Japanese Change Process for Innovation

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New patterns of cooperation are being facilitated that will eliminate U.S.-Japan frictions

I would like to explain how changes in patterns of the innovation process have taken place in Japan. I believe that some friction between the United States and Japan might have resulted from the old paradigm. But within new patterns, cooperation will be highly facilitated and we may find that new forms of cooperation will be possible.

SIX CATEGORIES OF CHANGES

I will summarize these paradigm changes into six categories, as shown in Table 1. These changes are everywhere in the field of manufacturing companies, in business, in innovation pattern, in R&D activities, in technology utilization, and in the innovative process.[1]

First, the major changes in manufacturing companies. Manufacturing companies are those that produce. However, the R&D expenditures being made by the leading companies are now larger than their capital investments. While capital investment is directly related to the current production, R&D investment is investment in the future. Manufacturing companies are now changing from producing organizations to thinking organizations.

Second, there are changes in business. In the past, one technology used to correspond to one business and one company used to assist one technology. But now, especially in Japan, technological diversification has progressed so much that it is hard to distinguish a company's principal business from its secondary business. In many cases the principal business of a company is now overtaken by its secondary business.[2]

Third, there are the changes in innovation patterns. In the past, innovation patterns used to be represented by the technical breakthrough. An example is nuclear development. But today, as is illustrated by the emergence of terms such as mechatronics and optoelectronics, different kinds of technologies are fused into totally new innovative technologies. And this is more powerful than the mere combination of the multiple technologies. The so-called three main areas of high technologies, biotechnology, electronics, and new materials may be good examples of this technology fusion.[3]

Fourth, major changes are observed in the field of the research and development activities. Think of the DRAM (Direct Random Access Memory) industry. In that field every three years a new product is developed and the competition is thereby becoming keener and keener.

If I take another example, in the field of opto-electronics, the research and development activities in Japan in optical fibers was first led by glass manufacturers, but they faced two problems. One was the problem related to fragility and the other was transmission loss. Glass manufacturers with their theoretic base or mind set, just tried to solve these problems through the purification of the glass. But as long as they were extending ideas of the industry that they belonged to, they could not resolve those problems at all.

Later, however, the two problems were resolved. The first problem of fragility was resolved by the cable industry. They developed a new coating technology applicable to optical fibers. The transmission loss was resolved by the user, NTT, which discovered that the use of longer wave lengths were effective in reducing transmission loss.

Those examples clearly illustrate that in the future companies will have to compete more with those companies or those industries outside of the traditional discipline rather than compete within the same discipline or within the same industry. That is why I define this paradigm change as a shift from visible competitions to invisible enemies.[4]

Fifth, there are the changes in technology utilization that reflect a shift from single purpose technology to dual use technology. This is represented by the emergence of electronics. For instance, these days the boundary between civilian technology and defense technology is very vague and unclear.

That is to say, in the past the direction of technology spinoff was

The Six Paradigm Changes in Science and Technology Policy

1. Paradigm Change for Manufacturing Companies from Producing Organization to Thinking Organization
2. Paradigm Change for Business from Single Technology Base to Technology Diversification
3. Paradigm Change for Innovation Patterns From Technical Breakthrough to Technology Fusion
4. Paradigm Change for R&D Activities From Visible Competitors to Invisible Enemies
5. Paradigm Change for Technology Utilization From Single-Purpose Technology to Dual-Use Technology
6. Paradigm Change for Innovation Process From Linear Progression to Non-linear Process

Table 1

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R & D EXPENDITURES COMPARED WITH INVESTMENT FOR FACILITIES IN MAJOR JAPANESE COMPANIES (FY 1986)

(Hundred Million Yen)

COMPANY	R & D Expenditures	Investments for Facilities
HITACHI, LTD.	2,515	1,008
TOYOTA MOTOR CORPORATION	2,500	2,970
NEC CORPORATION	2,400	1,600
NIPPON TELEGRAPH AND TELEPHONE CORPORATION	1,775	16,132
TOSHIBA CORPORATION	1,716	1,195
FUJITSU LTD.	1,580	846
NISSAN MOTOR CO., LTD.	1,550	950
MITSUBISHI ELECTRIC CORPORATION	1,120	620
MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD.*	924	120
MITSUBISHI HEAVY INDUSTRIES, LTD.	870	707
MAZDA MOTOR CORPORATION	800	1,100
NIPPON DENSO CO., LTD.	619	870
CANON INC.	609	540
SHARP CORPORATION	590	516
NIPPON STEEL CORPORATION	550	1,650
SONY CORPORATION*	507	504
SANYO ELECTRIC CO., LTD.	506	655
THE TOKYO ELECTRIC POWER CO., INC.	468	11,302
FUJI PHOTO FILM CO., LTD.	421	424
KOBE STEEL, LTD.	362	835
RICOH CO., LTD.	353	182
TAKEDA CHEMICAL INDUSTRIES, LTD.	349	221
ASAHI CHEMICAL INDUSTRY CO., LTD.	345	532
MITSUBISHI CHEMICAL INDUSTRIES LTD.	320	380
KOMATSU, LTD.	312	128
KAWASAKI STEEL CORPORATION	307	1,049
ISHIKAWAJIMA-HARIMA HEAVY INDUSTRIES CO., LTD.	300	137
ISUZU MOTORS LTD.	300	296
SUMITOMO METAL INDUSTRIES LTD.	288	823
VICTOR COMPANY OF JAPAN, LTD.	281	198
NIPPON KOKAN K.K.	274	784
OKI ELECTRIC INDUSTRY CO., LTD.	249	213
MATSUSHITA ELECTRIC WORKS, LTD.	247	230
SUMITOMO CHEMICAL CO., LTD.	243	323
FUJI HEAVY INDUSTRIES LTD.	241	556
THE KANSAI ELECTRIC POWER CO., INC.	240	6,561
FUJI ELECTRIC CO., LTD.	216	152
KAWASAKI HEAVY INDUSTRIES, LTD.	212	225
SANKYO CO., LTD.	204	99
ASAHI GLASS CO., LTD.	200	420
SUMITOMO ELECTRIC INDUSTRIES, LTD.	199	290
SHIONOGI & CO., LTD.	193	101
FUJISAWA PHARMACEUTICAL CO., LTD.	190	76
TDK CORPORATION	188	272
EISAI CO., LTD.	187	47
KONISHIROKU PHOTO INDUSTRY CO., LTD.	180	194
KAO CORPORATION	175	557
CHUBU ELECTRIC POWER CO., INC.	156	5,104
KOKUSAI DENSHIN DENWA CO., LTD.	126	455
MATSUSHITA COMMUNICATION INDUSTRIAL CO., LTD.*	120	10
MANUFACTURING COMPANIES (SUB-TOTAL) 1 EXCLUSING (*)s	26,812 (25,261)	25,605 (24,971)
OTHER COMPANIES (SUB-TOTAL) 2	2,765	39,554
TOTAL 1 + 2	29,577	65,159

NOTES: Suffixed members (*) are the ones above settlement terms are different from the others.
FY1988 starts July, 1985 and ends June, 1988. Established members are the ones above R&D expenditures are greater than Investments for Facilities.

SOURCES: Japan Companies Handbook (1987)

Table 2

from defense to civilian. Technologies developed for defense were spun-off onto the civilian side for utilization. However, now the transit is reversed in the word "spin-on," describing the effect from the civilian side to defense.

I am not an expert in this field, but I would like to offer one anecdote that shows technology actually runs or flows from high to low. In 1948, when Bell Laboratory developed the transistor technology, the company knew that defense would be greatly interested in the transistor technology. But its managers realized also that if they released the technology too early to defense, they would make them classify the invention and that would prevent Bell Labs from using the technology. Therefore, they released the technology to defense only one week before public announcement.[5]

The last change is the innovation process. In the past it was a linear progression, but it is now changing toward a nonlinear process. In the past the innovation process used to be a linear progression from science to technology: something was invented or developed first for science and then applications were found. The linear process used to progress from research, to development, to production and finally to distribution.

But this again is changing. For instance, in the field of biotechnology monosodium glutamate is used as a food additive in Japan with the original technology to produce the monosodium glutamate developed by Kyowa Hakko K.K. But eventually it turned out that this technology is applicable for the production of all kinds of amino acids. This indicates that now, in this instance, the flow is from technology to science. In the field of superconductivity, although the principle is not yet fully elucidated, applications have been aggressively pursued.[6]

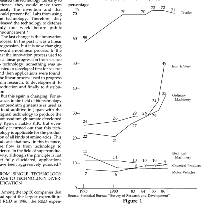
FROM SINGLE TECHNOLOGY BASE TO TECHNOLOGY DIVERSIFICATION

Among the top 50 companies that had spent the largest expenditure of R&D in 1986, the R&D expenditures in many cases exceeded the spending for capital investment, as depicted in Table 2. For example, the ratio of R&D expenditure to capital investment is 2.5 for the top company and it is 2.0 for the next company. If you exclude the utilities like NTT that primarily provide services, and if you just take the subtotal of manufacturing companies, R&D expenditure has already surpassed the capital investment, as shown in the table. The point I want to make here is that this change has occurred only recently.[7]

If you look at data edited by Nomura Research Institute, based on 68 manufacturing companies, spending on capital investment used to surpass that of R&D expenditure. However, just recently the situation has reversed and now the gap is becoming larger and larger.

This shows the trend toward diversification. Data is available in Japan for the research and development expenditures by industry and by product for 21 industries and for

PROGRESS OF DIVERSIFICATION IN R&D
(Percentage of R&D Expense into Product Fields outside Principal Ones to Total R&D Expense)



Source: Statistical Bureau "Survey of Research and Development"

Figure 1

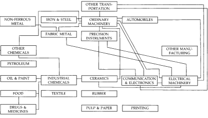


Figure 2

32 product fields. This data has been compiled since 1970. In the field of electrical applicances manufacture, for example, electrical applicance is the major or principal product. But nowadays the R&D is distributed in diverse areas. The ratio of the total R&D expenditure by the industry to the R&D expenses for areas outside of its principal product field can be calculated. The textile industry, for example, stands at 0.54 and of shipbuilding it is 0.67. This means that outside businesses are more significant than the principal product area.

The progress of the diversification can be taken in time series. The textile industry that staggered the most and suffered downturns in business the most has been the most diversified. By contrast, the automobile industry, which has been the most profitable, has been least diversified. The iron and steel industry has finally changed since the beginning of 1980s. In Figure 1, I have given the percentage of R&D expenses in the product field outside the principal R&D expenses. It was at about 20% for the iron steel industry before 1975 and the graph shows that it grew rapidly, reaching 50% after 1980.[9]

FROM TECHNICAL BREAKTHROUGH TO TECHNOLOGY FUSION

Technology fusion, which I mentioned earlier, is the most conspicuous trend in high technology industries. This trend can be analyzed by using data on R&D expenditures by industry and by product fields. In Figure 2, 21 industries are listed and those that are tied or linked with lines means that there is a reciprocity of R&D investment existing between the two industries. In 1970, however, this trend was not so conspicuous.

In the fields of high technologies, namely biotechnology, electronics, and new materials, these trends are mot comspicuous. In biotechnology, already in 1974 the reciprocal investment relation has been established among the three different fields: food, drug and medicine, and industrial chemicals. In the field of mechatronics, it is a little bit complicated. The four fields of machinery, precision instruments, communications and electronics, and electrical machinery, had already established a sort of quadruple reciprocal investment relation in 1975. In the case of mechatronics and biotechnology, technological fusion used to occur within fabrication industry or material industry. But now in the case of new materials, for instance, in new ceramics, the R&D reciprocal investment relation was established in 1982 among ceramics, ordinary machinery, and electrical machinery.[10]

FROM LINEAR PROGRESSION TO NONLINEAR PROCESS

Lastly, the innovation process has changed from a linear one to a nonlinear one, as shown in Figure 3. On the top we have a linear progression that is from research to development, production, distribution. But in the middle we have a new relation where this process flows from production to research or from development to research as well as from research to develop-

THREE TYPES OF INNOVATION PROCESS

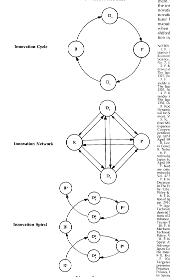


Figure 3

ment. In the last case if you applied the instance of the optical fiber innovation, this can be termed an innovation spiral. The glass manufacturer has its own cycle and cable manufacturer has another cycle and when the orbit of the cycles are shifted a little bit, technical innovation occurs.[11]

NOTES

1. F. Kodama, "Can Empirical Quantitative Study Identify Changes in Techno-Economic Paradigm?" forthcoming in Science, Technology and Industry Review, No. 7, OECD, 1990.

2. F. Kodama, "Technological innovation drives structural changes in corporations," The Japan Economic Journal, Vol. 26 No. 1315, June 1988.

3. F. Kodama, "'Technology fusion' yields innovations from breakthroughs," The Japan Economic Journal, Vol. 26 No. 1325, August 1988.

4. F. Kodama, "High tech developments render traditional management obsolete," The Japan Economic Journal, Vol. 26 No. 1332, October 1988.

F. Kodama, "Research and Development Dynamics of High-Tech Industry," The Journal for Science Policy and Research Management, Vol. 1 No. 1, Tokyo.

5. N. Rosenberg, "Civilian 'Spillovers' from Military R&D Spending: The American Experience Since World War II," in Technical Cooperation and International Competitiveness (Ed. H. Fusfeld and R. Nelson), pp. 167-187, Rensselaer Polytechnic Institute, April 1988.

R. Levin, "The Semiconductor Industry," in Government and Technical Progress (Ed. R. Nelson), pp. 60, Pergamon Press, 1982.

6. F. Kodama, "U.S. call to share technology is based on faulty premise," The Japan Economic Journal, Vol. 26 No. 1307, April 1988.

F. Kodama, "Advances in new materials are critical to be breakthroughs in other technologies," The Japan Economic Journal, Vol. 27 No. 1391, November 25, 1989.

7. F. Kodama, "How Research Investment Decisions are made in Japanese Industry?" in The Evaluation of Scientific Research (Ed. by Ciba Foundation), pp. 210-214, John Wiley & Sons, 1989.

8. F. Kodama, "Technological Diversification of Japanese Industry," Science, Vol. 233, pp. 291-296, Washington, D.C., 1986.

9. Agency of Industrial Science and Technology, "Trends and Problems of Industrial Technology: Challenges to Innovations of 21st Century and International Contribution," (in Japanese), ISBN4-8065-2304-6, Tsusan-Tyousa-Kai, 1988.

10. F. Kodama, "Japanese Innovation in Mechatronics Technology: An Study of Technological Fusion," Science and Public Policy, Vol. 13 No. 1, pp. 44-51, 1986.

11. F. Kodama and et. al., "The Innovation Spiral: A New Look at Recent Technological Advances," presented to The 2nd U.S.-Japan Conference on High Technology and the International Environment, November 9-11, Kyoto, Japan, 1986.

F. Kodama, "Demand Articulation: Targeted Technology Development," presented to Seminar on Options and Priorities of Future Research and Technology Policies, Bonn, December 1989, forthcoming by Springer-Verlag.