ANALYZING JAPANESE HIGH TECHNOLOGIES

THE TECHNO-PARADIGM SHIFT

FUMIO KODAMA

Analyzing Japanese High Technologies: The Techno-Paradigm Shift

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Analyzing Japanese High Technologies

Preface

This book presents an empirical analysis of the generation, innovation, and diffusion of Japanese high technologies. It is not another parable of Japan's technological success.

Many people think that the Japanese socioeconomic system leads to her international competitiveness even in high technology areas. But the question remains: is this because the Japanese system differs from the Western system, or is it because a paradigm shift is occurring in technology. Put another way, is this because the Japanese built a unique socioeconomic system which is efficient in producing civilian high technologies, or is it because the existing Japanese system happens to fit the newly emerging techno-paradigm?

In order to answer this dichotomic question, first of all we have to understand what the new paradigm looks like. In this book, therefore, I have sought to formulate the characteristics of high technologies, by generalizing individual Japanese experiences. In pursuing this goal of generalization, however, I have been compelled to use the modeling approach, which is an abstraction of reality. However, I have described several concrete cases from which an abstraction is made.

Another purpose of this book is to collect my past articles published in academic and professional journals and presented at international meetings, into a book which can be read in a broader context and be available worldwide. For the purpose of synthesis, I am going to use 'techno-paradigm shift' as an intellectual integration mechanism. Although this word is difficult to define precisely, I could not find another expression which better described my thoughts.

Ideal readers are assumed to possess an academic background in mathematical modeling, though the arguments can be understood even if the mathematical details are not studied in depth. Professional experience in science policy will also prove helpful, though non-experts will benefit from reading this book, because policy implications are described in a broader context. This book is meant for several groups of readers, those conducting research in the field of policy science including graduate students, and managers of in-house training programs in government and industry.

This book comes out through my collaboration with my graduate students at Graduate School of Policy Science in Saitama University. I am particularly indebted to Yukichi Honda, Masahiko Kobayashi and Toru Muraoka, who produced excellent master theses under my guidance. In integrating their individual works into a book, I owe very much to generous support given by NISTEP (National Institute of Science and Technology Policy). Many people including visitors at NISTEP helped me with this integration. Particularly, I would like to express my thanks to Diana Hicks, a visiting fellow from SPRU, for the tremendous efforts she made in reading and giving useful suggestions on my draft.

My deepest gratitude goes to my wife, Minako, and my three children, without whose patience and unwavering support, it would have been impossible to sustain my research for so many years.

Fumio Kodama
September, 1990, Tokyo

List of acronyms

AI	Artificial Intelligence
BEA	Bureau of Economic Analysis
BTL	Bell Telephone Laboratories
CAT	computerized axial tomography
C&C	computer and communication
CGW	Corning Glass Works
CMOS	complementary metal oxide semiconductors
CRT	cathode ray tube
DOD	Department of Defence
DRAM	dynamic random access memory
DSM	dynamic scattering mode
E&E	energy and electronics
ENNA	Engineering Advancement Association of Japan
ERA	Engineering Research Association
ETL	Electro-Technical Laboratory
FMS	flexible manufacturing system
IC	integrated circuit
IEA	International Energy Agency
IEEE	Institute of Electrical and Electronics Engineers
M&A	mergers and acquisitions
MC	machining centre
MCVD	modified chemical vapor deposition
ME	microelectronics
MIT	Massachusetts Institute of Technology
MITI	Ministry for International Trade and Industry
MOS	metal oxide semiconductors
MTBF	mean time between failures
NC	numerically controlled
NEC	Nippon Electric Company
NIES	newly industrializing economies
NISTEP	National Institute of Science and Technology Policy
NSG	Nippon Sheet Glass
NSK	Nippon Seiko
NTT	Nippon Telegraph and Telephone Corporation
OECD	Organization for Economic Cooperation and Development

PATTERN	planning assistance through technical evaluation of relevance numbers
PERT	program evaluation and review technique
PIPS	pattern information processing system
QC	quality control
RCA	Radio Corporation of America
R&D	research and development
SAPPHO	scientific activity predictor from patterns with heuristic origin
S/Es	scientists and engineers
SEI	Sumitomo Electric Industries
SIC	Standard Industrial Classification Code
SITC	Standard International Trade Classification
SPRU	Science Policy Research Unit
S&T	science and technology
UPSO	US Patent and Trademark Office
VAD	vapor phase axial deposition
VLSI	very large scale integration
VTR	video tape recorder

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Chapter 1

Overview: six categories of techno-paradigm shift

When geographical shifts occur in the balance of world industrial strength, those countries overtaken often attack the newcomers with accusations of a 'conspiracy'. In many cases this conspiracy is actually the spontaneous innovation of institutions by the newcomers, and these innovations in turn become the world model for a new industrial era.

As these new innovations fall outside the experience of the previous powers, they indeed appear to be some sort of conspiracy. As the targets of this criticism are unaware that something new is being done, they cannot effectively refute the charges against them.

This phenomenon is described as a 'historical paradox': a less developed country, in the process of trying to catch up with the advanced countries, unconsciously resorts to innovative policies that are even more progressive and modern than those of the more advanced countries, and only later begins to appreciate why it has chosen these policies. This sort of 'historical paradox' was witnessed at the turn of the century with England and France on one side and Germany on the other.[1] It also now seems to have appeared between Japan and the nations of the West.[2]

Many specialists have been pointing out changes in the basic pattern of technological innovation.[3] With the emergence of 'high-technology', various changes are occurring in the whole framework of science and technology policy, whether it be governmental policy or corporate policy. These changes are significant enough to merit the label: 'paradigm shift'.[3]–[6]

This shift is making obsolete the policy arguments of science and technology which have hitherto been common sense in theories of business administration and international relations. Because of the lack of full appreciation of the paradigm shift in science and technology, these phenomena, and malfunctions such as mismatch in management practices, the paradox in economic policy and international disputes, are occurring.

Such changes are everywhere: who makes high-technology available; how it is generated; and what it is utilized for. They are in the field of manufacturing companies, and in their principal business: the economic actors by whom high-technology is brought into the market. They are in research and development (R&D) activities, and in technology development processes: the human intellectual activities which generate high-technology. They are also in the innovation pattern, and in technology diffusion: the societal process through which high-technology is realized.

First, a fundamental redefinition of the manufacturing company is taking place. The manufacturing company is traditionally a site for production and the economist's formulation is a production function: capital plus labor make things. But in many Japanese manufacturing companies, R&D investment is much *greater* than capital investment. R&D investment surpassed capital investment quite recently and the change occurred rapidly. This signals a paradigm shift; if R&D investment begins to surpass capital investment the corporation could be said to be shifting from being a place for *production* to being a place for *thinking*.

Second, there are changes in business. In the past, one technology used to correspond to company. 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.

Corporate diversification in the United States is mostly the result of mergers and acquisitions (M&A). According to several analyses there, corporate growth through diversification is surprisingly low, and many attempts at diversification have even ended in failure. However, US analyses of diversification through M&A cannot explain the Japanese situation. Today's leading Japanese firms have entered the stage where they survive by adapting to the environment, relying on consistent, dependable R&D.

Third, major changes are observed in the field of research investment decision-making in industry. Investment decisions are no longer based on rates of return. It is more like the principle of surf-riding: the waves of innovations come one after another and you have to invest; if you miss you are killed. The pattern of competition is also changing; the competitor used to be another company within the same industrial sector, but in many cases nowadays the competitor is a company in a different industrial sector.

As the challenge for high-tech leadership could come from seemingly unrelated industries, without regard to country of origin, international agreements among companies in the same industrial sector to avoid protectionist pressure could easily be rendered meaningless. Conversely, companies could form technological alliances across national and industrial boundaries, competing for development with each other. High technology may thus change the conventional wisdom, the common sense in theories of business administration and international relations.

Fourth, there are changes in the technology development process. In the high-tech era, the key issue of technology policy has become not how to break through technological bottlenecks, but how to put existing technology to the best possible use. Accordingly, a day of reckoning has come for technology policy, which traditionally has emphasized the supply side of technology development. A need has now arisen for a technology policy which works from the demand side.

In developing new policies to meet this need, the most important element is the process of 'demand articulation'. Through this process, the need for a specific technology manifests itself and the R&D effort is targeted toward developing and perfecting it.

The public policy implication can be found in the Japanese government-sponsored research consortia. One which caught particular international attention was the VLSI (very large scale integration) research association which included all five of Japan's IC (integrated circuit) chip manufacturers at the time. In this research association, rather than focusing on the method of production itself, research efforts emphasized developing a prototype for IC manufacturing equipment and analyzing a process for the crystallization of silicon. In other words, potential users of optical steppers and of silicon materials joined together to articulate their needs.

In the United States, pre-competitive research is usually carried out at a university under the sponsorship of several private corporations. This represents a chronological concept of technological innovation, in which research begins at the scientific stage and progresses through the application and development stages. In Japan, however, pre-competitive research achieved through research associations is better represented by plotting industrial linkages on a graph of coordinates, in which the goal is to create an engineering infrastructure as the basis for competition. The key point to bear in mind is that there exist two separate types of pre-competitive research.

Fifth, there are the changes in innovation patterns. Conventional wisdom holds that technical innovation is achieved by breaking through the boundaries of existing technology. With regard to recent innovations in new fields such as mechatronics and optoelectronics, however, it would be more appropriate to view innovation as fusing different types of technology rather than as technical breakthroughs.

There are two types of technical innovation. One is the traditional 'technical breakthrough', of which the transistor offers a typical example. This appears to be the forte of the West. Another is 'technology fusion', a typical example of which would be the mechatronics revolution. This type of innovation is Japan's strong point.

Our analysis will clearly suggest that the technical innovations involved in high technology are more of the fusion type than of the breakthrough type. Expressed more accurately, a single technical breakthrough alone is not sufficient for progress in high technology. Rather, only through the organic fusing of several technical breakthroughs in a number of different fields can a new technology be created.

The *last* change is the technology diffusion that reflects a shift from technical change to institutional inertia. According to Christopher Freeman, the widespread generalization of information technology, not only in the 'leading' branches but also in many branches of the economy, is possible only after a period of change and adaptation of many social institutions to the potential of the new technology. Whereas technological change is often very rapid, there is usually a great deal of inertia in social institutions.

The diffusion of facsimile communication in Japan was not initiated before the revision of the Public Telecommunication Law. On the other hand, the diffusion of CAT (computerized axial tomography) scanners in Japan is a case where the relevancy of this technology to institutional changes accelerated rather than discouraged acceptance. If a technology is very novel to users and has an intrinsic usefulness to them, as occurred with CAT scanners, the introduction of the new technology triggers a chain reaction of institutional changes which creates a favorable environment for the rapid diffusion of the new technology.

The quantitative analysis of computer diffusion in the forty-seven Japanese prefectural governments reveals that its diffusion process is not as simple as described so far in terms of technoeconomic paradigm changes. Our study yields two levels of dichotomy. One dichotomy is between organizational complexity and technical complexity. Organizational inertia is in fact a determinant of the diffusion of computer utilization when computers are applied to those activities which are complex organizationally. The other dichotomy is between technologies applied to old activities and those applied to new activities. Institutional inertia is not critical to the diffusion of computers applied to new activities for which the institutional framework is not yet fully developed.

These six categories of paradigm shift are summarized in Table 1.1. All categories are derived from my past studies published in various academic and professional journals. Before going into detail, however, I am going to highlight these categories of techno-paradigm shift.

Table 1.1 Six categories of techno-paradigm shift

1.	Manufacturing companies: from *producing* to *thinking organization*
2.	Business dynamics: from *single technology* to *technology diversification*
3.	R&D activities: from *visible competitors* to *invisible enemies*
4.	Technology development: from *linear progression* to *demand articulation*
5.	Innovation patterns: from *technical breakthrough* to *technology fusion*
6.	Technology diffusion: from *technical change* to *institutional inertia*

1. Shift in manufacturing companies

Manufacturing companies are the primary participants in technological innovation; the leading factor in the various changes in this field is