramics and for magnets. In biotechnology, they are very active in the isolation and characterization of natural products. And obviously, they are also good in the fields of integrated circuits and robotics.

What is it in the Japanese culture that leads to excellence in a very few areas and in those fields in particular? One factor is the well-known Japanese respect for seniority, or the hierarchical structure of Japanese society. One of the most important references it any university is a volume which lists all of the professors in that university in order of their birthdays. This was obviously the order of their seniority, no matter how much they had published or what the quality of their publication was.

Regarding seniority, it appears that generations of graduate students will reproduce, with minor refinements, the work of their elders who have been successful in one field or another. With such a model, it is only natural that fields of research will be chosen in which only minor changes in established experimental procedures are going flourish. Organic synthesis, for example, particularly for natural products, is such a field in chemistry. The other fields mentioned: ceramic materials, robotics, and integrated circuits, are also of that character.

This is coupled to a very subtle part of Japanese culture which is open to detection but not often spoken about by the Japanese. A strong admiration for a few subjects pervades Japanese tradition; perfection is sought by imitation rather than by innovation. I found the clue to that in a book about Japanese brush painting. The introduction described the Oriental artist as having "little desire to depart from the main stream of tradition. Quality, not originality, is a mark of worth."

Making changes on well-established ground is admired, but plowing new ground is not. This attitude about originality is found in Japanese tradition. This is the reason why one sees only a very limited number of subjects in Japanese art and what may seem in our Western eyes to be a copy or almost a print, rather than an original, is to the Japanese an original of an approved subject which has been painted by many hundreds or thousands of artists over the years.

Japanese themselves refer to this attitude as a template mentality, one which prefers to follow a pattern rather than to break new ground. Please note that I am not saying that the Japanese are incapable of original thinking, or that a lot of original work is not being done in Japan. What I am trying to say is that great departures from established patterns are not appreciated in Japanese culture. In Japanese, the term "learn" (manabu) comes from "imitate" (manebu).

It is much the same in science in Japan: quality is much admired while originality is not. It is said that Hideki Yukawa, one of the few indigenous Nobel Prize winners, was completely looked down upon by the Japanese establishment because of his originality until the moment he won the Nobel Prize at which point he was suddenly respected.

Creativity is another example of an attibute which, in America, resides in the individual, but in Japan is found in the group. Thus, for Japanese science and technology, group innovation may take the place of individual creativity.

Another difference in Japanese research is the lack of Cartesian logic in Japanese philosophy or science. By Cartesian logic, I mean the philosophy of Rene DeCartes. This is the logic of reductionism which is the very basis of the western scientific system, but is not typically practiced in Japan.

As nearly as I can understand it, the Japanese way of solving problems, whether those of human relations, economics, or science, is to handle the problem as a whole, and not to subdivide it into its parts for easier understanding or handling. I asked more than once what happens if you do not understand or cannot handle a whole problem in its entirety. I was answered with a look of wonderment: "Of course then we just lay that particular problem aside and find a problem that is soluable by our methods."

I have commented on three things the Japanese do differently: one is reliable manufacture at good prices; a second is research collaboration; and the third is the kind of scientific research the Japanese are good at. I would like to add a few general remarks about cultural factors related to my experience in Japan.

Some Related Factors

It is said the Japanese people are highly homogenious by contrast to the Amercican population which came from many more diverse sources. But in the mid-1800's, Japan was more a collection of diverse fiefdoms than a single culturally unified nation. Ezra F. Vogel notes that Japan has become an homogenious country not only because of the new national media, like radio and television, but also because there is a common core of culture which has been transmitted to virtually the entire population.

"This core reduces the danger that cleavages will disrupt the social fabric and increases the chance that the populace will work together and pull together when the national interest requires it. Japanese homogeneity did not result from tradition alone, it was created and maintained by social policy, and eductional policy is one of the pillars of this social policy." *

Educational System

The Japanese educational system, like so many other things in Japan, is highly structured. At its peak is the University of Tokyo Law School, from which most of the top government administrators come. One strange things in Japan is to find mid-level or top-level administrators, even in the technical ministries, such as the Ministry of Health, not being professionals in their own science, but being graduates of the University of Tokyo Law School.

The examinations which regulate a student's admission to various steps in this rigid educational structure, and which determine the quality of the school the student may attend, are very fact-centered, and do not seem to encourage original thinking. There are several government reforms under discussion to remedy that, but it might take a long time to bring about real changes.

Politeness

Secondly, let me comment about Japanese politeness. Almost every visitor to Japan mentions the formal system of interaction which he notices among the Japanese and interprets by Western standards, as politeness. It is certainly true that any society which lives in such crampt conditions, as those which I described at the beginning of this paper, is going to develop a very elaborate system of social interaction. This system has been polished and purified for thousands of years and is in part a function of the hierarchical structure of Japanese society.

This "politeness" leads to a good deal of indirection in one's dealings with Japanese. When they say "yes," it means "maybe," when they said "maybe," it is translated into "no," and "no" is a word which the Japanese never use.

There is another side to this coin of politeness. The Japanese code of politeness is limited to a hierachical structure where the people involved know the people on their own and adjacent levels. The moment they get into a situation where they are among strangers, they may behave differently. Anybody who has walked into a Japanese subway station at rush hour will know what I mean. The amount of elbowing is quite remarkable for a supposedly polite society. But this may be true only when among strangers.

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* Ezra A. Vogel, Japan as Number One, Chas. E. Tuttle Co., Tokyo (1980).

Another component of politeness is friendship. It is well known that the Japanese are not only polite to visitors, but are also helpful and friendly. There were many times when I was given help and guidance in the streets in Japan. Friendship, however, is a part of that hierarchical structure mentioned earlier. It involves some of the most elaborate parts of Japanese politeness and ritual.

For example, not only does a guest bring a gift, but also the host gives a gift to each guest, and there are strict rules about the kinds and costs of such reciprocal gifts. Americans are generally excused from following these rituals on the grounds that they cannot be expected to master them. The same reasoning applies to language. (Japanese people are always surprised by even the most basic Japanese spoken by an American.) With such strict codes, friendship is a lifetime investment in Japan, an investment not readily extended to non-Japanese.

Language

A third comment which I wish to make concerns the Japanese language. Japanese uses the Chinese charaters, rather than an alphabet, of which some 2000 or more are required to read a Japanese newspaper, more for college studies. In addition to that difference, we must realize that these kanji characters are symbols which may have many meanings. In terms of structure, Japanese language is also quite different from English. It is a language in which there are no articles for the nouns, no difference between plural and singular, and no gender, he or she. This perhaps accouts for some of the familiar results when Japanese first try to speak English.

Japanese children seem to learn English at an early age in school. However, they learn it from people who themselves had no experience in speaking English. Therefore, while Japanese find it possible to read English, they have great difficulty in oral conversation. This has caused a flourishing trade in which all manner of English-speaking visitors are being paid by parents and by private companies to give English lessons that are really conversation lessons.

Management

A last general comment I wish to make is about the large amount that is written lateley about Japanese methods of running organizations and Japanese methods of decision-making. What I observed closely resembles what author William Ouchi of UCLA calls, "Theory Z." One of the main features of Japanese society which Ouchi reports as being necessary for success is the great trust that exists between superiors and those who work for them. The trust extends both ways and, as Ouchi remarks, "unless that trust is present almost any scheme of decision-making is going to fail."

One of the greatest inventions of Japanese industry is the "quality circle," where five to ten workers meet almost daily to discuss possible improvements in the manufacturing process. This may not do as much good in the U.S. as they do in Japan, where they serve to give group sanction to innovative departures from the old ways of doing things.

Technology Transfer and Cooperative Research*

If one asks how the Japanese achieve such effective technology transfer between laboratory and production, certainly one answer is that they hold many meetings on an industry-wide basis. There is not just technology transfer within a company, in Japan, but between companies and companies and universities through the many meetings of the various professional societies.

The topics discussed at many of these meetings include much more technical content and detail than is common in the United States. In addition, all major research laboratories become familiar with the work at other laboratories resulting in rapid dissemination of new results and less duplication of effort. The meetings also permit the Japanese to communicate knowledge of work outside of Japan very effectively.

I do not believe there is such a system in the United States which pools, analyzes, and disseminates information on international research activities as effectively as the Japanese system does.

There are a number of reasons why the Japanese meetings system works. One is the strong leadership of the university professors who serve as committee chairmen. There are strong ties between these professors and their former students that do not exist in the United States. And there are greater personal links to old acquaintances in Japanese society as compared to American society.

The Japanese Old-Boy Network

This process was described by several speakers at a seminar on high-tech competitivness held by the Japan Technology Transfer Association in Tokyo. That discussion helped to crystalize what I discovered from my two-dozen interviews.

Japanese industry has two powerful assets: a cohesive national policy on technology development, funded by the government, and a scientific "old-boy network," with links to every board room and laboratory in the country. The government spends nearly one-third of its R&D budget at universities and at government research institutes, and nearly all of this activity is centrally coordinated through government committees and the scientific old-boy network.

Here is how the two circles of power work. Perhaps you noticed that Japanese companies seem to sell similar products. So much so that it looks like they must be collaborating on the designs and specs. That is because "high-tech" Japan is a small country and all the engineers at the companies know each other. For that matter, so do the company presidents, who most likely went to same university together. When one company starts something new, the presidents call each other to discuss it. And Japanese companies do not suffer from the "not-invented-here" syndrome. Instead, they are eager to please their customers and would rather get their people involved in making something better for the marketplace.

Many foreigners imagine that government officials at the Ministry of International Trade and Industry (MITI) stand over the R&D stage like grand puppeteers, manipulating private industry at will. This is not the case, because the average MITI officer changes jobs every two years.

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* Thomas W. Eagar, ONR Far East Scientific Bulletin, March (1985).

MITI's method is its "committees." A mixture of industry leaders, academics, and consumers (users) are selected for dozens of committees on new technology and industry matters, ranging from restructuring a weak industrial sector to organizing a national program for advanced robotics or for manned spaceflight.

Through committee debate, MITI helps industry to form a consensus on which technology areas it should be concentrating. It also determines its own policy on the allocation of R&D funds in this way. By this "committee method", policy is actually negotiated by the leaders of industry, so it is accepted naturally by all the companies. That is the secret of Japan's cohesive industrial policy; the government acts as organizer and coordinator for private industry action.

MITI also has another advantage. It maintains its own research facilities similar in the United States to DOD, DOE, NASA and the Department of Commerce. Their Agency for Industrial Science and Technology (AIST) this year has a budget of some $700 million, which is distributed among 16 national laboratories. Japanese industry does not consider MITI to be a major source of research funds, since nearly 80 percent of Japan's R&D is paid for by the private sector.

Conclusion

In reporting some of the impressions and observations from my nine-month stay in Japan, I wish to convey the sense of admiration I felt while living in the Japanese society and trying to understand the principal reasons behind its incredible success in transforming science into technological innovations.

Although the pace of working at times rather exhausting, the experience of living among the Japanese people, for my wife and I, was extremely worthwhile.

We hope to continue the many professional and personal relationships which were initiated during this assignment and to share what has been learned with others interested in Japan and in this area of science policy research.

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