A Categorization of Technology and the History of Japanese Modern Technology

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1. INTRODUCTION

In September 1989, an interesting article entitled 'Where Japan Will Strike Next' appeared in the American business magazine *Fortune*. The article pointed out that Japanese technology has come to an end of the era of copying, and that the Japanese are confident—even arrogant—about their ability to innovate in technology.[1] Whether its analysis of the Japanese situation is valid or not, the article is impressive for Japanese readers, who have been accustomed to the long-standing view that 'the level of Japanese science and technology has been low'.

The change of view on Japanese science and technology began in the early 1980s. Since then, Japanese success has often been praised as if the original assumption of 'Japanese historical backwardness' were an illusion. Not only Japanese but people worldwide are eager to explain the mystery of 'the Japanese miracle'.

Notions of 'a Japanese miracle' seemingly contradict the conventional view of 'Japanese historical backwardness'. These two hypotheses, however, share a common presumption: that the level of Japanese technology before World War II was very low. The expression 'Japanese miracle' implies that Japan, which was

1) *Fortune*, Sep. 25, 1989: 34–43. This issue also contains an interview with Mr. MORITA Akio, the former Chairman of Sony, headlined 'A Japanese View: Why America Has Fallen Behind'.

supposedly undeveloped before World War II, became a highly-developed country in a very short period afterward. And the 'Japanese backwardness' hypothesis, of course, presupposes technological backwardness before the War.

This assumption also appears in a volume of *Nihon Kagakugijutsu-shi Taikei* (A History of Japanese Science & Technology), a kind of 'bible' for historians interested in the history of Japanese science and technology. In 1969, this work described the state of Japanese technology from the Meiji Restoration to the 1960s as follows:

> We must consider the general technological backwardness [of Japan] before [the Restoration]. ...Japan, which experienced a prolonged period of *Sakoku* [exclusion policy] and feudalism, could not develop a mature scientific atmosphere. Backwardness in science naturally led to backwardness in technology' [NIHON KAGAKUSHI GAKKAI 1969: 128]. 'The mainstream of Japanese technology came from overseas, and it is rather difficult to discover original technologies in Japan. In these contributions [of the work], we have found many distortions in Japanese engineering system. But there were few advanced technologies developed in Japan [NIHON KAGAKUSHI GAKKAI 1969: 239].

In sum, Japan supposedly lacked original inventions, but was good at copying. She was technologically behind. But is this the reality in Japanese history?

The aim of the present paper is to answer the question, employing these conceptual tools: (1) the institutionalization of technology and (2) a four-fold categorization of technology. The first conception, 'the institutionalization of technology', will be used as a standard indicator for evaluating the level of technology. Though originality has been almost the sole index to evaluate the level of technology, it should be supplemented by the idea of 'institutionalization'. With this new index, we can provide a more balanced description of the history of Japanese technological development. The four-fold categorization will be utilized to show what kind of technology is appropriate for evaluating technological capacity in modern society. 'The categorization of technology' also helps to answer the multi-faceted question: 'What is the definition of technology?'

2. THE INSTITUTIONALIZATION OF TECHNOLOGY

1) Science as a Social Institution

In his book, *Kagaku no Shakai-shi* (A Social History of Science), the late Prof. HIROSHIGE Tetsu, a well-known Japanese historian of science, criticized the catching-up historiography of Japanese science as follows:

> It is true that, in the Meiji Period, Japan endeavored to introduce science from Western countries, and treated it as something to be learned. We need not to deny the fact. But what is important is that until the middle of the nineteenth century, when Japan started to transplant science systematically,

> science had undergone substantial change from that of the seventeenth-century. ...And even in the Western countries, science was just then undergoing a process of institutionalization. Thus the transplantation of science into Japan should be regarded as part of a worldwide institutionalization of science [HIROSHIGE 1973: 15–16].

Here, Hiroshige criticizes the prevalent view of the backwardness of Japanese science, which based on the fact that Japan imported science from abroad. It is true that modern science as theoretical knowledge was developed in the West. However, science is a social institution as well. Scientific institutions were developed almost simultaneously in the West and in Japan. Thus, Hiroshige tried to introduce a new indicator of 'institutionalization' to consider the level of Japanese science in comparison with that of the West.

The 'institutionalization of science' was not his original idea. For example, Joseph Ben-David discussed it in Chapter 5 of his *Scientist's Role in Society* (1971), a standard textbook on the sociology of science. Today, 'institutionalization' is a familiar idea for researchers of science and technology studies.[2)]

Historically, the institutionalization of science followed two stages. The first step was 'the classical institutionalization of science' in the seventeenth century. Its essence was the establishment of scientific communities and the social recognition given to their activities. In England, for example, groups of natural philosophers appeared in the first half of the seventeenth century, and the Royal Society of London was chartered in 1662 by the King, Charles II. Its secretary, Henry Oldenburg, started to publish *Philosophical Transactions,* one of the first scientific journals in the world.

The second stage was the 'professionalization of science'. Even after the classical institutionalization, science was not a profession but an amateur's hobby pursued mainly by the nobles and clergy. But at the École Polytechnique, founded in France in 1794, scientists like Monge and Laplace were hired as science teachers. This was the beginning of science teaching in higher education.

The institutionalization of science was related to changes both in scientific theory and social changes in general. For example, the period of classical institutionalization of science coincides with the era of the 'Scientific Revolution'. The professionalization of science kept pace with the 'Industrial Revolution' and with the emergence of capitalism. Professionalization led to the specialization of academic disciplines. It is suggestive that professionalization and the 'second scientific revolution' happened simultaneously.[3)]

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2) [BEN-DAVID 1971]. For institutionalization of science, see also Yoshida [1980]. An interesting discussion of scientific institutionalization is found in Steven Shapin and Simon Schaffer [1985].

3) On the conception of scientific revolutions, see I.B. Cohen [1985]. The second scientific revolution is discussed in Chapter 2. The emergence of scientists in industry could be regarded as an indicator of another revolution in science. But I prefer to discuss this aspect in the context of the institutionalization of technology.

2) The Institutionalization of Technology

While the institutional approach has attracted historians of science, in technology studies there have been few discussions about the development of technological institutions and the social structures of technology development. The term 'sociology of technology' is not as popular as 'sociology of science', though the study on the 'social construction of technology' started to develop recently. However, just as in the case of science, it should be very important to follow establishments and changes of technological institutions, because they reflect changes in technology itself.

What kind of institutions have accompanied the development of technology? First, it will be possible to discuss the 'institutionalization of technology' after the manner of scientific institutionalization.

It seems appropriate to regard the guild system of engineering, based on apprenticeship, as the 'classical institutionalization of technology'. Of course, technology must have appeared when human beings emerged. The same could have been the case for scientific activities. Institutions supporting science and technology might have been very primitive at first. However, huge cathedrals in the Middle Ages could not have been constructed without social institutions. They premise a network of stonemasons, other artisans and relevant social systems.[4)]

As for modern technology, apprenticeships and guilds can no longer be components of the main technological institutions. Many contemporary engineers are graduates of universities. Not a few of them work as researchers at governmental or private research institutions. Consequently, it is proper to identify the following factors as indices of the institutionalization of technology: the appearance of technological education systems such as faculties of engineering in universities, and the emergence of governmental or private technological research laboratories. The establishment of technological societies, like the Institution of Electrical and Electronic Engineers (IEEE), to which teachers and researchers of engineering belong, can be counted as an indicator of institutionalization, too.

While these institutionalization aspects of engineering are similar to those of science, there are social aspects unique to technological activities.

In science, the priority of discoveries is settled by a more or less free consensus of members in pertinent scientific communities. In the case of engineering, however, the priority of inventions is usually decided by patents. Accordingly, the patent system is a unique institutional feature of technology.

In addition, there are laws regulating the applications of technology, such as the Electricity Enterprises Act. These laws should be included among the elements of technological institutions.

Business enterprises could also be regarded as institutions for technological

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4) Although this paper does not discuss the role of 'superior artisans' such as Leonardo da Vinci, this can be an interesting dimension of discussion.

purposes. For example, power and gas supply companies, makers of electrical equipment and home appliance firms should be included in technological institutions in the sense that technology cannot function without these systems.

Although details should be clarified by future studies, it is reasonable to conceptualize the history of technology as a development from traditional systems, based on apprenticeships and guilds, to modern systems consisting of higher education, research institutions, academic societies, engineering firms and legal systems.

Modern technological institutions, of course, do not necessarily exclude the traditional elements. As is shown in apprenticeship and craftsmanship today, current systems are based on or coexist with the elements of traditional systems.

Given this development, in what sense does the history of Japanese technology differ from (or resemble to) that of the West? It will be reasonable to assume that, as in the West, traditional institutions of technology existed in Japan before 19th century modernization. To assess the level of modern Japanese technology after the Meiji Restoration, we should consider the process of the formation of modern institutions of technology, and compare it with Western institutionalization.

3. THE INSTITUTIONALIZATION OF ELECTRICAL TECHNOLOGY IN JAPAN

1) Higher Education for Electrical Technology

As a case study, this chapter will focus on the formation of Japanese electric technology. We will compare the emergence of modern institutions for electricity in Japan with those of Europe and the United States. First, let us consider the establishment of university-level education.

In Japan higher education in engineering began at the Imperial College of Engineering (*Kōgakuryō,* which changed its Japanese name to *Kōbu Daigakkō* in 1877) under the Ministry of Public Works, (*Kōbushō*). The Imperial College of Engineering was chartered in 1871, and the first students entered it in 1873. Its initial primary aim was to supply engineers to the Ministry of Public Works, which was established to promote the absorption of Western technologies. The College consisted of seven departments: civil engineering, mechanical engineering, telegraphy, architecture, mining, applied chemistry and metallurgy. Many leading engineers in the Meiji Period graduated from these departments. When the Imperial University (*Teikoku Daigaku*) was established in Tokyo in 1886, the Imperial College became a part of its Faculty of Engineering (*Kōka Daigaku*).[5]

5) For the Imperial College of Engineering, see Nihon Kagakushi Gakkai [1964], Nakayama [1978], Kyū Kōbu Daigakkō Shiryō Hensankai [1931], Miyoshi [1989] and SHIMAO Eikoh, 'Some Aspects of Japanese Science, 1868–1945', *Ann. Sci.,* **46** (1989), 69–91.

Teachers at the Imperial College of Engineering were invited from Europe. The first Principal, Mr. Henry Dyer, a Scotsman, set the basis for the educational system there. Driven by the ideal of establishing a university-level system of engineering education, he sought to create a new educational system in Japan, the virgin territory for Western technology.

In those days, in Western countries, engineering was not regarded as something to be taught in universities. No systematic education was given to engineers, even at the University of Glasgow where Dyer studied. He therefore considered such exceptional precedents as the École Polytechnique in Paris and the Eidgenössische Technische Hochschule in Zürich, and designed Japan's College as a ground-breaking institution which would combine theory with practice. His effort to establish a new type of college for engineering was rewarded, as the College won international attention. It was praised by Western scientific journals, including *Nature*.[6]

Thus Japanese engineering education started at the university level. The first bachelor degrees of engineering were given to eight graduates from the Imperial College of Engineering in 1879. In contrast, it was not until 1899 that the Technische Hochschule (TH) in Germany obtained the right to grant a degree for engineering, equal to those given for other fields in the universities. In the United States, the number of colleges which offered engineering education quickly increased in the 1860s as a result of the Morrill Act. In the 1890s, MIT carried out a reform to implement high-level engineering education. Compared to them, the Imperial College of Engineering in Tokyo was an early university-level institution in engineering.[7]

In the field of electrical engineering, the first European professorship for telegraphy appeared in Dresden in 1875. The first department for electrical engineering was founded in Darmstadt in 1882. By contrast, the department of telegraphy in the Imperial College of Engineering was the first one for electrical engineering in the world [TAKAHASHI 1990: 1–32].

2) The Establishment of National Research Institutes

Among the many graduates from the Imperial College of Engineering, Dr. SHIDA Rinzaburo, the first graduate of the department of telegraphy, Prof. NAKANO Hatsune, Dr. FUJIOKA Ichisuke and Dr. ASANO Ōhsuke, its third year graduates, are known as the 'four kings' of electrical engineering in Japan.

One of the kings, Dr. Asano, became the first director of the Electro-Technical Laboratory (*Denki Shikenjo,* now *the Denshi Gijutsu Sōgō Kenkyūsho* under MITI), the oldest Japanese national research laboratory.[8]

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6) *Nature,* May 17, 1877: 44–45.

7) For the introduction of engineering education in Western countries, see Nakaoka [1981], Takahashi [1986], Léon [1961], Prahl [1978], Schelsky [1963: Chap. 5] and Servos [1980: 531–549].

The origin of the Electro-Technical Laboratory is said to be the Shop for Insulator Testing (*Gaishi Shikenjō*) of the Ministry of Public Works. With the abolition of the Ministry in 1885, the Shop was put under the Ministry of Communications (*Teishinshō*). It was reorganized into the Electro-Technical Laboratory in 1891, and Asano was named to its Director.

The primary mission of the Electro-Technical Laboratory was mainly the testing of telegraphic equipment and insulators purchased by the Ministry of Communications. But Asano promoted research activities towards the goal of domestic production of electrical components such as capacitors and batteries. In addition, he tried to nurture the development of original technologies in his institute. Its engineering research on radio communications was especially advanced. It was started immediately after Marconi's invention. As a result, the Japanese Navy could use wireless communications for the early detection of the Russian Baltic Fleet, which led to the famous victory of Admiral Togo over the Fleet at the Battle of Tsushima in 1905 during the Russo-Japanese War.

The Electro-Technical Laboratory was one of the first national research laboratories for electrical studies anywhere in the world. The Physikalisch-Technische Reichsantalt of Germany, a typical and productive research laboratory, was founded in 1887, at almost the same time as the Electro-Technical Laboratory. In the United Kingdom and the United States, similar institutions were established only after 1900.

3) The Establishment of the Institute of Electrical Engineers

The Japanese Institution of Electrical Engineers (*Denki Gakkai*) was organized in 1888 on the initiative of Dr. SHIDA Rinzaburo, another 'king' of Japanese electrical engineering. When Shida graduated from the Imperial College of Engineering in 1879, he was sent to the University of Glasgow. Shida studied there under Prof. William Thomson (Lord Kelvin), who later praised his achievements at Glasgow. After returning to Japan, he first worked for the Ministry of Public Works, then for the Ministry of Communications. He contributed to the development of electric systems from the side of the government. He asked Mr. ENOMOTO Takeaki, the Minister of Communications, to be the first President of the Institution. Shida himself took the position of secretary in charge of higher level administration. In the same year when the Institution was organized, its journal was started.[9]

By comparison, the Institution of Electrical Engineers was founded in England in 1871. In the United States, it was created only in 1883, just five years before

8) For Asano and the Electro-Technical Laboratory, see Horioka [1944], Denki Shikenjo [1944]. For a different opinion on the origine of the Electro-Technical Laboratory, see Kamatani [1988: 120–121, 129].

9) For Shida and the Japanese Institution of Electrical Engineers, see Denki Gakkai [1888: 3–8] and [1988].

Japan.

After considering these three indices of institutionalization, university-level education, the national research laboratory, and the institutes of electrical engineers, it seems reasonable to argue that the institutionalization of electrical technology in Japan was achieved almost simultaneously with that in the West.

If these indices are deemed inadequate, it might be added that the first Japanese electric power supply system was started in 1887, just five years after Edison supplied electricity for the first time in the world. It was Dr. Fujioka, one of the kings and 'the father' of the Japanese electric power industry, who established Tokyo Dentō, the first electric power company in Japan.

4) The Results of Institutionalization

As is shown, Japanese institutionalization of electric engineering kept pace with that of the West. But perhaps this was only nominal? It is possible that, although institutionalization was achieved, no substantial result accrued to the electrical industry.

Instead of offering direct evidence, this paper provides some information which suggests circumstantial evidence for the good performance of the Japan's electrical institutions (fig. 1 & table 1).

Fig. 1 shows the annual amount of electric power supplied in various countries.[10] It is reasonable to assume that the total power supply reflects the level of industrialization and also the effect of the institutionalization of electrical engineering.

The graph clearly shows that there are three classes of supply growth in electric power. The first class includes only the United States. American electric power supply grew far beyond that of other countries, clearly illustrating the extraordinary American industrial development of that period. The second class consists mostly of European developed countries. It is interesting that Japan belongs to the same class. In fact, Japan followed almost the same curve as that of the United

Table 1. Technological Inventions and their Introduction to Japan

	Invention	Introduction to Japan	Time Lag
Telegraph	1837 (Morse)	1869	32 years
Telephone	1876 (Bell)	1877	1
Electric Power Supply	1882 (Edison)	1887	5
Wireless Telegraph	1897 (Marconi)	1897	0
Radio Broadcasting	1920 (KDKA)	1925 (JOAK)	5

10) [MITCHELL 1975, 1982a, 1982b].
The table for Europe contains some mistakes in numerical order, which were corrected by comparison with other materials. The first figure plots values approximately every five years.

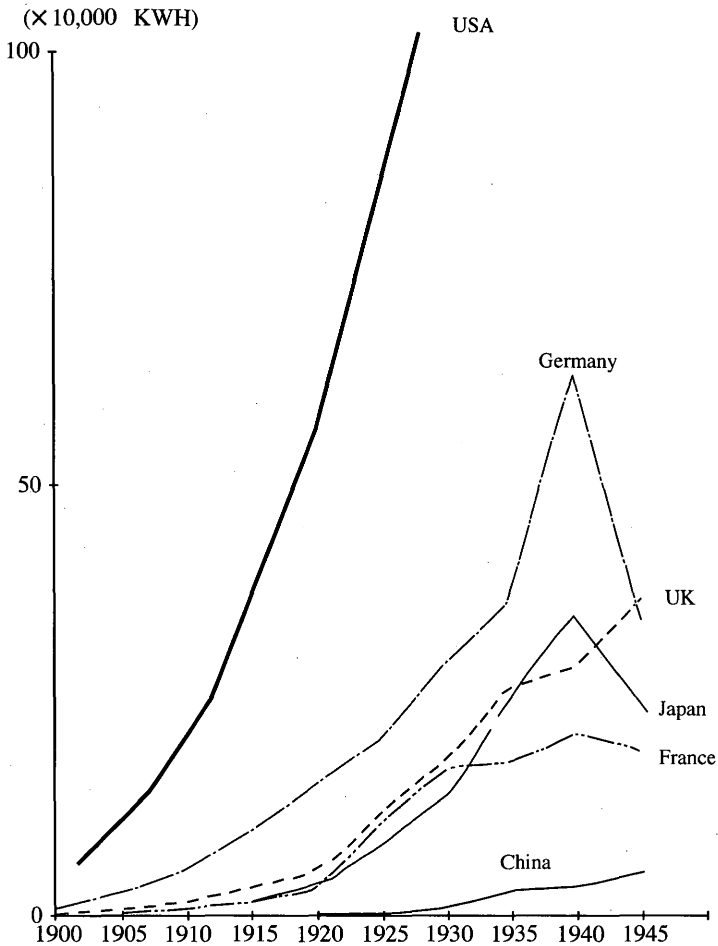

Figure 1. The Amount of Electricity Supplied

Kingdom, and even surpassed that of France. By contrast, underdeveloped countries, like China, belong to yet a third tier.

Table 1 indicates time lags between technological inventions abroad and their introduction to Japan.[11] It shows that the electric power supply, the telephone, and so on were introduced into Japan quite early. In the case of wireless telegraphy, there was no time lag. The only exception here is wired telegraphy, which was invented long before the Meiji Restoration. These data suggest that the institutionalization of electric technology in Japan was not nominal but substantial.

11) Compiled from the chronological table appended to Nihon Kagakushi Gakkai [1969] and the table in Kisaka [1978] etc.

4. A CATEGORIZATION OF TECHNOLOGY

The discussion above could raise the following criticism: Even if it is true that Japan's institutionalization of electric technology was achieved almost at the same time as that of the West, nevertheless, one could question whether electrical technology is a pertinent field for evaluating technological level. Japan might have been able to catch up quickly with the West in this field because electrical technology was comparatively new.

Certainly Japan did systematically adopt such technologies as railways, steam engines, iron manufacturing and so on from the West in the early Meiji Period. However it took a long time before Western style iron manufacturing was successfully established in Japan.[12] If we focus on these technologies, it is possible to argue that Japan was technologically behind. However, I would like to claim that these technologies are irrelevant to understanding the achievement of contemporary Japan, or, rather, to evaluating the level of industrial societies. To clarify this point, it is helpful to divide technologies into four distinct categories.

In table 2, according to various characteristics, technologies are classified into four categories of traditional technology, modernized traditional technology, scientific technology, and advanced technology. To state the conclusion in advance, we should not pay much attention to the category of modernized traditional technology, where Japan started behind the West, but rather to the group called scientific technology, which is essential to modern industrial societies. Before explaining why, let me delineate the particular characteristics of each of the four categories.

First, we have to admit the fact that the principal features of 'advanced technology' are not actually known yet. Its characterization must be kept open for future consideration. It is preferable to avoid confusing discussions about its definition. The character of 'traditional technology' has already been mentioned. Its institutional basis was the guild system, which was conspicuous during the medieval period. In Japan, for example, there were special gunsmiths for Samurai called 'teppō kaji'. We have already referred to the role of masons in Europe in the construction of cathedrals. These people kept their technology secret in guilds to protect their privileges. The only way to acquire the technique was to become an apprentice to a master. Due to their secrecy, innovations in 'traditional technology' were based on experience, and its development was slow.

'Modernized traditional technology' (hereafter MTT) appeared with the partial dissolution of the guild system. For example, the École Polytechnique offered education in military and civil engineering. Here technological secrecy was discarded. Drafting, which had not existed in traditional technology, was initiated there by Monge as descriptive geometry. The systematization of design facilitated the introduction of mathematical methods. It was not accidental that

12) For the establishment of the steel industry in Japan, see Iida [1988].

Table 2. Four Categories of Technology

Category	Examples	Characteristics of Organization	Characteristics of Technology	Beginning
Traditional Technology	Architecture and Civil Engineering (Bridges, Water Supply, etc.), Arms, Shipping, Silk and Cotton Fibers, Metallurgy	Guild System exclusive esoteric apprenticeship	Gradual Development or Stagnation Small Scale Commercialization	Mostly before the Christian Era
Modernized Traditional Technology (Extension of Traditional Technology) (MTT)	Architecture Arms, Shipping, Fiber, Metallurgy (Iron Manufacturing) Steam Engine	Break away from Guild Training of Professional Engineer (Birth of School of Engineering, Systematic Education)	Systematization and Mathematizing of Traditional Technology Use of Drafting Sudden Change by Accumulation of Experience Combination with Industry	Industrial Revolution (The Second Scientific Revolution)
Science—Technology (ST)	Organic Chemistry (Synthetic dyes) Chemical Industry Electrochemistry Electricity and Electronics	Professional Education of Science Professional Education of Technology Firm Establishment in Universities Industrial Laboratory	Marriage of Science and Technology Creation of Objects of Technology by Science Combination with Monopolistic Industrial Capital (Large Factory)	Middle of 19th Century (The Third Scientific Revolution?)
High Technology	Semiconductors Superconductivity New Material Bio-technology	Same as above	Same as above	1970's

mathematization of technology developed during this period. Engineering became a series of complicated practices, and engineers with advanced education were required for their pursuit. A new group of people with university-level education began to demand engineering education even for craftsmen.

MTT, nevertheless, preserved the features of 'traditional technology', because the former shared the same technological objectives with the latter: the construction of buildings and bridges, the production of arms, iron manufacturing etc. Moreover, even though some practices with MTT were grounded in theoretical achievements, most of the actual activities were still based on experience. Even today, experience plays a vital role in the construction industry. The essential difference between MTT and traditional technology seems to be a function of the changes in the social groups who supported them.

It should be noted that James Watt's steam engine, which played a desicive role in the Industrial Revolution, is classified in the category of MTT. As an object of technology, steam engines were well known to engineers before Watt. Newcomen's engine was invented at the beginning of the eighteenth century, and constructed by craftsmen. Watt, who was a craftsman excluded from traditional guilds, made certain improvements to existing steam engines.

Scientific technology (hereafter ST) clearly differs both from traditional technology and from MTT. The most distinctive character of ST is the fact that objects of the technology are created by scientific research. This feature is conspicuous in the cases of electrical and electronical technologies, and chemical technologies. Electric current, for example, was discovered by Alessandro Volta through his scientific research; Humphrey Davy applied it to the arc light in his laboratory. After leaving the laboratory, it was diffused into society as electric lighting by the hands of engineers and craftsmen. The first important step toward the chemical industry was the synthesis of mauve dye. W.H. Perkin, an English scientist, discovered how to do this in his laboratory. This achievement was transferred into the domain of engineering and became the basis for the aniline dyestuff industry.

Like Perkin's mauve, the objects of ST are sometimes not natural products but ones created by human artifice. One of the results is that modern society suffers from the large number of artifacts represented by plastics.

The fundamental characteristic of ST affects the training of engineers. Because the technological objects of ST are scientific products, a basic knowledge of science is essential for engineers. For craftsmen excluded from guilds, it became increasingly difficult to shift into the field of ST. Independent inventors can no longer be main actors. We cannot expect another Edison. Leading engineers must be trained in a faculty or school of engineering. It is not rare to see engineers with doctoral degrees. Many engineers are hired by universities, governmental and private research laboratories.

Their behavior pattern is not that of pure scientists, nor that of traditional engineers. They have some characteristics of scientists as they are interested in trends of academic research. They also retain some of the characteristics of traditional engineers because they have to pay attention to industrial products. Nonetheless, they constitute an independent social group which is different from those of scientists and traditional engineers. They have their own area of activity and their own paradigms. Though English lacks a term for it, the German word for this is 'Technologie' (or 'wissenschaftliche Technik'), and the Japanese word for it is '*Kōgaku*'. The ability of the members of the '*Kōgaku*' community is evaluated not only by their achievements in academic societies for engineering, but also by the number of patents they obtain, or by the number of products they put into practical use.

At the turn of the last century, research laboratories were founded, for example, at Bell Telephone, General Electric and Du Pont in the United States. These can be regarded as a sign that ST began to establish itself firmly in society about that time.[13]

5. SCIENTIFIC TECHNOLOGY AND JAPAN

Traditional technology existed in history both in Western countries and in Japan(among other places). Japan was behind, however, in the area of MTT. Due to the delay, Japan had to import lots of MTT in the early Meiji Period, mainly from the United Kingdom. It was not until the end of the nineteenth century that these technologies anchored themselves firmly in Japanese society. For example, it was as late as 1904 that the government-owned Yahata Iron Works achieved stable consistent yields in steel production.

But however difficult the process might have been, it was not impossible to adopt MTT in Japan. The objects of MTT themselves were not wholly different from those of traditional technology. It was relatively easy to learn the new way of production for traditional objects. Until around the turn of the century, or until the so-called Japanese Industrial Revolution, many elements of MTT were domestically produced, even if the quality of products was not as high as that of imported ones.

The vital element for modern industrial society is actually not MTT but ST. In Japan, the output of the electrical and electronics industry exceeded that of the textile industry at the end of the 1960s, and it surpassed even that of the steel industry at the beginning of the 1980s. Current trade friction occurs around high-tech products which are assembled from complex electronic components. The twentieth century may be characterized as an age when the development of ST surpassed that of MTT.

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13) Furukawa [1989: Chap. 10], Leonard S. Reich, *The Making of American Industrial Research: Science and Business at GE and Bell, 1876–1926* (Cambridge, 1985); David A. Hounshell and John K. Smith, *Science and Corporative Strategy: Du Pont R & D, 1902–1980* (Cambridge, 1988).

Jumping from traditional technology to ST is not easy, as is shown in many failures in developing countries. But Japan could achieve it. Why? It is because MTT, by its nature, could be adopted without serious difficulty for traditional technology, and because, when Japan started its modernization, ST was in its infant stage even in the Western countries. Europe and the United States had just started to set up an institutional basis for ST, e.g. university-level engineering education and national research laboratories. In a sense, Japan opened its doors just in time for the start of ST in the developed counties. For this reason, in some situations, Japan could go ahead, as in the case of university-level engineering education.

Consequently, by World War II, Japan could reach a level of competence in MTT and ST which far exceeded the standard of developing countries, even if it was not possible to call Japan a first class industrial country.

6. CONCLUSION

The present paper classified technologies into four categories. Among them, ST is the most important feature of modern industrial society. This paper analyzed the development of Japanese ST using the indicator of institutionalization of technology instead of focusing on the traditional factor of originality. We found that Japan's institutionalization of ST was scarcely behind that of the Western countries. It is true that in the field of MTT, Japan was behind at the beginning of the Meiji Period. But with national endeavor, Japan acquired a technological ability well beyond that of underdeveloped countries by the beginning of the century.

As a result, although Japan's technological capacity was not advanced in the sense of creating a number of original inventions, she reached a level nearly equal to that of the Western countries both in MTT and in ST before the beginning of World War II.

The poor quality of many Japanese products prior to 1940 gave the impression that Japan was underdeveloped. It stimulated the efforts of the Japanese to 'catch up' with the Western countries. In fact, however, Japanese products were relatively inferior only to those manufactured by the most advanced industrialized countries. It is significant to note that, in spite of this, Japan herself could supply sophisticated products like vacuum tubes.

In other words, Japan occupied the rear position in the group of the advanced countries. This is illustrated by the fact that Japan joined World War II, a war among advanced nations, as one of its main actors. It is clear that Japan possessed the technological potential to develop gigantic warships and Zero fighter airplanes. Unfortunately, it made possible a reckless war against the United States, a highly industrialized country even in comparison with European nations in those days.

If the aforementioned discussion is accepted, one would conclude that Japan's recent 'success' is not a miracle at all. Japan was not underdeveloped before World War II. She had a considerable level of technology. After the War, the Japanese had to work hard to rebuild the destroyed industries. This was feasible, because it was based on technological and institutional networks well established before the War.

Japan was initially behind in MTT. But for ST, she followed the same pattern as the Western countries. It is no wonder that Japan rose to the world's highest levels during the 1980s, when the industrial center of gravity shifted from MTT to ST based on electronics.

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