Why did Japanese producers perform very well in manufacturing automobiles and electronic appliances during the 1970s and 1980s, but did quite poorly in providing PC and other IT services in the 1990s?

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1. INTRODUCTION

1.1. Summary

There is a remarkable difference in the overall performance of Japanese producers relative to American ones in the 1970-80s and in the 1990s. Japanese corporations performed very well in producing automobiles and electronic appliances in the 1970-80s, but they did quite poorly in producing personal computers (PC) and information-telecommunications (IT) services in the 1990s. This paper attempts to explain this difference. First, a brief summary of the growth of the postwar Japanese economy is given with emphasis on the importance of *strategic industries* (Section 2). The paper then discusses the characteristics of the process in which each product or service is created, produced, and improved (Section 3).

To lay a basis of the analysis in this paper, we consider the coordination for production by workers of corporations (Section 4). Two measures will be introduced to characterize coordination: *width* and *depth*. The width is the size of the range of coordination activities; it may be expressed by the number of workers who participate to the coordination in question. The depth is the average intensity of coordination activities; it may be represented by the degree at which coordinating workers understand each other. It is pointed out that the relative importance of the width and the depth of coordination differs depending on the characteristics of each product or service. On one hand, the depth plays an important role in producing such products as automobiles and electronic appliances. On the other hand, the width is more important in producing network-type products such as PC, hardware or software, and IT services.

The paper then compares Japanese corporations with American ones with respect to the width and the depth of coordination (Section 5). In average, the depth of coordination is greater with Japanese corporations, whereas the width of coordination is with American corporations. Thus, the difference in the performance of Japanese corporations between the 1970-80s and the 1990s came from the shift in the strategic industry of Japan from automobiles and electronic appliances to PC and IT services. Comparative advantage of Japanese corporations was changed in accordance with the difference in the characteristics of coordination between the two countries. The paper concludes with other explanations of the absence of comparative advantage in the PC and IT industries in Japan (Section 6).

1.2. Background

This paper is a case study in the economic theory of organization and information, of which Professor Don Lamberton played a pioneering role in the 1970s and 1980s.[1] The theory emphasizes the importance of the flow of information in the functioning of various economic organizations, such as firms, corporations, governments, nonprofit institutions, and the society as a whole.[2] Coordination is the form of work in economic organizations, and the flow of information is a primary means for coordination. This paper presents an approach for characterizing economic organizations; it is the distinction of wide and deep coordination. The distinction is related to, but not the same as, that of market and command, or that of centralization and decentralization (see Section 4.1 for details).

Japanese organizations, particularly Japanese corporations, have drawn close attention by research scholars since the 1980s, because the performance of Japanese corporations in manufacturing, especially in automobiles and electronic appliances, was high in the 1970s and 1980s. Attempts were made to explain the source of the high performance of Japanese corporations; the underlying structure of the Japanese society was also investigated.[3] It was pointed out that the *coordination of the Japanese style*, such as seen in tightly-formed workgroups, close relation between labor and management, and lifetime employment, contributed significantly to the high performance of Japanese corporations.

In the 1990s, the growth center of the economy in advanced countries was shifted gradually from manufacturing to PC and IT industries. This trend has been studied by a group of social scientists, Professor Lamberton being and an active leader in this research area.[4] Recently, however, it was pointed out in Japan that the growth of Japanese PC and IT industries was far slower than those of U.S. and in other advanced countries. Research workers have attempted to explain this observation,[5] but no agreement has been reached as to its cause. The main objective of this paper is to provide an explanation of this observation from the standpoint of the distinction of deep and wide coordination.

2. COMPARATIVE ADVANTAGE IN THE JAPANESE ECONOMY

2.1. The role of strategic industries

The development of the Japanese economy during the postwar period depended on the success of a small number of strategic industries. The Japanese economy, at each stage of its development, was able to generate one or two strategic industries having the capability of exporting goods to the world market. In the 1950s, textile industry was the driving force of the economy, and in the 1960s, ship-building industry became the most important exporting sector. Iron and steel industry was the source of development of the Japanese economy in the 1970s. Since the beginning of the 1980s, two industries, automobiles and electronic appliances, have been contributing to the Japanese economy as major strategic industries. From this observation arises naturally a question "what industry(ies), if any, will become strategic to the Japanese economy for the coming age?"

The determination of strategic industry depends on the level of technological development, the skill and the cost of the labor force, the availability of capital and money, and above all the structure of the world trade market. This is nothing but an application of the principle of comparative advantage in the international division of labor. Until the middle of the 1980s, the core of the development of the Japanese economy was in the manufacturing sector, from which all of the Japanese strategic industries emerged. The sectoral composition in the overall economic trend was changed in the 1980s; the service sector, particularly the IT-related industries, became the main source of economic growth.

In the 1990s, actually, the Japanese economy has not been able to find a new strategic industry; it is merely riding on the momentum from the past. A significant portion of the two strategic industries in the 1980s, i.e., the automobile and the electronic appliance industries, has moved to other East- and Southeast Asian countries. Automobiles are still assembled in, and exported from, Japan, but a large portion of the parts of automobiles produced in Japan is imported today. Factories of electronic appliances have also moved out of Japan, although products with high value-added can still be produced competitively within Japan. It is clear that Japan is rapidly losing comparative advantage in automobiles and electronic appliances; without some new strategic industries, Japan will likely face a squeeze from the international balance of trade in the future. In the worst case, the level of per capita GNP in Japan may start decreasing.

2.2. PC and IT industries in Japan

The need for strategic industries to the Japanese economy has long been recognized by MITI (the Japanese Ministry of International Trade and Industry). For most of the industries strategic to the Japanese economy in the past, MITI adopted industrial policies such as protection during the period of infancy and promotion of research and development. Most of MITI's policies were successful and contributed greatly to the growth of the Japanese economy.

In as early as the mid 1960s, MITI considered the computer industry (of mainframe computers, then) to become a potentially strategic industry to the Japanese economy in the coming age. MITI, together with NTT (the NTT Public Corporation, then), protected and subsidized "NTT-family manufactures" of telecommunications equipment so that they might become competitive producers of mainframes. As a consequence, major computer manufactures in Japan, such as NEC, Fujitsu, Hitachi, and Toshiba, survived within Japan under the worldwide dominance by IBM. Further, starting in the late 1970s, MITI also subsidized research and development for LSI (Large Scale Integrated circuits) by these manufactures; consequently, the productivity of LSI memories in Japan was raised significantly toward the middle of the 1980s to the extent that trade frictions took place between U.S. and Japan.

The personal computer industry (PC industry) was born in the beginning of the 1980s. During the 15 years after its birth, the PC industry grew virtually from nothing to the size comparable to that of the telecommunications industry or of the broadcast industry. As is widely known, PC is a child of the mainframe computer. By the time PC was born, the design and the operation of mainframe computers had been well developed. The distinction between hardware, operating systems, and applications software had already been established. The main objective at the time of the birth of PC was how to create a new type of computer which is smaller in size, and cheaper in value, than mainframes. The drive for creating PCs was promoted by the emergence of LSI. In particular, the advent of MPU (Microcomputer Possessing Unit, or CPU: Central Possessing Unit) was a key factor in the creation of PCs. Thus at the time that PC was first marketed in U.S., European countries, and Japan, the idea of PC today was already there. In short, it was considered to be a miniature of mainframes.

When the production of personal computers (PCs) was started in the early 1980s, however, MITI adopted virtually no industrial policy for the PC industry. The Japanese PC industry was put into competitive environment, although MITI did not advertise as such. Probably, MITI was too busy with the LSI industry to extend protection to the emerging PC industry. MITI may have considered LSIs as an indispensable element in almost all industrial activities, whereas the PC industry as a branch application of LSIs. Also, MITI may have adopted no industrial policy for the PC industry since PC was considered to be a miniature of mainframes, which were the core of computer products.

There was an expectation in Japan that, because the future PC was considered to be a miniature of the mainframe, Japan should receive comparative advantage of producing PC. Japanese corporations were well known, by that time, for the capability to create miniature products such as transistor radios and portable tape recorders. Although Japanese corporations might not be able to create a new product or service from scratch, they were good in improving and trimming a product which had been produced and sold in the market. The PC in the beginning of the 1980s fitted perfectly to this frame. In addition, PC was considered to be similar to electronic appliances, for which Japanese producers possessed comparative advantage; PC, after all, is a product obtained by assembling electric and electronic parts, as electronic appliances are.

Today, we know that this expectation did not materialize. Almost all major software products used in Japan are imported from U.S., though minor changes of rewriting the language from English to Japanese may be made in Japan. Second, the operating system is under monopoly by the Microsoft Corporation. Third, even in the area of hardware, Japanese products barely compete with U.S. ones. New ideas in designing hardware and software seem to come exclusively from U.S. The overall performance of the Japanese PC industry, when it is compared with that of other manufacturing industries such as automobile and electronic appliances, is a disappointment to the Japanese.

The objective of this paper is to pursue an answer to the question: Why was the performance of the Japanese PC industry low relative to that of the American PC industry?

Computer software, telecommunications services, and other IT products and services were also considered in the early 1980s to be a candidate for strategic industries to the Japanese economy. Computer software is a product close to computer hardware; anyone who can produce computer hardware efficiently should be able to produce computer software efficiently. Telecommunications services can be viewed as an extension of computer services, too. First, for telecommunications, computerized equipment such as smart terminals and digital switches are widely used. Second, telecommunications network combines computers (terminals). The properties possessed by computers should therefor be shared by telecommunications network, too. Third, telecommunications network may be viewed as a giant-size computer of which the functions are not concentrated into one geographical location, but distributed and dispersed over many distant locations. In the late 1980s and the early 1990s, a great deal of effort was concentrated on producing computers, softwares, telecommunications services, etc., in Japan as efficiently as possible. The quality and the quantity of skilled labor devoted to producing them in Japan was remarkable.

The outcome from these efforts devoted in the PC and other IT industries, as we see it today, was quite different from the outcome in the automobiles and the electronic appliances industries. The objective of this paper is to explain this.

3. CHARACTERISTICS OF PRODUCTS AND SERVICES

3.1. Determinants of comparative advantage

In this paper, we will attempt to explain the presence and the absence of comparative advantage in Japan with products such as personal computers, telecommunications services, automobiles, and electronic appliances. This section is devoted to comparing the characteristics of each of these products.

In the standard textbook of economics, it is stated that comparative advantage of a product is determined by technology and factor endowments. Such a statement may be appropriate to explain the difference in comparative advantage *at large*, say, the one between agriculture and manufacturing, or the one between light-weight manufacturing and heavy-weight manufacturing.

In this paper, however, we are concerned with comparative advantage of products classified into finer categories; say, personal computers and electronic appliances. For such a microscopic comparison, factor endowment such as the capital-labor ratio is not important; the main determinant of comparative advantage should be sought with some aspects of technology and management spelled out in more detail.

We need to consider technology and management for creating and developing a new product, for constructing a production system, and for improving the product and the production system. The level of technology and management appropriate for this kind of analysis depends on the quality and the type of technology-oriented workers and how they are organized. It should be the case that some difference in the characteristics between PC and electronic appliances, on one hand, and the level of technology and management of producer corporations, on the other hand, *interact* each other to generate the presence or the absence of comparative advantage.

In the remaining portion of this section, we will consider the difference in the characteristics of products we are interested in. In the following part of this section, we will consider the characteristics of technology and management.

3.2. Comparison of the structure of products and services

Tables 1 and 2 list the products (and services) we will work on in this paper. We are interested in PC and IT-related products such as telecommunications hardware/infrastructure and software/services, as they are candidates for strategic industries to the Japanese economy in the future. For the sake of comparison, we also consider automobiles and electronic appliances, since Japan obtained comparative advantage on them in the 1980s. We also consider LSI (CPU and memories), since Japan also obtained *imperfect* comparative advantage on LSI memories in the 1980s, and LSI is information-related products. Thus, we will consider eight products altogether: telecommunications hardware/infrastructure, telecommunications software/services, PC hardware, PC software, automobiles, electronic appliances, LSI used as CPU for PC, and LSI used for memories of PC. As stated in the preceding section, we will be interested in finding the presence of comparative advantages in Japan with automobiles and electronic appliances in the 1970-80s, and the absence of comparative advantages with telecommunications hardware/infrastructure, telecommunications software/services, PC hardware, and PC software in the 1980-90s.

In general, a product has many characteristics, such as physical properties, economic data, utility to users, characteristics in the production process, and so on. We will be concerned with those characteristics which have direct relationships with the level of technology and management. In particular, we will compare these eight products from two standpoints: the structure of each of the products and the characteristics of research and development for each of the products. In addition, we also compare each of the products in terms of institutional factors affecting free entry and promotion of competition.

In the second row of each of Tables 1 and 2 is entered the location of comparative advantage for each of these products. On one hand, U.S. has comparative advantage on telecommunications software/services, PC hardware and software, and LSI, particularly CPU. On the other hand, Japan has comparative advantage on automobiles and electronic appliances. Comparative advantage on telecommunications hardware/infrastructure and LSI for memories is shared by U.S. and Japan.

We first concentrate on the physical and the functional structure of each of the eight products. It is seen that the first six products in Table 1 are produced by combining parts, i.e., by assembling components. Telecommunications hardware/infrastructure is a network system, which is composed of cables, switches, terminal equipment, and others. PC hardware is far smaller than telecommunications hardware/infrastructure, but it is composed of components, too. Telecommunications software/services and PC software are information products, i.e., *software-type products.* A software-type product is a collection of steps (i.e., orders or instructions) to be followed by a computer hardware (for the case of PC) or by telecommunications network system (for the case of telecommunications services). Frequently, the steps composing a software-type product are grouped into a set of subprograms. Furthermore, subprograms are grouped into upper-level programs, and so on; the entire system possesses a hierarchical structure. Unlike telecommunications hardware/infrastructure or PC hardware, the components of a software product are combined not physically, but informationally. As a consequence, as indicated in Table 1, the degree of flexibility of an interface among the components of a product differs depending on whether the product is assembled physically or assembled logically. Software interfaces are flexible so that a portion of a product can easily be changed or replaced. The same is true with telecommunications hardware/infrastructure or with PC hardware. The interface between their components, however, is less flexible; it needs more work to replace a part of the hardware product than a part of the software product.

Automobiles and electronic appliances, too, are produced by assembling parts. Needless to say, they are hardware products. In that sense, they are similar to telecommunications hardware/infrastructure and PC hardware. However, the interface between hardware components is stronger with automobiles and electronic appliances than with telecommunications hardware/infrastructure or PC hardware. It is rare, if not impossible, to replace a part of an automobile with a different part except for consumables such as tires or batteries. One could modify a part of an automobile, e.g., a steering wheel, if one would like to do so. However, such modification or replacement is not common. Certainly, such is not intended at the time the automobile was designed. For the case of electronic appliances, replacing a part of a product does not occur except when a part is broken. As a consequence of this, every part of an automobile or of an electronic appliance is designed to wear out at approximately the same time. In comparison with this, a part of telecommunications hardware/infrastructure or a part of PC hardware can be replaced or upgraded at the user's convenience.

In summary, the degree of the flexibility of interfaces is highest with telecommunications and PC software, second highest with telecommunications hardware/infrastructure and PC hardware, and lowest with automobiles and electronic appliances.

The last two products in Table 1, CPU and memories for PC, are produced in one piece; they are fabricated, not assembled. Hence, there is no possibility of upgrading CPU or memories by replacing a portion of it, though upgrading is possible by replacing the entire unit. When a part of the product is broken, there is no way to fix it. For this reason, we can state that, although LSI is produced for information processing, it is structurally closer to automobiles and electronic appliances than to telecommunications hardware/infrastructure or PC hardware.

3.3. Comparison of R&D for products and services

The characteristics of the structure of each of the eight products are reflected in the way R&D is carried out. The rows of Table 2, i.e., "Characteristics of R&D," summarizes it.

First of all, we compare the amount of R&D investment for each product. For telecommunications hardware/infrastructure, the size of R&D investment is large, since telecommunications network is large and expensive and is extended to the entire country. For example, a switch for telecommunications exchange is shared by, say, one thousand subscribers, and an optical fiber can transmit one thousand telephone calls at the same time. It pays to invest a large amount of money to develop a new type of telecommunications switch.

The size of R&D investment needed to develop a piece of software or a service may not be as large as in telecommunications hardware/infrastructure. The exact amount of investment, of course, depends upon the function of the software or the contents of the service.

When it comes to personal computers, the size of R&D investment for hardware and software is far smaller than that for telecommunications, since the economic size of a telecommunications network and the economic size of a PC is very much different. In Table 2, the size of R&D investment for PC hardware and PC software is indicated respectively as Medium and Small.

Automobiles need a large amount of R&D investment but a medium gestation period. The size of R&D investment for electronic appliances is smaller, and its gestation period is shorter, than automobiles. This comes from the fact that the average price of electronic appliances is far lower than the price of automobiles.

LSIs are very small in size but the size of R&D investment is large and the gestation period is long, particularly so for CPU. It is reported that the initial design of 32-bit CPU architecture was started in as early as the middle of 1970s, 20 years before the shipment of Intel 486, the first 32-bit CPU. Even for memories, the size of R&D investment is very high and the gestation period extends for several years.

4. CHARACTERISTICS OF COORDINATION

4.1. Width and depth of coordination

All of the products listed in Tables 1 and 2 are outcome of sophisticated engineering and managerial efforts. A single output relies on the coordination of a large number of workers, professional and others. For this reason, the way in which the coordination for production is achieved affects strongly on the quality and the price of each of these products. In this paper, we attempt to explain the presence or the absence of comparative advantage in U.S. and Japan with each of these products from the difference in coordination between the two countries. To do this, we first describe the characteristics of coordination in U.S. and Japan.

To avoid possible misunderstanding or confusion, let me clarify the meaning of *coordination* to be used in this paper. In general, coordination in economic activities indicates the fact that goods and services are produced by combining the labor of more than one workers of different skills. Thus, coordination always comes with division of labor. A classical example of coordination by Adam Smith is the one in a factory of pins. Today, coordination exists within a large corporation composed not only of factories but also of headquarters, administration offices, warehouses, and other branches engaging in various functions. Coordination also exists between corporations, as between the supplier and the buyer of a part of the output produced by the buyer.

Economic theory commonly states that sellers and buyers of a product coordinate in the market; they are guided by the price of the product working as a signal. In this paper, we deal with the coordination on the supply side of a market (i.e., coordination between the producers of the goods) , since our objective is to compare comparative advantage between Japan and U.S. in a particular industry. Thus, we will talk about coordination, e.g., between producers of PC in U.S. and that in Japan.

Coordination on the supply side of a particular industry may be dealt with from a variety of viewpoints. Rather than attempting to list all of the possible coordinations on the supply side, we will pick up those coordinations which play an important role in the determination of comparative advantage in U.S. and Japan.

In general, comparative advantage obtains when the product is supplied with high quality and low price. Therefore, we will concentrate on the coordination which is useful to bring about quality improvement and price reduction. There are two areas of activities which affect the quality and the price of a product: R&D and production management. In the following, we will focus our attention on coordination in these two areas of activities. Thus, we are going to compare coordination in U.S. and coordination in Japan in R&D and production management. In order to express the difference in coordination between Japan and U.S., we consider certain attributes of coordination. In this paper, we will be interested in the *width* of coordination and the *depth* of coordination.

The width of particular coordination is the size of the range of coordination activities; it is typically expressed by the number of workers who are directly or indirectly involved in the coordination. For example, when we consider research and development in designing a new type of LSI, the number of workers comprising the team engaged in the development of the new type is the width of the coordination. When telecommunications provider considers offering a new type of service on its network and decides to purchase a software which can realize the contemplated service, then the width is expressed by the sum of the numbers of workers participating to the teams of software venders which can, and are willing to, sell appropriate software to the telecommunications provider. When several software venders compete each other and only one of them can sell a product to the telecommunications provider, we still consider the size of the coordination to be the sum of the numbers of the workers in all of the software venders which could sell their product to the telecommunications provider.

The depth of coordination is the average intensity of coordination activities; it indicates how closely the activities for the coordination are combined. It may be called the strength, or the density, of the coordination. Roughly speaking, the depth of coordination is the amount of the information which needs to flow between the workers engaging in that coordination. For example, in a team engaged in research and development for a new type of automobiles, the design work needs a lot of information exchange between the members of the team; thus, the depth of such coordination is very large. In reality, the workers of such a team need to talk a lot each other, need to pass and receive many documents and diagrams, need to meet many times in conferences, and so on.

The attributes of coordination are not limited to width or depth. We may consider a large number of attributes of coordination, since coordination is a form of human activities by many workers and, consequently, there is a large number of viewpoints to characterize a coordination. In this paper, however, we will limit our attension to width and depth only, since these two are by far the most important in determining comparative advantage on the products listed in Tables 1 and 2.

4.2. Comparison of coordination in U.S. and Japan

We next compare the coordination on the supply side of production in U.S. and Japan in terms of width and depth. Coordination within a large corporation may, to some extent, be similar between U.S. and Japan. The development of a new product is done in the R&D department. For the case of automobiles and LSI memories, a large-sized team is formed within the R&D department to develop a new model. For the case of telecommunications software/services and the case of electronic appliances, multiple teams for developing a new product or a service may be formed in a corporation; in many cases, they compete each other. From the standpoint of the corporation as a whole, it pays even if only one of the teams succeeds and all the other teams do not. In a large corporation, R&D is performed, and the resources for R&D are supplied, mostly within the corporation.

When it comes to production management, Japanese corporations are known for their *lean production management*. In many cases, production activities are performed by a number of teams of relatively small size; the number of the workers of a team for production is somewhere between five to fifteen. The width of coordination in such a team is limited, though the depth is large. Every member of a team knows everybody else very well; e.g., not only of what task a team member is assigned to but also how the assignment is performed by the team member is known. Thus, when something unusual takes place, such as the case that a part of the machine being used by the team breaks down, or the case that one of the team members becomes absent for several days, it is still possible for some other team members to take over whatever task is to be done without significantly lowering the efficiency of the team work as a whole. A number of efforts to strengthen the depth of coordination in such a team is performed even outside the workhours. For example, team members frequently go out to dine or have a party together in order to get to know well. The system of *permanent employment*, which is common among Japanese corporations, helps deep coordination be formed.

Thus, a prominent characteristic of Japanese coordination lies in its depth. The cost of having deep coordination, naturally, is the width of coordination, which is usually small in Japanese corporations. Since the workers in a team tend to communicate intimately with a relatively small number of fellow workers, a solid team is formed as a consequence, and it is difficult to form a team of large size. In the typical case, Japanese workers do not communicate with others outside their own team.

This characteristic of Japanese coordination may be viewed as a culture or tradition of the Japanese society. Japanese people are educated from childhood to adapt themselves to such environment. Almost all of the social structures in Japan are formed to support, and to be supported by, Japanese-type coordination. In short, we can regard it as a Japanese culture. To seek the origin of this culture, or to seek the elements supporting this culture, is an interesting research subject. In this paper, however, we will not be concerned with investigating this question.

In general, coordination in U.S., in contrast to that in Japan, can be characterized by its width. In U.S., the importance of communication with fellow workers in their team is not as high as in Japan. Instead, U.S. workers spend more time and efforts to communicate with workers outside their team. Again, this is a culture of the American society. In this paper, we accept this finding as given and consider its implications; we will not explore its origin or the factors supporting it.

First of all, the labor mobility is higher in U.S. than in Japan; in particular, there is no permanent employment in U.S. There are workers in U.S. who continue to stay in one organization for a long time as a consequence of their own choice and their employer's choice. There is certainly cost to the worker of moving from one organization to another, and also there is cost to the employer of replacing a worker for another. In Japan, both the cost of changing a place to work and the cost of replacing a worker is extremely high. In U.S., it is not so high. The difference is a matter of degree. The high cost of moving and replacing in Japan may be a source of, and also a consequence from, deep coordination.

An implication of wide coordination in U.S. is that the domain of procurement for a product is wide. Thus, U.S. corporations purchase from suppliers outside their own organizations as well as inside. One could say that U.S. producers are more open to outside than Japanese producers are.

5. EXPLANATION OF COMPARATIVE ADVANTAGE

5.1. Automobiles and electronic appliances

In this section, we attempt to explain the presence or the absence of comparative advantage in U.S. or Japan for each of the eight products listed in Tables 1 and 2 from the difference in the characteristics of coordination between the two countries.

Japan obtained comparative advantage on automobiles and electronic appliances in the 1980s, and the value of export of these products has been the greatest among all of the Japanese exporting industries through the 1990s; they are the strategic industries of Japan at the present time.

Automobiles and electronic appliances have more similarities than differences according to the characteristics listed in Tables 1 and 2. These products are assembled from parts, and the interface between the components of a product is strong for both of them. R&D for improving a product and for developing a new model is done mostly within the producer corporation. The difference between automobiles and electronic appliances come from the difference in the unit price. Roughly speaking, the average price of an automobile is ten to twenty-five times greater than the average price of an electronic appliance. Consequently, the number of models supplied by a producer is far greater with electronic appliances than with automobiles.

Both of R&D and production management in automobiles and electronic appliances fit to Japanese-type coordination. The development of a new product is done entirely within the producer by a team of workers coordinating closely; i.e., under deep coordination. The average size of an R&D team in automobiles is far greater than the size of an R&D team in electronic appliances. In automobiles, the overall design of a new model is determined by the time that the development project is started, so that every R&D team, responsible for the detailed design of the model, is supposed to be successful in its project. The exception to this is the team for basic research such as one developing a new technology. In electronic appliances, when R&D for a new product is started, multiple R&D teams are formed to search diversified possibilities of development. Each team works more or less independently and, say, one out of ten R&D teams succeeds in average. The reward to each of the R&D teams, however, is not much different (except for an exceptional contribution).

Thus, the way R&D is performed in the automobiles and the electronic appliances industries is similar, although the average size of an R&D team is different between them; an

R&D team attempts to coordinate closely to combine the best outcome from each member of the team. Such an objective is best carried out in Japanese corporations relying on deep coordination.

Deep coordination in each team plays an important role in integrating the work of the members of the team. A team does everything for developing and designing a new product; coordination is limited within the team. Different parts of the new product are designed by different members of the team. Without deep coordination, there will be misfits and contradictions between the components of the new product. The best output from all of the components will be achieved by a team under deep coordination.

In the production management of automobiles and electronic appliances, too, the Japanese-type coordination works very well. The production of an automobile or of an electronic appliance starts with the production of each of its parts. In many cases, parts producers in Japan are subsidiaries of the producer corporation and receive close controls from it. Deep coordination is observed in the relation between the parent and the subsidiary corporations. This is desirable since automobiles and electronic appliances are produced in a large quantity. Once a model is developed and designed, and a production management system is established, the main objective is to maintain a smooth stream of production from parts to the final product. Minor improvements for minimizing the damage from troubles in the production system and for leading to cost reduction are quite effective. In Japanese corporations, such minor improvements are realized through deep coordination.

By exploiting the advantage of deep coordination, Japanese producers of automobiles and electronic appliances succeeded in model development and cost reduction in the 1980s to obtain a large share in Japan's total export. Even today, the comparative advantage with automobiles and electronic appliances still stays in Japan.

5.2. LSI: CPU and memories for PC

LSI (large-scale integrated circuits), as the name suggests, is produced in one piece, i.e., it is an integrated product. The ways in which CPU and memories are designed are the same except that the degree of complexity of circuits is far greater with CPU than with memories. The design and the development of LSI should be performed by a team with deep coordination. Further, production management of LSI, CPU, or memories, also calls for deep coordination. Once a particular model of CPU or of memories is established and its production is started, the production line should be managed and maintained by a team with deep coordination. For instance, maintenance of clean-air environment is vital to the rate of good turnaround in LSI production. Lack of deep coordination may contaminates only a tiny portion of the product, leading to massive discard of products.

Minor and partial improvements of a production line of LSI is not inconceivable, but such would hurt the advantage of large-scale production. The production of LSI is similar to the production of information in that the initial investment is very high but the marginal cost of production is low, since the production of each piece is done basically by copying the mother circuits.

Such characteristics of R&D and production management of LSI should fit to Japanese-type corporations, since deep, rather than wide, coordination is called for. However, in reality, the supply of CPU for PC has been effectively monopolized by the Intel Corporation, a U.S. producer. This comparative advantage in producing CPU with U.S. came not from the difference in the mode of coordination, but from the natural monopoly for technical reasons. Intel started producing CPU in the early 1970s and have kept the monopoly of each of the successive CPU models until today.

Comparative advantage for producing LSI memories has been shared by U.S. and Japan since the middle of the 1980s. Initially, U.S. had comparative advantage on memories. In the middle of the 1980s, MITI of Japan led major Japanese corporations such as NEC, Hitachi, and others, to promote intensive R&D for producing LSI memories. These Japanese corporations paid a great deal of effort to establish and improve an efficient production line for memories, thereby increasing the rate of good turnaround and decreasing the unit cost. The export of LSI memories from Japan to U.S. was increased significantly in the middle of the 1980s; trade wars on chips between U.S. and Japan took place. In the middle of the 1990s, U.S. and Japan share the comparative advantage of LSI memories; they both export and import, and the trade balance of chips between the two countries is somehow maintained. Recently, Japanese corporations tend to produce ASICs (Application Specific Integrated Circuits), of which the characteristics lie between CPU and memories.

5.3. PC hardware and software

PC hardware is a physical product assembled from components such as CPU, hard disks, a keyboard, a display, and others. Each component of PC hardware can be designed and produced independently of others, since the interface through which a component is combined with other components of PC hardware is standardized and predetermined. In other words, PC hardware is a single product in the usual sense, but it is not a single product in the following sense: PC hardware is a collection of components (products) connected each other systematically but loosely. In this sense, a PC hardware is like a network; a component may be replaced or upgraded as long as the interface requirement is satisfied. In this paper, we call such a product a *network-type product*.

Historically, the design of PC was derived from that of the mainframe. In this sense, PC is a miniature descendant of mainframes. Since Japan was successful in producing miniature products such as transistor radios and cassette tape recorders in the 1960-70s, it was expected in Japan at the time PC emerged for the first time that Japan should be able to obtain comparative advantage of producing PC. Actually, Japan did not. From the time PC was produced in a large number in the early 1980s, i.e., the time the IBM PC was introduced and dominated the business PC market, U.S. kept significant comparative advantage of producing PC. Until 1992, however, the Japanese PC market was effectively separated from the U.S. market for the reason of language difference. In 1992, however, thanks to significant technological progress, the language barrier was removed and a rapid increase in the import of PC from U.S. to Japan started. The average price of PC in Japan, as a consequence of this, dropped by 50% within a year. Major Japanese corporations producing PC have been struggling to keep their share in Japan by giving up most of the profits they had enjoyed prior to 1992. Since the size of Japanese PC producers are large and they diversify into the production of other computer-related products and communication equipment, they can afford to do that.

What was the reason that U.S. obtained comparative advantage in producing PC hardware? The answer is the efficiency achieved by wide coordination. The fact that PC is a network-type product, and not a product like automobiles or electronic appliances, of which the components are combined tightly and does not allow partial replacement of upgrading, made R&D based on wide coordination very effective. Specifically, PC hardware producers in U.S. seek the source of their components not only within U.S. but also worldwide. In the late 1980s, Taiwan became a base supplying efficient and inexpensive components of PC to U.S. producers. In the early 1990s, Singapore, Malaysia, and other ASEAN countries joined. Japanese PC producers tried hard to develop and produce their own parts for PC. Because of the lack of wide coordination with them, they ended up with products far more expensive than the products from U.S. producers.

Japanese corporations, however, are still strong in producing certain hardwares such as displays for PC. A display, in effect, is an electronic appliance; it is in no sense a network-type product; Japanese corporations having deep coordination worked well in producing such products.

Comparative advantage of PC software is possessed by U.S. more than comparative advantage for PC hardware is. Whereas PC hardware is a physical product assembled from components, PC software is an information product assembled from logical components. Aside from this difference, PC hardware and PC software are alike each other in their structure and in their characteristics for R&D. Software can be replaced partially and upgraded almost freely. The design and the development of a software component can be done quite independently from the entire software product, since, as PC hardware, the interface between software components (i.e., subprograms) and the main software is well established. Thus, software can be produced and improved component-wise, making the presence of wide coordination very effective. For this and other reasons, Japan imports most of the major softwares from U.S., and Japanese export of softwares to U.S. is virtually nil.

5.4. Telecommunications hardware/infrastructure and telecommunications software/services

When considering comparative advantage in telecommunications hardware/infrastructure and software/services, we should note that there is a couple of major differences here from the products we have been analyzing. One difference is that telecommunications services cannot be exported or imported, since it is provided on the spot by combining the productive factors located near to the user. (There is an exception to this; international telephone services today may be imported through *call back* services.) The second difference between telecommunications and other products is that public regulations play an important role in telecommunications. Historical and technological reasons calling for public regulations are well known. In this section, we limit our attention to the implications on comparative advantage in telecommunications to that arising from the characteristics of product or service only.

Telecommunications hardware/infrastructure, when considered logically and functionally, is similar to PC hardware. It is made of physical components of a network-type product (system) for processing (transmitting and exchanging) information. In other words, telecommunications network is like a very sophisticated and large-scale PC of which the components are located separately but connected each other. Of course, the physical and the economic scale of telecommunications network is far greater than those of PC, and the number of users of telecommunications network is also far greater than that of PC. In spite of these differences in scale, telecommunications hardware/infrastructure is structurally similar to PC hardware. In particular, a portion of telecommunications network can be replaced and upgraded freely. Such a partial improvement is a daily matter in the operation of telecommunications network. Since, however, a component of telecommunications network such as local and long-distance switches or cables is large in scale and high in value, a component of telecommunications network itself may be considered as a sophisticated electronic appliance. In producing such a product, not only wide coordination but also deep coordination may be effective. This is a part of the reason that Japan possesses some comparative advantage in producing telecommunications hardware.

Telecommunications software/services are like PC software. They are information products to be designed and improved logically. The reason that U.S. has comparative advantage with PC software applies equally to telecommunications software/services. As in telecommunications hardware/infrastructure, telecommunications software/services may not be directly exported or imported. In particular, Japanese telecommunications providers such as NTT tend to design and produce telecommunications services within the corporation. However, past records indicate that most of telecommunications services such as tone-dialing, call-forwarding, caller ID services, and others, were first created and offered in U.S.; Japan followed providing those services a number of years after they became available in U.S. If free trade prevailed with telecommunications software/services, it would have been observed that U.S. had definite comparative advantage on them. We point out that a portion of this comparative advantage must have come from the presence of wide coordination in U.S. We do not have, however, an analytical tool to determine what percentage of comparative advantage came from the difference in the type of coordination, and what percentage of it came from historical, locational, regulatory, and other differences.

6. CONCLUSION

In this paper, we attempted to explain the presence or the absence of comparative advantage with IT-related products such as PC hardware and software and telecommunications hardware/infrastructure and software/services. We have argued that one of the main reasons of the presence on the absence of comparative advantage lies in the difference in the characteristics of coordination between U.S. and Japan. Wide coordination in U.S. fits to network-type products, and deep coordination in Japan to non-network-type products. Since PC and telecommunications services, in fact almost all information-related products and services, are of network-type, U.S. naturally obtains comparative advantage on them. This is the main conclusion of this paper.

The determinants of comparative advantage, however, are not limited to the characteristics of coordination. For the case of CPU, natural monopoly arising from technological reasons is the main reason that U.S. has obtained comparative advantage on it. The same is true for PC operating systems. For the case of PC hardware, it is pointed out that the lack of effective judiciary system in Japan prevented suppliers of compatible models from entering into the market, thereby slowing down the development of competition. Furthermore, at the time that possible reorganization of NTT was discussed in Japan, it was repeatedly stated that the lack of competitive power with NTT came from excessive regulations imposed by MPT. We do not intend to deny these points. After all, comparative advantage is an outcome of multiple and complicated economic and social factors. What we have been seeking in this paper was a determinant of comparative advantage which *is common* to all information-related products and services, including PC and telecommunications services.

If the main conclusion of this paper is accepted, then the following question arises naturally: "Is it possible to introduce wide coordination into Japanese corporations to obtain comparative advantage on information-related products and services? And if so, how can that be done?" This is an open question to be investigated in the future.

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Table 1
Characteristics of IT Products/Services in Comparison with Other Products (1): Physical and Functional Structures

Products/Services	Telecom hardware/ Infrastructure	Telecom software/ Services	PC hardware	PC software	Automobiles	Electronic appliances	LSI: CPU for PC	LSI: Memories
Location of comparative advantage*	JP, US	US	(JP) US	US	JP	JP	US	JP, US
Structure of products or services								
Assembled from components (?)	Yes	Yes	Yes	Yes	Yes	Yes	No	No
Interface between components	Weak	Weak	Medium	Weak	Strong	Strong	None	None
Standardized interfaces between components (?)	Yes	Yes	Yes	Yes	No	No	NA	NA
Upgrading component	Possible	Free	Free	Free	Partially possible	Almost impossible	Impossible	Impossible
Need for balance between components	Low	Little	Low	Little	Medium	High	NA	NA

”JP” indicates Japan, “US” United States.

Table 2
Characteristics of IT Products/Services in Comparison with Other Products (2): Research and Development

Products/Services	Telecom hardware/ Infrastructure	Telecom software/ services	PC hardware	PC software	Automobiles	Electronic appliances	LSI: CPU for PC	LSI: Memories
Location of comparative advantage*	JP, US	US	(JP) US	US	JP	JP	US	JP, US
Characteristics of R&D								
Size of R&D investment	Large	Medium	Medium	Small	Large	Medium	Very large	Large
Gestation period	Very long	Medium	Medium	Short	Medium	Short	Very long	Long
Pattern of R&D organization:								
Team / Individual	Team	Individual	Individual	Individual	Team	Team	Team	Team
Centralized / Decentralized	C/D	Very D	D	Very D	C	Medium	C	C
Pattern of emergence of new products / services: (Continuous improvement / Discontinuous innovation)	Continuous and partially innovative	Continuous and innova-tive	Continuous and partially innovative	Continuous and innova-tive	Continuous improvement	Innovative	Continuous improvement and en-hancing	Continuous increase in capacity and speed
Causes preventing free entry and full competition	Remains of natural mo-nopoly/ regulation	Regulation	Patents, copyrights (on bus, BIOS)	Copyrights	None	None	Technological monopoly	Protection of circuit design

”JP” indicates Japan, “US” United States.

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[1] E.g., Lamberton (1971, 1988, 1992a).

[2] For the reseach work of economic organizations, particularly that of productive firms, during the recent years, see, e.g., Putlerman, et al (1996) and Buckley, et al (1996).

[3] See, e.g., Johnson (1982, 1995), Aoki (1988), Wolferen(1989), and the references given in these books.

[4] See Lamberton (1992b, 1993, 1995a, b).

[5] See, e.g., Kokuryo (1997), Methe, et al (1997), and MPT (1996, ch.1).