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COMPARATIVE STUDY OF THE TRAINING, CAREERS, AND ORGANIZATION OF ENGINEERS IN THE COMPUTER INDUSTRY IN THE UNITED STATES AND JAPAN

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Introduction

The purpose of this research is to identify the similarities and differences between Japanese and U.S. engineers in high-tech industry in terms of their training, careers, and research organization. The basic questions we posed at the beginning of the research are the following two: what are the similarities and differences in engineers' careers and the way their research and development activities are organized in Japanese and U.S. high-tech firms, and what are the implications of those similarities and differences for Japanese and U.S. firms.

To provide background information for our study, we tried first of all to find the relevant materials which were available easily and found that published materials about the management of Research and Development in Japan were few. Both scholarly and general interest in the United States-Japan comparison has been concentrated on the management of the firm and on the blue-collar organization. Relatively little attention has been given to the more technical side of the firm.

We planned, then, to compare the training and careers of engineers, the organization of research projects, and the management of the research process in R&D in the computer industry in the two countries. The computer industry was selected as typical of high-tech industries.

Problems

Japanese firms have emerged as key global competitors of major U.S. firms across an ever-expanding range of product lines. There is a widespread perception that whereas U.S. firms have an edge in invention, the Japanese firms are more successful in embodying innovations in products and moving them into the marketplace. In consequence there is growing interest on both sides of the Pacific in identifying the factors underlying these competitive advantages. Japanese firms are eager to improve their capacity for invention while U.S. firms want to improve their linkages between design and manufacture. Firms on each side would like to learn how to incorporate the advantages of the other without sacrificing their own.

There are two ways to do this. One is to identify the key factors producing one's competitors' advantage, and then to emulate those within one's own organization. The second is to internationalize: to set up research and development facilities in one's competitors' home bases and tap directly into the competitive strengths of their society's engineers and organization. Both U.S. and Japanese firms have been quicker to adopt this second strategy than to undertake the first, although developing research facilities in Japan or in California may be the first step in the process of emulating the more successful features of one's competitors' research organization.

Each strategy—emulation and internationalization—has potential dangers. The first entails great risks if too few of the structures and processes of the Japanese firm are adopted —or too many—without a clear understanding of how they operate in the original context or of how they will relate to one's own organization. The second will falter if the firm unwittingly impose its own model on the new facility, thereby eroding the very advantages the firm is trying to capture. Avoiding either set of dangers requires a clear understanding of the differences and similarities of the R&D activities between Japanese and the U.S. organization.

Our research has so far revealed many differences between the two countries. Differences were especially marked in recruitment, personnel administration, and career orientation. Based on a large number of empirical findings described below, we made the following generalization:

The differences in characteristics of R&D activities between U.S. and Japanese computer firms are not partial but systematic. Many variables contribute to the overall differences. Those differences, as a whole, show a certain pattern or gestalt. They are systematic, structural, and institutional, rather than personal.

We will elaborate this conclusion by showing our major findings.

Research Methodology

The data have been drawn from interviews and questionnaires conducted at three Japanese firms in the computer industry (Toshiba, NEC, and Fujitsu) and three U.S. firms in the same industry (Digital Equipment Corporation, Data General, and Honeywell Office Systems). In the Japanese firms, both interviews and questionnaire distribution were conducted both at the central corporate-level R&D facilities and at the product-division-level R&D facilities. In addition, the researchers interviewed engineers from the Japanese firms who were in residence at M.I.T. In the U.S. firms, interviews were carried out at their Boston area facilities; questionnaires were more widely distributed (at two sites for both DEC and Data General).

The interviews were with R&D managers, personnel staff, and individual engineers with each company. The companies themselves assumed the responsibility for distributing the questionnaire. Each company was asked to select a stratified sample of engineers (from among those who had been with the company two, five, ten, and fifteen years). Completed questionnaires were received from 286 Japanese engineers (188 from corporate-level centers and 98 from divisional level labs) and 110 U.S. engineers. Response rates followed patterns that have been widely established in comparative research in Japan and the United States: Japanese response rates were 90–100%, U.S. rates 40–50%. The usual explanations for this discrepancy are, first, that Japanese employees are more accustomed to filling out fairly lengthy questionnaires in the workplace; second, that a questionnaire permitted by management has real "authority" in the Japanese context that it does not have for U.S. employees.

The respondents from divisional level labs in Japan (n=98) and the 109 respondents in the U.S. were thought to be comparable, and so they were selected as the subjects of the analysis for the results of the questionnaire survey which will be described below. One American engineer was excluded from the sample. He was working in basic research; his job has nothing to do with new product development. All other engineers in the subject group were involved in new product development in the computer business.

Analysis

The Structure of Research and Development

Despite considerable variation among the three companies in each society, there are clearly identifiable "Japanese" and "American" patterns. All three Japanese companies have two levels of R&D facilities: corporate-level and divisional. The corporate-level centers can take the form of a Central Research and Development Center, as in Toshiba and Fujitsu, or a number of corporate-level R&D groups, as in NEC. The divisional level facilities are closely integrated with manufacturing, in terms of physical location, communication patterns, and flow of personnel.

The three U.S. companies in our sample also have two types of R&D organization, which may at first glance seem to be analogous to the Japanese structures. All three U.S. firms have Advanced Technology Groups which are working, as the name suggests, on new technologies and applications. In addition the firms have development and design groups which are organized by product division. There are clearly differences across the two societies, however. The American Advanced Technology Group are smaller, they specialize more in the initial stages of R&D, and they play a less crucial role in new product development than the central facilities of the Japanese corporations. The U.S. development and design groups are also less closely linked to manufacturing than their Japanese counterparts, in terms of organizational structure, physical location, and flow of personnel.

Although it was not easy to select comparable subsets from our questionnaire respondents because of the structural differences described above, we selected the respondents from divisional labs in Japan (n=98) and the respondents from development and design groups in the U.S. (n=109) as the subjects of our analysis of the results of the questionnaire survey for this paper.

The Japanese firms in the Japanese computer industry generally are large integrated electrical equipment manufacturers with a broad product line and a structure that is highly standardized across those product lines. The emerging divisions in computers and information systems adopted and adapted existing R&D structures in the form of central research institutes and the divisional labs. The close linkages between the latter and manufacturing thus predate the emergence of the computer industry, and it has provided the Japanese with one of their key competitive advantages.

In the United States, two of our firms are much younger and more specialized than the Japanese firms, and have developed their R&D organization in response to the emerging demands of the industry and the needs and predilections of the engineers who have dominated it. Even of Honeywell's Office Systems Division, which is part of a huge and highly diversified corporation, seems to be a fairly autonomous facility that has developed along the same lines as other companies in the industry instead of adapting a company specific structure and integrating with other Honeywell organizations. The Japanese firms hold advantages in having, in addition to the central R&D facilities, separate and comparatively large scale divisional level research labs that specialize in developing and improving production technology. They also have large-scale research and manufacturing capacity in semiconductors and other components of computer systems. Both these features may well be among the factors contributing to the higher profile that manufacturing has in the Japanese companies compared to that in any of the U.S. firms.

Because the Japanese firms are more diversified than the U.S. firms, a comparison of levels of spending on research and development in the computer area is a difficult matter. In 1982, the Japanese firms' corporate spending on R&D, for all divisions of the parent company, was as follows:

NEC	5.3% of sales
Toshiba	6.1% of sales
Fujitsu	10.4% of sales

The R&D spending of the U.S. firms in 1983, by contrast, amounted to over 10% of sales for all three firms:

Data General	10.2% of sales
DEC	11.1% of sales
Honeywell	12% of sales

However, Japanese spending in the computer industry was probably much higher than spending on R&D over the whole range of product lines. The least diversified firm, Fujitsu, had the highest level of R&D spending.

The criteria for deciding on how much to allocate to R&D varied from company to company in Japan. Each firm gave us a different response on how the amount was derived. One took a fixed percentage of sales; another took the previous year's spending as a base and then decided how much more was needed to compete in each industry; the third used the level of profit and loss in each division as a criterion. In U.S. firms, percent of sales seems to be the primary benchmark.

How the funding is distributed among projects is a more complex question, and one that even relatively senior research managers found difficult to answer. In Japanese firms, half of the research funding comes from the divisions, which use the money both for their own product development and improvement plans and to request specific research and development projects from the corporate-level facilities. But how the decisions were made on the allocation between funds used within the division and funds used for commissioned research was not clearly articulated by the central research managers. In all six companies, "marketability" and fit with existing product lines seem to be important criteria for funding a project, but how that evaluation is made is a complex process that seemed mysterious to many of our informants on both sides of the Pacific.

The attitude to the concept of "research" varies across these companies. Managers and engineers in all three U.S. firms emphasized that their company was not engaged in "research," which seemed to have negative connotations of being academic and divorced from product development. In two of the three Japanese firms, however, "research" had a much more positive connotation. All three Japanese companies claimed to spend more than 5% of their R&D budgets on "basic research." It was not entirely clear to us that the actual activities carried out differed as greatly between the U.S. and Japanese firms as did the attitudes to "basic research." Recently, there has been a growing feeling in Japanese industry and government circles that Japan must increase its capacity in basic science and technology, for two reasons. The first is that Japan is seem to be reaching a point where it has reached the limits of "followership" and is itself at the cutting edge of technology in many fields. The second is that the widespread image of the Japanese as "technology parasites"—users but not generators of the world's stock of science and technology—is both offensive to Japanese national pride and dangerous in the sense of exacerbating anti-Japanese feeling in countries that are running a trade deficit with Japan. As a result there are considerable pressures for "basic research" as an activity. Japanese engineers are powerfully attracted to the idea of doing "research"; U.S. engineers are not.

Recruitment

The recruitment process is the area in which there is the greatest uniformity across the three Japanese companies. Major Japanese firms hire almost all their managers and engineers from among the new university graduate applicants. The recruitment of "experienced" employees—those having already worked in other companies—is exceptional. This is true in each of our three Japanese companies. Managers in all three firms said their company had no system for recruiting engineers with experience at other companies. The percentage of engineers with working experience at a different company (or companies) is 49% in U.S. (n=109) and only 3% in Japan (n=98). The U.S. engineers on average spent five and a half years with their first employer.

Although Japanese engineers find it difficult to change companies, particularly later in their careers, the experience of interaction with other companies' engineers takes an important role as a functional substitute of the movement of engineers. For example, the Very Large Scale Integrated (VLSI) Semiconductor Project, supported by the Japanese government (1976–1980), provided a very good learning experience for a new generation of Japanese engineers (Sakakibara, 1983). Also joint projects which are organized by Nippon Telegraph and Telephone (NTT) have provided similar learning experiences for Japanese engineers.

Let us outline the significant observations drawn from our interviews which characterize recruitment of new graduates by major Japanese corporations (also see Table 1, which summarizes the results of the questionnaire survey).

(1) University students are divided into two different markets: nontechnical and technical graduates.

(2) The market for non-technical graduates is essentially free, and initial job searching is in general very similar to that in the American market. Based primarily upon public knowledge, personal contacts, and private recruitment literature, students approach companies individually to explore job opportunities.

(3) The technical graduate market is characterized by bid/negotiation systems at the department levels at universities. Student desires are followed, but are constrained by setting a low maximum limit on the number of graduates from one department (two to four students usually) that may enter any one company. Professors in charge of placement or tutorial professors will write only one recommendation for a particular student, and it will be to an "open" company, one that has a space for the student. These professors have, therefore, influence in guiding graduates to firms.

(4) Recommendations from professors of technical students are accepted without question by employers. In the case of top universities' graduates, hiring those with recommendations is virtually automatic (one of the personnel managers we interviewed actually said, "those students are employed automatically.") Hiring of students who apply without a recommendation is generally "not done." For graduates at lower ranking institutions, companies show greater independence. Recommended students are not necessarily employed.

(5) If a company rejects top university students who have recommendations, it will become difficult in the future for that company to hire students from that university. Therefore, Japanese corporations tend to hire a fixed number of students from selected major universities every year. The hiring level will be maintained even in the face of recessions.

(6) To assist the recruitment of technical personnel, corporate efforts are made to establish and maintain close relationships with universities through the supply of equipment, research grants to faculty, and personal contacts, e.g., personnel staff frequently visit professors and placement officers.

Table 1 summarizes the results of the questionnaire survey, showing the differences in the characteristics of the recruitment processes in the two countries. It indicates clearly that, among the ten sources of information listed in the Table, both the placement office at the university and references by professors are more important in the recruitment process in Japan than in the U.S., while trips to companies are more important in the U.S.

Therefore, the individual engineers in Japan have somewhat less choice in what company they join than their counterparts in the U.S. First, employment options (at least at major firms) are limited to those companies for which the professors write recommendations. Second, one's first employer is likely to be one's last (at least until early retirement age): the major companies do not hire engineers who have worked for other firms.

One of the important implications of the characteristics of the recruitment process concerns the homogeneity of engineers. The Japanese way of hiring new graduates with recommendations guarantees a certain level of engineers' quality and homogeneity of educational background, expertise, and orientation. Variety in the recruitment of engineers in U.S. companies makes their engineering groups more heterogeneous. This difference in heterogeneity of engineering groups between the two countries might have important implications for research management in the both countries. It is possible that the management system in the U.S. firms may be more robust in adapting to new situations, because of the greater flexibility and variation that are tolerated within the U.S. firms. Also the difference in heterogeneity of engineering groups between the two countries might have implications relating to the widespread perception that whereas U.S. firms have an edge in

TABLE 1. IMPORTANT FACTORS IN THE RECRUITMENT PROCESS

Question: "Listed below are several sources of information which may have been useful in applying for your current job. Please indicate the usefulness of each of the sources below."

Sources of information	Japan (n=98) Mean (S.D.)	U.S. (n=109) Mean (S.D.)	t
Publications:			
Ad in newspapers or magazine	2.27 (1.17)	2.25 (1.52)	0.13
Direct mail	1.97 (1.20)	1.41 (0.97)	3.46***
Organization:			
Public employment agency	1.42 (0.77)	1.35 (0.86)	0.55
Private employment agency	1.45 (0.83)	2.26 (1.71)	−4.17***
Placement office at univ.	4.06 (1.13)	2.08 (1.59)	9.84***
Personal contact:			
Campus recruitment interview	1.57 (1.02)	2.08 (1.58)	−2.59**
Trip to company	2.89 (1.47)	3.58 (1.61)	−3.02***
Personal acquaintance in company	2.93 (1.56)	3.12 (1.83)	−0.76
Conference/meeting	1.93 (1.22)	1.58 (1.15)	1.98**
Reference by professor	3.70 (1.34)	1.38 (0.94)	13.75***

(1) Mean score of 5-point, Likert scale from 1=of no use to 5=extremely useful.
(2) *** $p<0.01$
** $p<0.05$

invention, the Japanese firms are more successful in embodying innovations in products. Homogeneity of engineering groups is appropriate for such activity as embodying innovations in products; it is not useful for invention because an important foundation for invention is the variety of sources of information. These varied sources of information can facilitate awareness or knowledge of invention.

Training and Education

Entry Training. There are clear differences between the Japanese and the U.S. firms in terms of entry level training programs. All three Japanese firms put their engineers through standardized training programs for new managerial recruits. These are a non-technical programs that introduce the incoming engineers to the basic structures and processes of the company. The programs cover periods of from six months to two years, though attendance is just part-time after the first two months. Undoubtedly the main reason for the programs is that (as we shall see below) nearly all the engineers are expected to enter line management positions after a certain period spent in research and development. In all three Japanese firms, only new college graduates are brought into the research and development organization.

All three U.S. firms, in contrast, send their recruits directly into project work groups, with no standardized training. "College hires"—those engineers recruited directly out of college—generally receive considerable attention and on-the-job training from members of the work group they enter, largely as a matter of group self-interest; such people need guidance and training to become effective contributors to the work group. Mid-career entrants receive much less systematic attention; they are assumed to have a base of knowledge already.

Mid-Career Training. In both Japanese and U.S. firms, on-the-job training is the most general and effective form of training undergone by the engineers in terms of technical skills. However, in the United States, there are far more opportunities for someone who works in the company to take courses outside the company in colleges and technical institutes. It is not uncommon for someone to join the company as a technician and to take courses in the evenings at a local college in order to get a Master's degree. He or she can thereby advance in rank in the company, or develop new areas of expertise in which to work. Within the engineering ranks, it is possible for someone with a degree in mechanical engineering to take evening courses in a new area of specialization, such as software programming, and thereby to change fields. In the United States, therefore, the engineer and the technical employee have many more opportunities to shift careers, ranks, or fields of specialization than is the case in Japan. Major Japanese college and universities neither offer evening courses for working people nor do they admit mid-career entrants to regular courses.

This is not to say that engineers in Japan never receive formal technical training after they join the company. In both Japanese and U.S. firms, the opportunities for engineers to upgrade and update their training are considerable: 52% of the Japanese sample and also 52% of the U.S. sample of questionnaire respondents had taken additional science, engineering, or mathematics courses since they received their last degree.

Yet there were two differences between the Japanese and U.S. mid-career training patterns, despite the similarity in opportunity. First, U.S. engineers were much more likely to be motivated by a desire to improve their career opportunities; for Japanese engineers, a more important reason for taking such courses was that they were assigned to them by the company (see Table 2). This difference suggests the greater standardization and company control of careers in Japan; human resource development is much more an individual matter in the U.S. Second, Japanese firms relied more than U.S. firms on in-house program. Each company has its own training centers and experts.

Of course, there is the exception to the in-house mode in Japan. As we mentioned above, all three Japanese firms send a small number of engineers abroad (usually to U.S. institutions) each year for advanced study. Such engineers are given sufficient money to study and live abroad from their companies; the company controls access and uses it as a reward and an incentive for especially promising engineers.

TABLE 2. COMPARISON OF MOTIVES FOR TAKING COURSES

Question: "How important was each of the following motives for taking the additional scientific, engineering, or math courses since receipt of last degree?"

Motives	Japan (n=51) Mean (S.D.)	U.S. (n=56) Mean (S.D.)	t
To update existing skills	4.25 (1.01)	4.00 (1.21)	1.18
To add new skills	3.71 (0.97)	4.56 (0.68)	−5.09***
To improve chances of promotion	2.02 (1.09)	2.77 (1.26)	−3.23***
To improve chances of assignment to more interesting activities	2.30 (1.29)	3.18 (1.40)	−3.30***
Assigned to course by company	3.32 (1.44)	1.32 (0.89)	8.31***

(1) Mean score of 5-point, Likert scale from 1=unimportant to 5=very important.
(2) *** $p<0.01$

Career Structure

Dual Career Ladder. All six companies in the study claimed to have a formal dual career ladder, with equal opportunities for managerial and technical specialization: one ladder leads into R&D management, and another leads into ongoing active involvement in R&D. However, the engineers within the companies did not always perceive either that such a dual career ladder existed, or that the technical ladder received equal rewards with the management ladder. This discrepancy was especially strong among the Japanese engineers; a larger proportion were unaware of the existence of the dual career ladder than in the U.S. companies (40% in Japan, 13% in the United States). This discrepancy was even greater in terms of perceptions of the salary, status, and promotion rewards: fewer Japanese engineers than U.S. engineers (23% in Japan, 29% in the United States) believed that the rewards in the technical track were equivalent to those of the managerial track.

We should note here that, as a general rule, the managerial track of the dual career ladder in U.S. means R&D management while it can also mean line management in the product divisions in Japan. This might have something to do with the differences mentioned above.

A further point should be noted: there was considerable variation among the three U.S. companies in the level of satisfaction with the dual career ladder. In one company there was considerable dissatisfaction expressed with the opportunities to enter the technical track and with the rewards that awaited someone who chose it. In another U.S. company, there was much higher satisfaction, and some engineers expressed the view that the technical track was the more prestigious and highly rewarded.

Career Path. Not surprisingly in view of the findings on the dual career path, most Japanese engineers aim at promotion into management, rather than at a career in research. This reflects both the greater rewards for the managerial ladder and the much higher degree of standardization in career paths in the Japanese companies. In Japanese companies generally, major salary increases come only with promotion, and promotion takes place at very standardized points in one's career.

The "typical" career pattern for the Japanese engineer is very clear, and is widely understood. Every engineer knows with a very high degree of probability what his career will be like. A young Japanese engineer who is assigned on entry to the corporate-level R&D facilities will spend 6 to 8 years there, and then move to a divisional lab, usually as a carrier of a development project on which he has been actively involved. That transfer is usually welcomed by the engineer: he receives in the process his first major promotion in rank (which usually occurs around the early-30s) and it is defined as an upward move in career terms. It has the added attraction of involving playing a key role in taking a development project on which the engineer has been working since its earliest stages farther in the design and manufacture process than he has ever been able to go before. After this transfer, the engineer works in the divisional lab until the time comes for further promotion (the late-30s), and then the upward ladder can lead either into R&D management in the lab or into line management in the division. Not all engineers are happy with the escalator that takes them to the divisions, however. A significant number of researchers remain in the central facilities, and it is from these engineers that the management of corporate R&D is drawn.

On the contrary, it is very difficult to identify a "typical career" in the U.S. firms; individual variation is enormous, and is magnified by the relatively high degree of cross-company mobility in this industry.

The standardization of Japanese career paths is accentuated by the fact that the organizational structure of the R&D groups is the same as that of administration, manufacturing, or sales: the hierarchy of sections (*ka*) and departments (*bu*) is identical, and the titles of section chief and department head carry the same status in every function. They also carry much the same salary across functions.

Indeed, the standardization of salaries is another important contrast between career patterns in the Japanese and U.S. firms. Starting salaries vary within only very narrow limits in the Japanese firm, and managers in all three companies made it clear that their firms do not use salary to reward exceptional contributions. Engineers receive the same entry-level salaries as managerial recruits, and get the same annual increases, with very little variation within each cohort. The outstanding performer is rewarded with the recognition of superiors and colleagues, by more challenging assignments, and by the prospect of rising higher in the firm in the long run than his less able colleagues.

There is a widespread perception among Americans that Japanese experience greater job rotation and job flexibility. This perception is based largely on the description of blue-collar workers in large factories in Japan. In the computer industry, and among engineers, we see a pattern that could be identified as conforming to this stereotype: the daily tasks of Japanese engineers are far less specialized than those of their U.S. counterparts. However, this should not be taken at face value. One of the major factors in this variety is the fact that Japanese laboratories have far fewer technicians than is the case in the United States, and therefore researchers do more "technician's work" in Japan. But more important is that the job rotation is highly standardized in Japan. At each level the researcher is expected to perform a certain variety of tasks. He has little choice in the matter. In the case of the U.S. engineer, there is more specialization in daily tasks, but much greater opportunity for the individual to move into new or related areas of specialization: shifting of an engineer's career or field of specialization was seen more frequently in the United States than in Japan. Behind this difference lies the fact that, in the United States, there are far more opportunities for someone who works in a company to take courses outside the company in colleges and technical institutes.

Age and Career. As might be predicted from the above discussion, there are much more highly standardized links between age and career in Japan than in the United States, and age is a more important variable in determining career stage in Japan. There is relatively little variation among the engineers in the Japanese firm in the age at which they move on to new positions and new statuses.

There are also differences across the two societies in the perceptions of the significance of age. We asked engineers to judge at what age engineers peak in terms of four aspects of their careers (see Table 3). On three of four dimensions—putting the greatest effort into work, beginning to face problems of technical obsolescence, and performing best as a manager—the U.S. sample believed on average that engineers peaked at an earlier age than did the Japanese sample. The gap between the U.S. and Japanese average age of "putting the grestest effort into work" was about two and a half years (27.97 vs. 30.61). The greatest gap was in "performing best as a manager": the Japanese peak age was estimated at over three years higher than the U.S. estimate (42.40 vs. 38.94). By the U.S. engineers, peak

TABLE 3. COMPARISON OF ENGINEER'S VIEW ON AGE AND CAREER

Question: "We would like to ask you a number of questions concerning your views on age and career. At roughly what age does an engineer . . ."

At roughly what age does an engineer . . .	Japan (n=98)	U.S. (n=109)	t
	Mean (S.D.)	Mean (S.D.)	
Put the greatest amount of effort into work?	30.61 (5.08)	27.97 (4.64)	3.54***
Perform the most technically sophisticated work?	31.81 (4.42)	32.47 (5.05)	−0.93
Begin to face problems of "technical obsolescence"?	40.41 (5.38)	38.83 (6.53)	1.65
Perform the best as a manager?	42.40 (8.46)	38.94 (9.31)	2.47**

*** $p<0.01$
** $p<0.05$

managerial performance was estimated to follow peak technical performance by six years; among the Japanese engineers, it was seen to come more than ten years later. Behind this large gap lie two factors: the Japanese see technical mastery as being less important for effective managerial performance than the U.S. engineers, and they assume managerial responsibilities later in their careers.

Appraisal of Engineers

There are also differences between the United States and Japanese companies in the mode of appraisal of engineers' performance and in the factors which go into the appraisal (see Table 4). The U.S. companies rely heavily on the formal face-to-face assessment interview between the engineer and his immediate superiors. This interview provides immediate feedback to the engineer on the appraisal of his or her performance during the year, and provides opportunity for the engineer to respond. This feedback is an important difference between the two societies. Japanese engineers do not see their annual evaluation, nor do they receive a formal report on them from their superior. In relation to this, Japanese personnel staff explained that a wide variety of factors were considered in evaluating the individual's performance. But some Japanese engineers complain about the opacity of the evaluation process in Japan: they do not, as a rule, have access to the evaluations that are submitted. This undoubtedly makes for somewhat greater uncertainty in Japan about how one is evaluated, the more especially since there is so little variation in salary or promotion rates to provide concrete indicators of how well one is doing.

The bases of evaluation may be somewhat unclear in Japan, but the time frame is not. Japanese personnel staff repeatedly stressed the long-term evaluation process existing in their firms. In fact, more engineers in Japan than in the U.S. see that their companies take a long view in the evaluation process, taking five to ten year time periods for the overall evaluation of an engineer's capabilities and performance (48.0% of Japanese respondents, 10.6% of the U.S. respondents, see Table 4). The U.S. engineers by and large do not perceive that their companies take such a long-range view.

In both Japanese and U.S. firms the key role in the evaluation and appraisal process is played by the engineer's supervisor. But there is greater weight assigned to the judge-

TABLE 4. PERCEPTIONS OF APPRAISAL PROCESS

Question: "The following questions concern your views about the appraisal of engineers in your organization. Please indicate how much you agree or disagree with the following statements."

Statements	Percent indicating "agreement" Japan (n=98)	U.S. (n=109)
The performance of engineers is evaluated by the end results of their efforts rather than by the amount of effort itself.	71.4%	55.6%
Data collection on the performance of each engineer is highly mechanized, i.e., scoring systems exist for rating specific types of behavior.	7.1%	18.9%
The evaluation criteria for each engineer are individualized according to special circumstances, job and organizational situations.	64.3%	50.5%
In this organization judgemental or subjective appraisal by the engineer's superior is emphasized.	90.8%	59.8%
A regular formal face-to-face assessment interview is emphasized in the appraisal of engineers.	28.6%	70.4%
The performance of an engineer is evaluated over a period of five to ten years so that his potential capabilities can be taken into account.	48.0%	10.6%
In this organization encouragement and rewards usually outweigh criticism or negative sanctions.	34.7%	57.0%
In this organization people get financial rewards in proportion to the excellence of their job performance.	15.3%	55.1%

ment of the immediate superior in the Japanese case—a perception that is undoubtedly an integral part of the lower level of specificity of the criteria of evaluation in Japan.

Finally, the evaluation of performance is seen to be much more clearly reflected in financial rewards in the U.S. firms; it is not seen to affect financial rewards strongly in the Japanese firm.

One question that Americans tend to ask about Japanese companies is, "Do the Japanese really work harder?" For the engineers in these six companies, the answer is "Yes," if hours worked provide an accurate standard by which to judge. The Japanese engineers said they worked, on average, 53 hours a week; the U.S. engineers said they worked an average of 44. Moreover, there was much greater variation around this average in the U.S. sample than in Japan. One reason for the lower level of variation in the Japanese firms may simply be peer pressure. But another factor may well be the longer time span of the evaluation process. The Japanese engineer has, potentially, a longer time during which to prove himself. In U.S. companies, engineers learn relatively quickly whether they will be "stars" or good but not outstanding engineers. They may therefore cease to push themselves at an earlier point than do the Japanese engineers.

Project Organization

Selection of Project Leaders. Both in the questionnaires and the interviews one of the foci of our inquiries was how project leaders were chosen and how individual engineers were assigned to projects.

The factors involved in promotion to project leader differ significantly across the two

TABLE 5. IMPORTANT FACTOR IN THE PROMOTION TO PROJECT LEADER

Question: "What factors do you think are the most important in being promoted to project leader in your company?"

	Japan (n=98) Mean (Ranking)	U.S. (n=109) Mean (Ranking)
Administrative ability***	1.69 (1)	0.47 (5)
Seniority***	1.32 (2)	0.58 (4)
Technical expertise***	1.21 (3)	1.82 (1)
Track record of participation in successful projects***	0.96 (4)	1.61 (2)
Ability to work well with others***	0.71 (5)	1.46 (3)

(1) Mean score of importance (3 points for the most important factor, 2 points for the second, 1 point for the third, and 0 point for others).
(2) *** $p<0.01$

TABLE 6. FACTORS IN ASSIGNMENT TO LAST PROJECT

Question: "In your assignment to your last project, how much influence did each of the following have in your getting that assignment?"

	Japan (n=98) Mean (S.D.)	U.S. (n=109) Mean (S.D.)	t
Your previous supervisor	4.52 (0.93)	2.67 (1.65)	9.71***
Manager of your department/lab	1.84 (1.31)	3.54 (1.55)	−8.15***
Head of the project	3.46 (1.60)	3.09 (1.53)	1.60
Personnel staff	1.40 (0.91)	1.29 (0.82)	0.93
Your own expressed wishes	2.47 (1.42)	3.84 (1.42)	−6.67***

(1) Mean score of 5-point, Likert scale from 1=very little influence to 5=very great influence.
(2) *** $p<0.01$

societies, and reflect different conceptions of the role of the project leader (see Table 5). The U.S. firms expect the project leader to be a technical leader who makes the key decisions about technical problems. The Japanese firms expect the project leader to take more of a "chairman" role in terms of technical problem-solving, although his authority is no less securely grounded because of this. Hence technical expertise and track record of participation in successful projects are seen as the key factors in promotion to project leader in the U.S. firms (see Table 5), whereas they are ranked third and fourth, respectively, out of five factors in Japan. In Japan administrative ability and seniority are much more important than technical expertise; in the U.S. firms they are seen as almost irrelevant.

Assignment to a Project. The survey of engineers revealed that the most important factor in assigning engineers to a project in the U.S. is seen to be the expressed wishes of the engineer; in Japan it is the wishes of the superior, either one's current superior or the leader of the new project itself (see Table 6). This is consistent with the lower control which Japanese engineers exert over their own careers.

There is also much more opportunity to volunteer for a project in the U.S. companies than in Japan, where putting oneself forward aggressively is not behavior that is regarded favorably. There is also much more freedom to leave a project in the middle in the U.S. firm, if one's interests change or other opportunities arise. This was seen to be much more difficult in Japan.

Both these variables—the assignment to a project and the ability to leave a project—reflect an overarching difference between the U.S. and Japanese firms in terms of individual responsibility and initiative in shaping one's career. In the U.S., the engineer is expected to assume the primary responsibility for maximizing his or her abilities and designing the best possible career. In Japan, the company assumes the primary responsibility for this. This makes careers much more standardized within each company in Japan, so that whereas U.S. personnel managers and engineers found it virtually impossible to describe a "typical career" at their company, Japanese respondents found it fairly easy. It also means that the Japanese firm can use career structure both to facilitate the transfer of technology across functions through the transfer of people and to maximize its overall stock of "human resources."

Monitoring. Formally, the monitoring of projects is much less rigorous and less frequent in the Japanese companies. Two of the firms have annual reviews of ongoing projects, at the time when budgets are drawn up; the third has semi-annual reviews. This is in marked contrast to the United States, where two of the three firms have phased review processes and the third company is considering instituting the phased review to provide specific milestones for each project. Scheduling also seemed, at least formally, much more flexible and informal in the Japanese firms, although we were told that scheduling is very aggressive once the project moves to the divisions.

However, despite this apparent looseness of monitoring and scheduling, Japanese engineers report feeling significantly more time pressure than do their U.S. counterparts. In response to a question asking for a rating of the feeling of time pressure on a scale of 1 (mild) to 5 (severe), the average Japanese ranking was 4.41, compared to a U.S. average of 3.55. This response suggests the existence of strong pressures to deliver results and to work intensively, despite the lack of externally imposed formal milestones. The principal sources of this pressure are clearly the department head and the section head, who keep a daily eye on how well work is progressing in each project involving members of their groups.

Hand-Off of Project. In all three U.S. companies, the dominant mode of handing off R&D to manufacturing was to have one individual responsible for the smooth transfer of the project from design through manufacturing. This individual's title varies across firms, but the function is basically similar among all firms. He or she is responsible for several projects at once, is a permanent member of the design organization, and has not usually been actively involved in the "hands-on" part of the research. To augment the role played by this person, one of the U.S. firms seconds a person from manufacturing to participate in the project soon after it is formally approved. In the other two companies, while the Program Manager has the formal responsibility for the transfer, technical problems are usually resolved by one or two key development people having extensive telephone calls with the factory people, or in rare cases paying quick visits to the factory. One problem with this sytem is that by the time the project has moved into manufacturing, many of the design people have moved on to new projects.

In all three Japanese firms, the movement of the engineers involved in the project takes an important role in handing off R&D to manufacturing. None of the Japanese companies have a special coordinator role comparable to that of the Program Manager in the U.S. firms. Research managers at all three companies stressed in our interviews that the constant flow of people from the center to the divisions (transfer with a project is not the only occasion of such changes) as the key factor in smooth technology transfer. Over-specification (a problem in some U.S. companies) was not seen as an issue in the Japanese companies. Several Japanese research managers pointed out that it was a particularly American problem. Specifications are not often worked out until the product reaches the divisions. The American practice of working out detailed specs is seen as resulting from a lack of trust in manufacturing people. The fact that factory managers are themselves engineers, some of whom have come from the central and divisional labs and themselves have had active design experience, may be an important factor in the greater trust in Japan. The career ladder that leads from design into line management in the manufacturing divisions is clearly an important element of the technology transfer process.

Implications

Our study aimed at answering two key questions. The first was: what are the similarities and differences between the Japanese and U.S. firms in terms of their organization of research and the careers of their engineers? The second was: what are the implications of these similarities and differences?

Close Linkage between R&D and Manufacturing

If we focus on differences rather than similarities between the two countries, one of the most significant differences between the U.S. and Japanese firms is the very close linkage between R&D and manufacturing. The linkage in Japan operates on all three levels: corporate structure, project team, and individual engineer. All three Japanese companies maintain two levels of R&D facilities: the corporate-level research centers, which handle new product development to the stage of the first prototype, and divisional-level labs, which take the product from that point through manufacture, testing, and subsequent product improvement. The corporate-level centers are physically removed from the divisional labs, but the research hand-off involves the transfer of engineers to the divisional lab on permanent assignment. The divisional-level labs are linked to manufacturing in terms of physical location, communication flows, and the constant movement of people. At the level of the individual engineer, the standard pattern of career development involves a transfer from the central lab to the divisional lab to divisional line management. This close linkage on all levels between R&D and manufacturing is a key element of the Japanese firms' competitive advantage in getting products rapidly through development to the market.

Locus of Responsibility for Designing a Career

The second finding of the study was a basic and pervasive difference in the locus of responsibility for guiding the engineer's career. In the United States, it is the individual engineer who bears the primary responsibility; in Japan, it is the company. The greater company responsibility and control begin with the more extensive entry-level training and extend to mid-career training, assignment to projects, and job rotation. That the engineer must rely on the company rather than on his own initiatives to guide his career makes the initial choice of an employer a critical decision, and this is part of the reason why engineers at major universities want to work for the very large companies and are willing to accept a labour market system that lowers the level of individual choice but increases their chances of being hired by a leading company. The structure of the technical labour market is one in which the university professor plays a key role in allocating his students to major employers, a system that makes it very difficult for smaller companies and foreign firms to recruit graduates of the better universities.

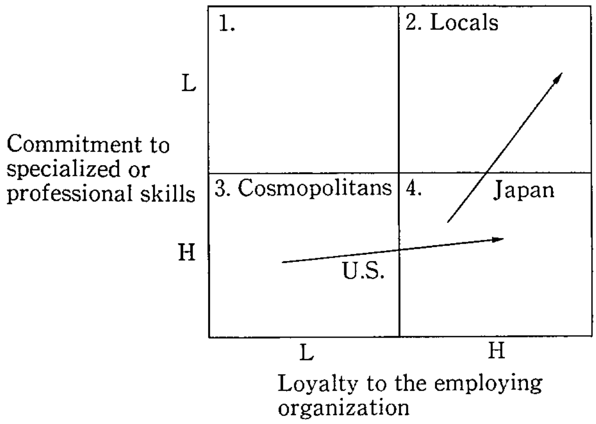
Career structure in the Japanese firms is more standardized and slower moving than in the U.S. firms. Initial training is longer and more systematic, and includes an orientation programme that involves both the entering engineers and managers. Evaluation of the engineer stretches over a longer time period. Administrative duties and responsibility for supervising and evaluating the work of others comes later than in U.S. firms. Japanese engineers also work longer hours, and there is much less variation in hours across the sample of engineers. One factor in this may be the longer and slower evaluation process; engineers have a long time in which to prove themselves, whereas in U.S. firms "stars" tend to be identified and rewarded fairly quickly. Rapid salary increases and rapid promotion are not used as rewards in the Japanese firms; incentives seem to be provided by the respect accorded by colleagues and superiors and long-term career prospects within the firm. All three Japanese and all three U.S. firms have formal dual career ladders, but engineers in both countries regard the managerial ladder as offering more status and higher financial rewards and as being more accessible than the technical ladder. The regard for the managerial ladder is higher in Japanese than in U.S. firms.

In fact, those differences reflect the widespread and fundamental differences between the development of engineers in Japan and the United States. The difference between the locus of primary responsibility for designing a career in the two systems is a basic difference, and it is integrally linked to many others. Those differences, as a whole, show a certain pattern or *a gestalt*. It is difficult, therefore, to separate this fundamental difference from the many manifestations it takes in the careers and attitudes of engineers in the two countries.

Cosmopolitans and Locals

The data in this paper also hold implications for the dynamic paths of careers of the U.S. and Japanese engineers. Alvin Gouldner has suggested a typology of latent social roles based on two major variables: commitment to specialized or professional skills and loyalty to the employing organization. He suggested that the most stable configulations are those of the "locals," who score high on loyalty to the employing organization and low on commitment to specialized or professional skills, and the "cosmopolitans," who score high on commitment to specialized or professional skills and low on loyalty to the employing organization (Figure 1). These categories are stable because there is no role conflict. However, stability is not necessarily conducive to innovation. "Locals" (category 2) have few information networks across organizational boundaries that provide stimulation and new ideas. "Cosmopolitans" (category 3), with their low loyalty to the employing company, are not likely to be willing to contribute what they regard as "their" research to the company, and therefore a high concentration of cosmopolitans is not conducive to the accumulation of R&D results within the company. Therefore, the most productive category for R&D

Figure 1.



organizations is likely to be category 4, with a high degree of commitment both to the profession and the employing organization. It is also, however, likely to be the most difficult to manage.

If the dominant patterns in the U.S. and Japanese firms can be placed on this matrix, we would find the U.S. engineers largely in category 3 at the beginning of their careers, and moving into category 4 as they spend more time in the company (at least in the sucessful company). Japanese engineers are more likely to enter the company in category 4, but they move into category 2 as their careers progress. At least in terms of the individual, then, the U.S. pattern is likely to be the more productive in terms of technological innovations.

Internationalization

The basic systematic differences between U.S. and Japanese computer firms described in this paper are likely to cause some serious problems for companies on both sides of the Pacific. With the increasing global competition in the industry, and the increasing awareness of very different comparative advantages existing in the two societies, increasing numbers of firms are moving to establish R&D facilities in the other society. Japanese firms are increasingly interested in establishing research centers in Silicon Valley, Route 128, or Research Triangle Park; U.S. firms are moving to set up research facilities in Japan. Our data suggest that they may face some serious problems in reconciling the very different patterns of R&D management and personnel systems in this process, problems which are not yet clearly recognized. The differences cannot be dealt with in piecemeal fashion, because they are integrally interconnected. It is possible that the U.S. firm may have a slight advantage in resolving these problems, because of the greater flexibility and variation that are apparently tolerated within U.S. firms.

Japanese Firms' Technology Strategy

There is a growing trend among Japanese firms today to set up laboratories to perform basic research (Table 7 shows some examples of those laboratories). What is driving these

TABLE 7. EXAMPLES OF NEW JAPANESE LABS

Name	Opening	Staff	Research
Hitachi Basic Research Lab	1985	50	Bioelectronics, AI
NEC Basic Research Lab	1982	130	Bioelectronics and materials
Toshiba VLSI Research Center	1984	n.a.	VLSI and materials
Matsushita Electric Semiconductor Research Center	1985	n.a.	VLSI
Canon Central Research Lab	1985	n.a.	Optics, electronic materials and AI
Fanuc Basic Research Lab	1984	8	Intelligent robot
Meiji Institute of Health Science	1984	n.a.	Medicines

moves? The answer given by most Japanese analysts is that Japan as a society faces some serious problems in continuing its long-standing strategy of being a rapid and skilful "technology-follower," drawing on the basic research performed in the "advanced nations" of North America and Europe and embodying it in products that are produced with high quality at relatively low cost. The process innovations which Japan has contributed have not been either as widely respected abroad as the scientific and technical research on which they have built nor (at least until recently) have they been as widely emulated.

There are two basic reasons for the fact that Japan is seen to be approaching the "limits of followership." One is the growing resentment of Japanese "imitation" or "technology copying." This resentment is producing a growing reluctance on the part of U.S. and European firms and individuals to license technology to Japanese firms. The second factor is that Japan is in many areas of science and technology approaching the limits of existing research, and is itself on the "frontiers" of knowledge. As a result there is a new determination within Japan to foster basic scientific and technical research, a determination which is exhibited in such government policy statements as the annual White Papers on Science and Technology and in the statements of Japanese corporate managers.

However, the linkage between basic research and product innovations has been found by many analysts to be a tenuous one. Clearly basic research provides the necessary background for product development. However, because it is frequently a "public good"—in the sense that it cannot be approached by a single firm—the role of the firm in expanding Japan's science and technology research capacity might seem to be somewhat unclear.

What options are therefore open to the Japanese firms that feel a general desire to see their home country's science and technology base enhanced? One is a practice long followed by U.S. firms: to fund research at the major universities. Interestingly enough, although Japanese firms are among the most active and venturesome corporate contributors to the research budgets of major U.S. universities and institutions, they have been extremely reluctant to make such contributions to Japanese universities. There are a number of long-standing historical reasons for this reluctance: one is the fact that the most prestigious universities in Japan are national universities which have not (until new guidelines were produced last spring) been allowed to accept research funding from private sources. A more general reason, however, is undoubtedly that Japanese corporate managers have very little respect for the research capacity of most Japanese universities.

A second option would be to acquiesce to higher taxation or special levies that would contribute to government funding of research. There would seem to be plenty of room for such an option in Japan: government funding of the total national R&D budget is lower there than in any of the other highly industrialized countries (in 1981, government provided 25.0% of the total R&D expenditures in Japan, 47.2% in the United States, 43.1% in West Germany, and 57.6% in France). Yet Japanese firms have apparently preferred to pursue a third strategy: that of undertaking expanded basic research activities themselves.

As *Business Week* recently reported (February 25, 1985), Japanese manufacturers have completed more than 25 new industrial research labs during the past two years. Many of these are designated as "basic research labs." Clearly such firms are making a public commitment to basic research activities.

Yet they may face some serious obstacles to pursuing this strategy successfully over the long term. The most serious problem is *organizational:* the organizational structures and processes in Japanese firms, as set out in this paper, are not appropriate for basic research in many respects. For example, the dominant career pattern of engineers described above is useful for applied research, but it is inimical to the accumulation of basic research skills within central laboratory. It may not be easy for firms which have so successfully organized their research process for "D-intensive" activities to accommodate the changes necessary for basic research activities. It may also be difficult to maintain the tolerance for the slow (or even very low) payback to the firm on its basic research, once the pull of following the current trend has waned.

What lies behind that pull? Clearly there is both an external and an internal impetus. The external impetus lies in the lure of enhancing company prestige, through contributing to an emerging national goal and to a reduction of international resentment of Japan's "technology-user" image. There is also an internal constituency within the firm: the "cosmopolitans" among the researchers at the central labs who want their firms to pursue strategies that will give them enhanced opportunities to become visible to the larger scientific and technical world.

Whether these constitute a strong enough incentive to override the impediments to the increased focus on badic research in Japanese firms remains to be seen. The problem has to do with the "software" of organizational processes and of strategy formation rather than with the "hardware" or research facilities. The challenge for Japanese firms is to develop this "software" in the coming years.

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