Technology Transfer

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1. The Role of Technology Transfer in Economic History

1-1 A World History of Technology Transfer

Japan's opening of its ports in 1859 brought with it the beginnings of trade with Europe and the United States (US), and, at the same time, opened a way for it to import technologies from the West. Since then Japan has achieved industrial modernisation through the deliberate and selective introduction of these technologies. This paper will describe Japan's industrialisation as a process of technology transfer from the West, from a global perspective. It will analyse the sixty-year period that stretches from the last days of the Tokugawa Shogunate (1850s) to Japan's involvement in the First World War (1910s).

General usage of the term technology transfer is relatively recent, and there are several approaches in treating it as a subject. However, these approaches can be broadly divided and understood as either an economic analysis of the activities of globally-active enterprises or a sociological analysis of technology transfer between different cultures (Ito 1986: 63, Komota 1982: 1).

Much of the current debate on technology transfer is largely concerned with the contemporary policy challenge of how developed countries can provide effective technical co-operation to developing countries. Since this policy debate is one that is premised on an institutional framework that reflects the latter half of the twentieth century, it may not have much relevance to the discussion of technology transfer within economic history. Nevertheless, we should note that nineteenth-century Japan stands out as the sole historical example of a successful transfer of technology from the West to a non-Western society. So setting aside the question of whether Japan's experience, taken as is, has any lessons for developing countries of today, the technological transfer that occurred from the West to Japan from the end of the Tokugawa Shogunate through to the early Meiji period (1868-1912) still merits examination as an one-of-a-kind event in world history (Hayashi 1984: 139-).

The transfer of technology around the globe is obviously not a modern phenomenon. Since ancient times it has played a critical role in economic history. That *hard* technologies, such as iron production, or the *soft* technologies, such as an alphabet, originated in a specific location and subsequently travelled to other locations is indisputable archaeological fact. The technologies that developed in the three centres of civilisation in the pre-Christian world, China, India and the Mediterranean, spread to their respective peripheries. The *Kojiki* and the *Nihonshoki*, the two oldest extant chronicles of Japanese history, record how the transfer of metalwork technology, silk weaving and other know-how from China contributed to the founding of Japan as a nation. The economic development of Western Europe from the twelfth century onwards owes much to the printing and manufacturing technologies for paper, gunpowder and compasses that developed in China and the Muslim world. Even blast-furnace steel manufacture and clock making can be attributed to technologies that originated from China (Needham 1970 [Yamada [trans.] 1974]).

When viewed in this manner, pre-Renaissance Western Europe was initially technologically underdeveloped and less prosperous than the East. However, as a result of the transfer of technology described above, as well as further independent innovation based on it, Western Europe was able to develop its own technologies of gunmaking, shipbuilding and navigation. These new technologies paved the way for the *Age of Discovery*, during which time Western European technology influenced other parts of world (Cipolla 1965). It was in this period that Western technologies for processing minerals and gunmaking first arrived in Japan. Learning how to refine metals for coins provided the material basis for the Bakufu to establish a monetary system during the Tokugawa period (1603-1868). Gunmaking technology, on the other hand, sped the process domestic unification that had begun in the late sixteenth century and brought about the creation of a nationwide market. However, as domestic demand for guns was low during this prolonged period of peace, the impetus for Japan’s military technology to develop to the same extent as Western Europe’s was scant (Perrin 1979 [Kawakatsu [trans.] 1984]).

Similarly, this first instance of technology transfer from sixteenth century Western Europe to Tokugawa Japan had a limited effect on the development of the economy. Even with the *Sakoku* or ‘seclusion’ enforced during this period, some degree of scientific knowledge continued to flow into Japan from the Netherlands via the port of Nagasaki. However, while scholars of Western studies enthusiastically compiled this learning, it by no means represented the transfer of practicable industrial technology. Indeed, it was still a time when the West was attempting to reproduce the production technologies for the Japanese and Chinese ceramics that it was importing.

Over in Great Britain, as the industrial revolution progressed over the eighteenth and the early nineteenth centuries, new technologies to build steam engines, coke-fired blast furnaces, spinning machines, railways and steam ships were steadily being developed and applied (Arai, Uchida and Toba [eds.] 1981). The industrial revolution in Continental Europe and in the US that followed was chiefly achieved through the transfer of these technologies. As such, the transfer of technology from Britain to Germany, France and the US is a topic of major significance within the study of modern Western economic history, when viewed as a phenomenon that enabled the spread of industrial know-how and industrialisation. This topic lies at the intersection of socio-economic history and the history of technology and innovation, and since Henderson’s groundbreaking book on this subject (Henderson 1954), scholars of economic history and the history of technology have described the process of technology transfer for individual industries as well as specific countries in detail (*L’Acquisition des Techniques par les Pays Noninitiateurs* 1973, Kroker 1971, Jeremy 1981).

The transfer of technology from Western Europe to Japan during the latter half of the nineteenth century can be viewed as part of the process that began in Britain with the industrial revolution and spread all over the globe. Within the current body of historical research that focuses on the Meiji Restoration or Japan's industrial revolution, the topic of Japan's assimilation of Western technology has been thoroughly examined following the publication of Hiroto Saigusa's seminal book (Saigusa 1940). As a result, scholars of modern Japanese economic history are well versed in Meiji government policies to promote industrialisation and introduce Western technologies to specific sectors. However, current historical perspectives have held to one premise; they view the processes of Western socioeconomic development and technological progress as models that can be applied universally. Thus, the transfer of Western technology to the less developed Japan of the sixteenth century just followed a path set by the inevitable course of history. Furthermore, using this logic, the transfer of technology from Britain to the Continent and the US would possess the same qualities and characteristics as the transfer of technology from the West to Japan.

Recent progress in research on economic history of the Tokugawa period, however, shows that prior to its adopting Western institutions Japanese society was already assimilating and developing technologies. Scholars have discovered technologies that originated in Tokugawa Japan and others that were developed from earlier Chinese and Western influences. A significant and common feature in the development of all these technologies was the creation of a uniquely Japanese production culture, which made skilful use of the limited resources available during the *Sakoku* (seclusion) to create highly processed goods that were particular to and a speciality of a given region (Uchida 1982: 17-25, Uchida 1989).

When we compare the technologies developed in Tokugawa Japan with those originating from Britain, France, Germany and the US, we see that they clearly belong to a different cultural context. Technologies that stemmed from Western Europe are characterised by their roots in the twelfth century; the pursuit of complex mechanisms; and the demand for mass energy consumption (White 1962 [Uchida [trans.] 1985: 122-151]). Fossil fuel technology to generate energy from coal that Britain developed during the eighteenth century drastically expanded the scope for applying these technologies, and they spread easily to other Western nations that held common cultural traditions. This was the beginning of a large-scale industrial revolution (Harris 1974, [Uchida [trans.] 1974: 106-114]).

With its own distinct institutions and systems for technology, Japan faced certain challenges in adopting Western technologies. A simple example illustrates this point well. The transfer of technology from Britain to the Continent and the US was facilitated by the migration and emigration of entrepreneurs and skilled workers. However, because of racial, cultural and linguistic differences, technology transfer to Japan via this method was rather an exception than the rule.

Gerschenkron's model (Gerschenkron 1962: 8, Nakagawa 1981: 49-78), which maintains that latecomer industrialised countries gain an advantage because they can kick start their economic development by borrowing technologies from forerunner industrialised countries, forms the basis for international technology transfer as defined by economic history. Yet, even if this logic applies to Western nations, the challenges mentioned in the previous paragraph mean that any edge that Japan possesses as a latecomer would be diminished.

A re-examination of the process of technology transfer from Western Europe during the Meiji period, adopting a global perspective, is still in its early stages (Kobayashi 1981, Hayashi 1986, Jeremy [ed.] 1991). In the following sections I will adopt this viewpoint to analyse Japan's experience in adopting and assimilating different systems of Western technology from the end of the Tokugawa period.

1-2 Types and Means of Technology Transfer

In general terms, technology is transferred through the actions of both the supplier and receiver of a technology (such as enterprises or the governments). Technology transfer can take a number of different forms, depending on the capacity and policies of the parties involved, the size of the technological gap, the amount and quality of the technical information available, the degree of supplier intervention and the initiative shown by the recipient. The various forms of technology transfer can be classified as follows, with reference to historical events and the conventions of contemporary international technology transfer. The methods recipients use to obtain technology are listed below in order, from A to K, starting with the types of transfer where the recipient exhibits a high degree of dependence on the supplier country to types where the recipient exercises a high degree of independence.

A. Overseas factories founded through direct investment by suppliers
B. Businesses established by migrants from the supplier country
C. Joint ventures
D. Management contracts with suppliers
E. Turnkey contracts, where suppliers guarantee the transfer of technology when they construct a factory
F. The employment of engineers and skilled workers provided by the suppliers or by businesses owned by the receivers
G. Purchase contracts for machinery and know-how
H. Technology transfer as an integral part of the machinery imported by the recipient
I. Patent licence agreements
J. Production of imitations
K. In-house development of a technology

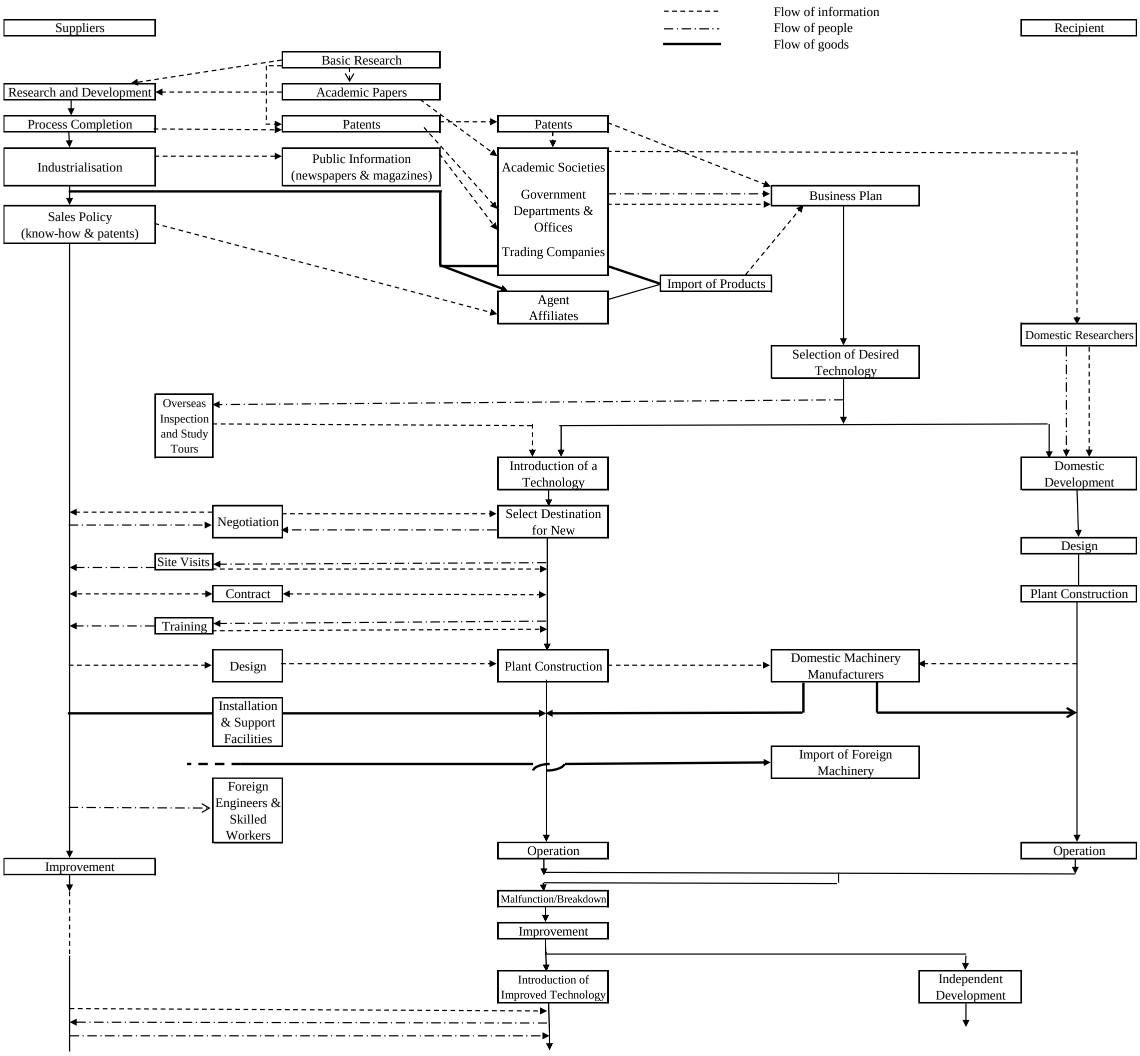
Types A and C (joint ventures and overseas concerns) are initiated by a supplier as part of a management strategy that promotes multinational business, while type I (a patent licence agreement) becomes widely practiced once an international patent system has been established. As discussed previously, type B (migrant-owned business) is a common means of technology transfer in Western countries, but much less so in Japan. A turnkey contract or type E is the usual means of technology transfer that accompanies the export of industrial plants from developed countries to developing countries today. In principle, any form of technology transfer throughout history belongs to one or other of the types listed above, although each type is somewhat influenced by the international economic relations prevalent at the time. As I will show in Section 2, the transfer of technology that took place from the West to Japan at end of the Tokugawa Shogunate and throughout the Meiji period could belong to any of the types listed here.

Differences among the various types of technology transfer can be understood clearly when one observes the movement of people, goods (machinery or products) and knowledge (public information or know-how), which provide the means for technology transfer. Normally, in the transfer of technology, people move between suppliers and receivers in both directions, however, goods and knowledge travel only in one direction, from suppliers to receivers.

Figure 3-1 illustrates the movement of the three means of technology transfer for type G (a purchase contract for machinery and know-how) over time. Purchase contracts were the primary method Japan used to introduce foreign technology during the Taisho (1912-1926) and Showa (1926-1989) periods (Uchida 1972: 67). Technology from the West flowed through established channels of public information such as academic journals and patent documents. A cadre of Japanese engineers, who had the ability to comprehend and evaluate the technology, travelled abroad to identify which technologies should be adopted and negotiated terms with the supplier business. On conclusion of the contract, the suppliers shipped the machinery or equipment to Japan, providing short-term engineers, technicians or skilled operators to install and test run the hardware. It was also standard for foreign workers to train domestic workers so that upon their departure, the receiver could operate the imported technology independently. Furthermore, in cases where the receivers were particularly capable, they could opt to import a portion of the machinery (H) or obtain a patent license (I). Finally, where no patent restrictions existed, it was possible for countries to reproduce a technology by copying imported products or making replicas using publically available information as in type J.

At end of the Tokugawa Shogunate and during early Meiji period, however, Japan did not possess the capacity for type H or I transfers. It lacked the means for obtaining public information and did not possess any domestically-trained engineers or technicians. Thus technology came solely via the goods and technical services provided by the supplier and the country began the process of introducing new technology without any resources depicted in the top half of Figure 3-1.

Figure 3-1 Technology Transfer Process



2. The Process of Technology Transfer from the West

2-1 End of the Tokugawa Shogunate (1868)

The first conscious decision by Tokugawa government to introduce foreign technology to Japan was in 1854, when it adopted Western-style armaments to equip its coastal defences (Uchida 1986: 166-173). Japan sought to replicate foreign technology as part of this effort and built furnaces at various sites nationwide to smelt and process metals (in particular for casting cannons). Scholars of Dutch studies and craftsmen designed and built these furnaces, relying solely on descriptions by Huguenin in *An Explanation of [the] Technology of Liège Artilleryman*

Arsenal[s] or *Riêjyu hôhei kôshô gijyutsu kaisetsu* ([Saigusa (ed.) 1942: 296]). The method of technology transfer employed in this instance is type J (the production of imitations). However, most attempts to refine iron ore and produce arms failed, and there is no evidence to show that the cannons or bullets produced were used effectively in the battles that brought an end to the Tokugawa Shogunate. The Dutch texts used to reproduce Western technology had been published more than twenty years ago and were already outdated in the West. Realizing the limits to imitating technology or developing it independently, the Bakufu and some of the powerful *han* (local governments in the Edo period) changed their strategy and reverted to buying firearms that were manufactured abroad as soon as Japan opened its ports in 1859.

Each Japanese *han* also produced copies or models of Western-style ships and steam engines based on the Dutch texts they had in their possession. However, the gap in technology between the results of their efforts and the foreign ships that actually visited Japan was so great that it led the Bakufu to start importing warships from the West (Imazu 1966: 56).

However, even after a country imports hardware the problem of how to make it operational still remains. The solution here lies in the movement of people from abroad who can impart the required know-how. In this sense, the construction of a Russian ship at Izuheta port in 1854 and the founding of the Nagasaki Naval Training Centre (*Nagasaki Kaigun Denshûjyo*) in 1855 were both groundbreaking events that transferred technology to Japan through enabling interaction between naval personnel. While the Izuheta case did not have the specific objective of transferring Russian technology to Japan, the Japanese, who built the wooden sailing ships, using designs by Russian naval officers and working under instructions set by Russian shipwrights, later became the first skilled labourers to work at Japanese naval arsenals or privately-owned shipyards. Thus, Izuheta can be regarded as a successful case of on-site technology transfer (Katsu 1973: 52).

The Nagasaki Naval Training Centre was established to train the crew of Japan’s first Western-style battleship, the *Kankô-maru*, which was a gift from the Dutch government to the Bakufu. Five Dutch navy personnel, including the naval officer Kattendijke, trained 167 samurai who had been competitively selected by the Bakufu and various *han*. Courses offered by the centre focused on soft or operational technologies such as navigation, artillery training and the care and maintenance of steam engines, which were a normal part of the curriculum for a battleship crew. The crew also received on-the-job training through an exercise to navigate to Kagoshima (Katsu 1973: 151-232, Kattendîke [Kattendijke] 1964). As the centre was a joint undertaking of the Dutch navy and the Bakufu, with daily management entrusted to Dutch instructors, it possesses the characteristics of a type C transfer (a joint venture).

Between 1860 and 1870 the Bakufu and each *han* imported a total of 166 ships of various kinds (Sugiyama 1981: 482). While these vessels were imported, it was the graduates of Nagasaki

Naval Training Centre and other similar centres that the Bakufu subsequently set up in Tokyo (then Edo) and Hyogo who operated them. This achievement demonstrates the deep impact that the transfer of soft technology from Nagasaki Naval Training Centre had. At the same time, the introduction of so many different types of sea vessel (goods) in itself acted as a means of technology transfer, and enabled the Bakufu and *han* to enriched their knowledge of warships, engines, and gunnery. In a similar way, the Bakufu army acquired soft technology both through the artillery it imported and the elite troop training corps that it set up to invite foreign military advisors to Japan.

Moreover, the Shogunate built the Nagasaki Steel Mill (and shipyard for repairs) in 1857 and the Yokosuka Steel Mill in 1866 as ancillary facilities for Nagasaki Naval Training Centre. These two facilities, which later became Mitsubishi Nagasaki Shipyard and Yokosuka Naval Arsenal, were at the forefront of Western mechanised factory production in Japan and also spearheaded the systematic transfer of hardware technology to Japan through the employment of foreign engineers and skilled workers. Kagoshima Spinning Mill, established in 1867 and run by the Satsuma *han*, also employed a similar approach. After the Meiji Restoration, the experiences of these three businesses formed a model for the new government's programme to engage foreign advisors with specialist knowledge, who came to be known as *oyatoigaikokujin* or 'honorable hired foreigners'.

2-2 The *Oyatoigaikokujin* System

The success of Western-style, government-run businesses in the railways, telegraphy and silk reeling that employed large numbers of foreign advisors hired by the Meiji government is well known, and the lives of many of the foreign experts involved have been explored (Saigusa, Nozaki, and Sasaki 1960, Kashima Shuppankai 1968-1973). However, praising foreign experts as the benefactors of Japan's modernisation or commending the resolve of the Meiji government who engaged them at extraordinary expense is insufficient treatment of the phenomenon if we are aiming to deepen our understanding of the role of technology transfer within economic history. Here, it is useful to examine how the *oyatoigaikokujin* or the foreign experts provided by suppliers and hired by Japan are positioned as an overall means of technology transfer within our classification of the various types, from A to K. In this connection, it would also be useful to discuss how supplier policy for transferring technology at the time enabled the movement of such a large number of people to Japan.

Using the Ministry of Public Works' Report on Development (*Kôbushô Enkaku Hôkoku*) (Ôkurashô [ed.] 1931) and other materials to compare the number and professions of foreigners hired, government-run businesses of the early Meiji period can be roughly divided into two types. The first type consists of businesses that employed large numbers of foreigners. As well as hiring engineers, these workplaces assigned a skilled foreign worker as a foremen to supervise each area of its business. In doing so, these businesses transplanted an exact replica of the supplier's factory organisation as well as importing its hardware. The majority of foreigners at a site came from the same country as the machinery and equipment that had been imported. Furthermore, in most cases, a foreign director, who was not necessarily an engineer, would oversee the work of his fellow countrymen. Yokosuka Shipyard, the Tokyo-Yokohama Railway, the Imperial Mint and Ikuno Silver Mine, as shown in Tables 3-1, 3-2, 3-3 and 3-4, provide four specific examples of the positions foreign workers held.

The second type consisted of businesses that employed a limited number of foreigner workers. Here none of the foreigners hired served as managers or performed clerical duties. Rather, they were hired as consultant engineers for designing and planning or as skilled workers assigned to specific areas of work. There were also cases where the foreigners of different nationalities worked together. Many local offices for industry and mining and the agricultural businesses run by the Japanese Home Office as well as some businesses run by the Hokkaido Settlement Bureau provide examples of this type of model.

Turning to our classification of the different types of technology transfer, we can regard businesses that employed large numbers of foreigners and procured management from the supplier as type D transfers. For those businesses that employed fewer foreigners, engaging them as specialist advisors or skilled workers from the supplier, type F is applicable. While both categories of business relied on hired foreign workers, they differed significantly in terms of the level of independence and involvement in the technology transfer that they displayed. In the case of the Kagoshima Spinning Mill, the British cotton spinning machinery manufacturer, Platt Bros & Co Ltd, dispatched seven engineers (or skilled workers) under a chief engineer named Holm. The team was able to return to Britain in one year having laid out the factory, installed the machinery and trained Japanese workers for each of the departments (Kagoshima-shi 1935: 311-314). The approach employed here to transfer technology through hiring foreigners lies between the two described earlier and corresponds to type E, i.e., a turnkey contract.

However, our greatest interest lies in those cases where technology was transferred through the use of management contracts. Here, gathering public and privileged technical information as well as making decisions about which technologies to introduce—which are regarded as part of the receiver's role in Figure 3-1—were entrusted to foreign experts or to the foreign firms that acted as the suppliers of the technology. Japanese did not undertake any missions abroad. Furthermore, foreign engineers and skilled workers managed the operation as well as the construction of the factories. As a result, technology transferred through this method was limited in scope and impact, affecting only those Japanese workers at the site of operation.

Table 3-1 Number of Foreigners Employed by Yokosuka Shipyard in 1872 (by Occupation)

Director 1 Deputy Director 1 Bookkeeper 1 Secretary 1 Chief Design Engineer 1 Design Engineer 1 Draughtsmen 1 Head of Ship Repairs 1 Ship Repairer 1 Shipwright 1 Caulker 1 Master Blacksmith 1 Blacksmith 1 Master Plater/Tin & Iron Worker 1 Plater/Tin & Iron Worker 1 Casters 3 Coppersmith 1 Master Iron-maker* 1 Iron-maker* 1 Lead Equipment Operators 2 Equipment Operator 1 Master Turner 1 Watcher 1 Doctor 1 Deputy Instructor 1

(All were French.)

Source: *Kôbushô Enkaku Hôkoku* [Kôbushô History Report]: 324-326.
* Provisional translation.

Table 3-2 Number of Foreigners Employed by the Imperial Government Railway of Japan in 1872 (by Occupation)

Director 1 Lead Building Engineer 1 Deputy Building Engineers 3 *Chief Design Engineers/Sub-Chiefs 9 Ironworkers 3 Chainmaker 1 *Ropemaker 1 Carpenters & Fitters 2 Woodworkers 4 Mason 1 *Track Constructors 7 Time Guard 1 Drivers 5 Dispatchers 6 Inspector 1 Railway Guards 5 Building Inspector 1 Warehousekeepers 2 Machinery Operators 9 Machinery Fitters 1 *Clockmaker 1 Carriage Builders 3 Head Bookkeeper 1 *Secretaries 8 *Doctors 3

(* All but one person employed in each of these occupations was British.)

Source: *Kôbushô Enkaku Hôkoku* [Kôbushô History Report]: 165.

Table 3-3 Number of Foreigners Employed by the Imperial Mint in 1873 (by Occupation)

Director 1 Secretary 1 Examiner/Analyser** 1 Master Gold & Silver Refiner 1 Examiners/Analysers** 3 *Metal Value Assessors Valuers** 2 *Rolling Mill Assistant 1 Head of the Stamping Bureau 1 Deputy Head 1 Stamp Sculptor-Engraver 1 Head of the Machine Bureau 1 Machinery Operators 2 Master Capacity Assessor 1 Captain 1 Shipping Equipment Operator 1 Doctor 1

(* included an Italian and two Portuguese. All the other foreigners were British.)

Source: *Zôhei Hyakunen* [A One Hundred Year History of Minting] (1971): Zôheikyoku Senyûkai: 13.
** Provisional translation.

Table 3-4 Number of Foreigners Employed by Ikuno Silver Mine in 1872 (by Occupation)

Master Miner 1 Geological Surveyors 2 Doctor 1 Miners 7 Bricklayer 1 Master Mineral Ore Refiner 1 Machinery Operators 2

(All were French.)

Source: *Kôbushô Enkaku Hôkoku* [Kôbushô History Report]: 91-92.

It is difficult to obtain an accurate picture of how these early businesses functioned if we take official accounts at face value. Every year, the Imperial Mint published its *Annual Report of the President of the Imperial Mint*, in the name of its director, William Thomas Kinder. Kinder, along with other foreign experts, was dispatched by the British Oriental Bank, which the Japanese government had contracted to manage the mint. It seems that these foreign directors and advisors had real command over Japanese workers (Hidemura 1968: 385-386). In the case of

Telegraphic Service of the Ministry of Public Works, however, the official report was created in the name of the Japanese second-in-command. The first few times it was released, the report appeared in both English and Japanese. Whether by intention or chance, differences are evident in the guidance given. For example, 'in the telegraphic service, we shall work in co-operation with foreigners, sharing the duties of construction engineers and maintenance staff, and requesting their support when necessary', appeared in Japanese ostensibly giving Japanese managerial responsibility. Meanwhile, the English version presented a clearly different situation where 'the telegraph wire will be managed through co-operation between Europeans and Japanese. The latter [the Japanese] will work under the supervision of foreigners as telegraph operators, clerks, engineers, inspectors and labourers' (*Nihon Teikoku Denshin Dai'ichi Hôkokusho* [The First Report of Japanese Imperial Telegraph Service], 1875: 22).

The realities of technology transfer within what can be considered as government-owed, foreign-run businesses like these could hardly have been systematic or smooth. The experience of Masahide Yoshida, regarded as one of the first Japanese engineers at the Telegraphic Service, illustrates this point. Yoshida was official of the Shogunate, and while a studying English at *Shûbunkan* school in Yokohama, a Briton called Gilbert recruited him along with other students. Gilbert had come to Yokohama in 1869 to set up a telegraph service for Japan. From his third day on the job, Yoshida was required to send and receive telegraphs despite having no idea what to do. Using his spare time to practise, he finally learned how to move the handle over the dial of the telegraphic device. However, because its operation required minimal academic ability, he requested a transfer to the construction of the wire. He worked as an interpreter and assistant to foreign engineers engaged in laying telegraphic cable between Tokyo and Nagasaki, and was chiefly occupied with negotiating with government officials at various locations along the line and translating instructions for the workers. In later years, he spoke of the challenges he faced in that role; 'they took on apprentices to operate the telegraph or to build the wire, setting them to work without any training or established construction practices. The men had no idea what to do. How could I interpret anything for them under those conditions?' (Yoshida 1935: 15-16).

The establishment of a mint, a telegraphic service, railways and shipyards were all endeavours with one aim; rapidly introducing same kind of infrastructure that existed in the West to a post-seclusionist Japan. It is not surprising then that these enterprises were run using a large number of foreigners who managed them in the same manner as the businesses they had managed at home. These businesses did not always consciously aim at transferring technology to Japan.

Let me turn my attention to a second challenge, i.e., the nature of the technology transfer policies of Western countries towards Japan. As an inevitable result of Japan's opening in 1859, it was useful, not to say necessary, for the various foreign legations, shipping lines and merchants to have Japan build the type of infrastructure described. Nagasaki and Yokosuka Steel

Mills became indispensable facilities for the repair of foreign ships because they now lay at the end of long-distance sea routes that linked Europe to the Far East (Sonoda 1985: 25). For Nagasaki Kosuga Dock, managed by the British firm of Glover, (Sugiyama 1981: 499) and Takashima Colliery (Ishii, Kanji 1984: 251, *Mitsubishi Kôgyô Semento Kabushikigaisha* 1989: 2-7), which both could be classified as type B or C, repairing foreign ships and replenishing fuel (charcoal) was their aim.

The construction of lighthouses and the telegraph service originated in a request from the British consul general, Harry Smith Parkes, to the Meiji government, shortly after the government's formation. The lighthouses that were constructed under the command the British engineer, R H Branton, ensured safe passage for foreign and Japanese ships alike. By the end of 1874 Branton had assembled a large team of workers, 88 men strong. It consisted of builders, lighthouse keepers and boat crews, in which Chinese and Filipinos as well as Britons served (*Ôkurashô* (ed) 1931: 285-298). While the Meiji government bore the cost of construction, Branton's team completed all the building work and undertook maintenance.

Let us take a look at technology transfer within the area of telegraphy. The US, the Netherlands, Prussia and Austria all presented Japan with telegraph boxes when the Treaty of Friendship and the Treaty of Amity and Commerce were concluded towards the end of the Tokugawa Shogunate. In 1866 an envoy of the Bakufu signed an agreement with the French government to build a telegraph service, but circumstances changed when the Meiji government took power, and through the mediation of the British consul general, a domestic telegraphic service was started up instead. The Danish Ôkita Telegraph Company was awarded a contract for sole agency. Behind these developments lay the completion of a long distance international telegraphic communication net technology that had grown out of the Anglo-French co-operation on submarine transmission cables in 1851. The telegraph network stretched from Europe to the Far East via an overland route that the Russian Government had laid, reaching Vladivostok in 1866. Between 1869 and 1871, submarine telegraphic cables laid by private British companies connected Aden to Hong Kong and Shanghai via Bombay and Singapore. The Ôkita Telegraph Company was set to extend coverage by connecting Nagasaki and Yokohama to the other cable networks. Thereafter, the Tokyo-Yokohama and Tokyo-Nagasaki telegraphic lines enabled foreign legations and merchants in Japan to have virtually instantaneous contact with home, which proved of great benefit and profit to them. From the beginning, the Telegraphic Service was set up to send messages in the Roman alphabet as well as in Japanese characters. The fact that 10 percent of the messages sent were in Roman characters demonstrates that the construction of telegraph system proved useful to foreign residents as well as to the Japanese government and public (Uchida 1989: 154). The technological advances in seafaring and telegraphy in the West that made passage to Japan possible were also the technologies that Japan needed to operationalise in order to create its own businesses. Now we understand the international backdrop to government-owned business that relied on foreign advisors hired through management contracts made with suppliers.

It is easy to imagine how the near total reliance of these Japanese businesses on imported machinery, equipment and materials brought handsome profits to foreign merchants, who were the mediators of the technology transfer. Jardine Matheson & Co and the Oriental Bank competed over an order to build and equip the Imperial Mint. The Oriental Bank won the order and provided Japan with the management expertise I described earlier. In addition, it obtained the rights to sell old equipment from the Hong Kong Mint as well as gold and silver ground metal (Ishii 1984: 249). For any project, merchants would also act as middlemen, providing Japanese government-run businesses with engineers and skilled workers from the merchants' home country. In this context, we can understand why a *Scotland connection*, brought to light by Masami Kita's study (Kita 1984: 3-28), existed among engineers dispatched to Japan by T B Glover and Jardine Matheson.

How was the movement of so many engineers and skilled workers, primarily from Britain, possible? Was the movement directed to Japan only? Or was it chiefly a result of the circumstances these workers faced in the West? According to Buchanan (Buchanan 1986: 501-524), as the pace of building railways, ports and other infrastructure slowed in Britain during the latter half of the nineteenth century, there was a surplus of civil engineers. Needing work, greater numbers of them chose to pursue careers building railways and cities in colonies such as Canada, India and Australia. As domestic investment in Britain slowed, machinery and equipment makers, beginning with the textile industry, also turned their attentions to exporting to colonies such as India.

In Britain the railways were built by contractors, who supervised subcontractors and teams of skilled workers. As domestic orders fell off in the 1850s, these contractors extended their activities first to the Continent and then on to India, South Africa, South America and Australia (Yuzawa 1988: 133-142, Tsunoyama 1972: 85-105). Once a railway engineer received an order to build a railway abroad, it was normal for him to travel to his destination with a retinue of assistants, skilled workers and labourers, having first secured the materials needed such as train tracks and locomotives from foundries and machinery manufacturers in Britain.

In the case of Argentina, 160 Britons, including engineers, came to build its railway in 1857 (Buchanan 1986: 509, Izawa 1938: 164). Thirteen years later, we can easily imagine how a similar team moved to Japan to begin construction on a railway here. Japan's adoption of the narrow gauge of 3 feet 6 inches is often thought to be an error, but I suspect that the British engineers engaged to complete the project naturally choose this gauge because they viewed railway construction in Japan as an extension of the work they had completed in the British colonies. The railways built in Australia and South Africa in around 1860 are of exactly the same gauge.

We can imagine how easy it was for foreign legations and merchant houses to attract foreign workers to work in Japan if we view their move as an extension of the overseas assignments that had become normal for engineers and skilled workers as number of British and French colonies grew (1850 to 1860).

Hiring foreign workers and experts through management contracts did not guarantee systematic technology transfer, but the system did have the merit of transferring the work practices of advanced countries to businesses in Japan. As a result, it created groups of skilled workers that were new to Japanese society, including machine operators, steam engine drivers, steelworkers and electricians, who formed the basis of modern industry. These new workers moved from government-run businesses to the private sector or set up for themselves, thus spreading the components of Western technology that they had acquired and paving the way for the Western-style management of industry by the Japanese from the 1880s onwards.

From around 1875 government-run businesses began shifting away from hiring foreigners, and by 1880 foreign engineers and skilled workers had disappeared from all but a few workplaces. Businesses that had used type D transfer (management contracts) now shifted to type F (hiring workers from suppliers). The shift resulted from a change in policy by the Meiji government, which could no longer afford to hire highly paid foreign workers. At the same time, it was also the natural consequence of fixed-term contracts expiring at around the same time, which many foreign experts did not expect to renew. Many businesses managed to continue operations without hiring replacement foreign workers because now there were skilled Japanese workers who could take their place. Foreign workers were retained only in those areas where the transfer of technology had been inadequate. Furthermore, businesses also continued to develop because trained Japanese technicians were ready to take over the duties of foreign ‘engineers’.

2-3 Engineering Education

After the departure of foreign engineers, Japanese engineers adopted the role of internalising and diffusing Western technologies in Japan. They now understood the fundamentals of Western technology and had the ability to put this knowledge to practical use by playing the role of receivers as shown in Figure 3-1. Japanese engineers took responsibility for each aspect of this role, from collecting and digesting technical information from abroad and selecting which technologies to introduce to negotiating terms with suppliers and directing factory construction and installation. Once a factory was ready, they also supervised its operation. The prime reason why the transfer of Western technology to Japan continued smoothly was because Japan trained large numbers of engineers to an exceptionally high standard throughout the Meiji period.

So how were these domestic engineers trained? In terms of the technical education system, engineers from the Meiji period onwards can be classified into three categories: early Meiji-era engineers, university graduates, and technical high school graduates.

Early Meiji-era engineers comprised of men who had studied Western technology before Japan had established a formal university and technical higher education system. The group consisted of men with three types of background. First, there were the scholars of Dutch studies from the late Tokugawa period who had taught themselves from technical journals. These men worked for Western-style businesses owned by the Bakufu or various *han*, and they were later recognised as 'engineers' by the Meiji government. Although few in number, many are still remembered for their achievements; Takato Ôshima for building the first blast furnace in Japan, Ayasaburô Takeda for building the star-shaped fort *Goryôkaku* and Saburô Utsunomiya, as Japan's first cement manufacturer.

Second, were graduates selected from the Nagasaki Naval Training Centre, the Yokosuka Shipyard School (1870), the Telegraphic Service Technical Training College (1871), the Imperial Japanese Naval Academy's Institute for Maritime Studies (1873) and the Railway Engineer Training Centre (1877), all of which were established as businesses that foreigners had been hired to manage. At these schools, foreign engineers taught Japanese trainees the engineering knowledge required for the functions they performed. The graduates later worked as foremen or junior technicians throughout Japan's modern army as well as in the telegraphic service, the railways and in shipbuilding, during their infant stages.

The education offered at these institutions was limited to foreign language training and the knowledge necessary to run the business at hand. For example, the Telegraphic Service Technical Training College focused almost exclusively on operator training. Yet, while the academic standard of these facilities in general was not high, it was sufficient to ensure that these businesses could continue as normal once foreign management had left. Graduates from the Railway Engineer Training Centre supervised the construction a railway line from Kyoto and Otsu between 1878 and 1880, which successfully opened up the route to traffic and included tunnelling through Osaka Mountain (Harada 1979: 60-65).

The third group of early Meiji-era engineers consisted of the first *ryûgakusei*, Japanese who were sent abroad to study. By the Western educational standards of the time, these graduates were extremely knowledgeable and experienced. On their return to Japan, they worked as senior technical experts for the government or for the private sector. Japan began sending students abroad to study engineering shortly before it opened its ports, and even before it began hiring foreign advisors and technicians. The very first overseas students were seven men sent to the Netherlands by the Bakufu when it ordered the warship *Kaiyô-maru* in 1862. Some overseas students also left the country without permission, including master engineers Yôzô Yamao and Masaru Inoue, who belonged to the anti-Bakufu *hans* of Satsuma and Chôshû. After the Meiji Restoration, these men became senior bureaucrats in the Ministry of Public Works. Even during the early years of Meiji government, Japanese students from every domain (*han*-controlled area) continued to travel abroad to study. They included men like Takuma Dan, who later became the director of Mitsui Mining Co Ltd. The navy also sent many trainees from the Yokosuka Shipyard School and the Naval Academy abroad to master technologies for shipbuilding and arms manufacture, as did *Kaisei Gakkô*, the precursor to Tokyo University. By 1880, Japan had sent around 80 students abroad to train as engineers.

Looking at overseas student numbers by the field of study, 21 studied shipbuilding, 17 studied mechanical engineering, 13 studied civil engineering, 10 studied mining and metallurgy, 6 studied arms manufacture and 4 studied chemistry. As for the destination country, 28 were sent to Britain, 20 to the US, 14 to France, 9 to Germany and 8 went to the Netherlands (the number visiting the Netherlands dropped to zero after the Meiji Restoration) (Uchida 1985: 112-116). A study by Kita (Kita 1984: 181-189) focuses on overseas engineering students who trained in Britain, but we should note that when figures are combined, a comparable number of students trained in other major industrialised countries. Furthermore, the destination for study was not always a university. Indeed, the majority of students attended various recognised technical schools, received on-the-job training, or had private lessons. However, this did not mean that they received a substandard education.

To understand why we should remember that for many years traditional Western European universities did not acknowledge nor offer technical education. In Great Britain, only universities in Scotland and London established mechanical and civil engineering chairs before the 1840s. Before the industrial revolution, it was the custom in Britain for an engineer to train on site, first serving an apprenticeship and then working as an assistant. Many of the British engineers who came to Japan had been trained in this manner. On the Continent, however, technical and vocational schools as well as universities had been established. The *École Polytechnique* was founded in Paris at the end of the eighteenth century. Graduates from the school proceeded to the *École d'Application* to graduate as technical specialists for the government. In contrast, the *École Centrale* supplied the private sector with engineers. In Germany, each state boasted a number of technical and vocational schools, including the mining school of Freiberg established in 1765. However, these schools were still considered a rank below universities until the end of the nineteenth century. In the US, there were few technical education institutions until the first half of the nineteenth century. Boston Tech, which later expanded into MIT, was founded in the 1860s – just before the Meiji Restoration and at around the same time that Columbia and Cornell universities first offered civil, mechanical and mining and materials engineering courses (Uchida 1985: 124-129, Kranzberg [ed.] 1986).

We see that when the first Japanese students went abroad to complete their education, the engineering education on offer varied considerably from country to country. Although France and Germany had relatively well-equipped technical schools, Japan had yet to establish a relationship that enabled it send large numbers of students to them. Thus, Japan sent the majority of its students to Britain and the US, where technical education was still in its infancy, and students served an apprenticeship according to the prevailing practice of the time.

Table 3-5 shows the number of early Meiji-era students and the technical education institutions they attended. We note that all the leading engineering institutes in Europe and the US of the time are represented. One cannot help but be impressed at how the most appropriate destinations for study were selected.

We see that most of first Japanese overseas students received an education on par with engineers of the first rank in Europe and the US. Thus, it is no surprise that on their return, these engineers were able to assume the responsibilities and positions occupied by foreign technical advisors and engineers.

Table 3-5 Number of Overseas Engineering Students (by Educational Institution)

Country	Founding Year	Number
[Britain]		
Royal Naval College, Greenwich	(1873)	6
University of Glasgow	(1840)	3
University of Edinburgh	(1840)	2
Royal School of Mines	(1851)	2
University College, London	(1841)	2
Owens College, Manchester	(1851)	1
[France]		
École d'application du génie maritime, Cherbourg	(1795)	5
École centrale des arts et manufactures, Paris	(1829)	2
École polytechnique, Paris	(1795)	1
École des mines, St Etienne	(1795)	1
[Germany]		
Bergakademie, Freiberg	(1765)	3
Technische Hochschule, Hannover	(1831)	1
[United States]		
Massachusetts Institute of Technology	(1864)	3
Rennselaer Polytechnic Institute	(1849)	3
Columbia College	(1864)	2
Rutgers College		1
Stevens Institute	(1870)	1
Rose Polytechnic Institute	(1870)	1
Worcester Polytechnic School	(1865)	1
Lafayette College		1

Source: Uchida (1985: 122).

Table 3-6 The Distribution and Types of Engineer Employed by Government Departments in 1880

●: Dutch scholars, ○: First overseas engineering students,
◆: *Early Meiji-era engineers* (domestically trained at various colleges and institutions),
△: Imperial College of Engineering graduates, ▲: University of Science graduates

(according to Shôzô Hikone [ed.][1881])

Home Ministry **Agriculture Promotion Bureau**	(Goyôgakari-jyunsô) ○Shôzô Inoue, Ishirô Wada
Civil Engineering Bureau	(Goyôgakari-jyunpan) ○Seizô Miyanohara, ▲Satoru Usui, ▲Tanenobu Oka, ▲Yasuto Koshiba, ▲Hide Koizuka, ▲Benjirô Kusakabe
Ministry of Finance **Bureau of the Mint**	(Kyokuchô) ○Yasuyo Ishimaru, (Cyû-gishi) ○Norichika Ôno, (Ittô-gishi) ◆Nobuharu Katô, ◆Tsuneyasu Yajima, ◆Takahiro Sugitani (Nitô-gisyu) ◆Shinsuke Hanada
The Department of the Army	(Hôhei Kyokuchô-taisa) ○Kazumichi Harada, (Tokyo Hôhei Kôshô Goyôgakari-chûsa) ●Tsuneyoshi Murata (Osaka Hôhei Kôshô Kanmu-tai'i) ○Tokusaburô Ôta
The Department of the Navy	(Gijyôkan-shôshô) ○Noriyoshi Akamatsu, (Gotô-syusshi) ○Tarozaemon Sawa (Dai-kikanshi) ○Shôtarô Yamagata, (Hachitô-syusshi) ○Naokata Kumagai, (Dai-jyôshi) ◆Kinzô Watanabe (Shô-shôji) ○Hidemiki Hamaguchi, ○Gosaku Akamine, ○Kinjirô Matsuda, ○Kanichi Shidô, ○Sukenaka Satô, ○Sotojirô Haji (Ittô-shi) ◆Shinzô Nishikawa, ◆Heizô Usami, ◆Korekazu Asai, ◆Heisaku Iwata, ◆Toshikuni Kirino (Nitô-shi) ◆Han'nojyô Yamana, ◆Kiheiji Kukita, ◆Izô Okada, ◆Yûshin Itô (Santô-shi) ◆Katsuji Mutô, ◆Hirotaka Kobayashi, (Jyunpan) ○Fukuhiro Tsumura, ○Tatsuya Yamaguchi (Heigakkô Kyôjyu-ho) ○Chokunoshin Sone, ○Chikashi Yokoi
The Ministry of Public Works **Bureau of Mining**	(Kyô) ○Yôzô Yamao (Gon Dai-gichô) ○Moriyoshi Asakura (Goyôgakari-jyunsô) ●Taktô Ôshima, (Shô-gichô) ●Rin'nosuke Koma, ○Shigesuke Môri, ●Taro Adachi (Gon Shô-gichô Kaigun-taii) ○Sôsuke Harada, (Nitô-gisyu) ○Sumiyasu Yamada (Shichitô-gisyu) △Masa Kuwabara, △Tatsuo Oki (Hachitô-gisyu) △Masakata Asô, △Kôji Miyazaki, △Masamichi Yoshihara, △Tôka Kojika, △Chikanari Matsushita, △Ryô Sengoku, △Tominori Kitsunezaki, △Kinichi Yamada △Rikusaburô Kondô, △Mitsugu Arakawa, △Masanobu Maki, △Yonehachi Takashima
Bureau of Railways	(Kyokuchô Gikan) ○Masaru Inoue, (Gon Dai-gichô) ○Toshinori Iida (Ittô-gisyu) Yatarô Kurobe, (Santô-gisyu) ○Hiroshi Hiraoka, ◆Yoshinaga Kunizawa (Yontô-gisyu) ●Yoshimasa Matsunaga, (Gotô-gisyu) ●Masatsune Kimura, ◆Kinsuke Hasegawa, Shû Shimazaki (Rokutô-gisyu) Hidetama Ôshima, Hidekichi Kawahara, ◆Mitsu'uta Musha, ◆Syudô Nagae, ◆Masa'aki Satake, ◆Shôgo Matsui, ◆Noriyoshi Kidera (Shichitô-gisyu) Kumasaku Ten'numa, ◆Norichika Uzuo, ◆- Kimura, Nobutake Shimada
Lighthouse Service	(Ittô-gisyu) ○Kentatsu Fujikura, Takamasa Nakazawa
Telegraphic Service	(Nitô-gisyu) Ginji Inagaki, (Santô-gisyu) ○Seisuke Tanaka (Yontô-gisyu) ●Daikichi Tanaka, ○Shigenobu Sei'ike
Bureau of Construction	(Gon Dai-gichô) ●Saburô Utsunomiya, (Shô-gichô) ○Kôzô Watanabe (Nitô-gisyu) ○Yôkichi Yamada, (Santô-gisyu) ○Kôichirô Sugi, (Shichitô-gisyu) △Yoshiaki Yasunaga, △Torazô Harada (Hachitô-gisyu) △Shôgo Mori, △Yasuo Torii, △Yôkichi Tatsumura, △Kurô Yoshimi, △Jin Saka, △Yasu Ieiri
Bureau of Maintenance & Repairs	(Nitô-gisyu) ○Shûji Matsuda
Hokkaido Settlement Bureau	(Goyôgakari-jyunsônin) ○Sôichirô Matsumoto, ○Seijirô Hirai, ○Shigen Ogawa

Source: Uchida (1985: 135-137).

Table 3-6 shows the distribution of engineers employed by government offices in 1880 (Uchida 1985: 135-137). Most engineers at the time worked in the public sector as modern Western-style industries had yet to develop in the private sector. Practically all foreign engineers had left Japan by now and the senior positions they had held were mostly filled by early Meiji-era engineers who had studied overseas. Some positions were filled by scholars of Dutch studies. As support, they relied on domestic technical high school graduates and the first engineers and scientists to graduate from the University of Science and the Imperial College of Engineering (1879).

While engineers continued to go abroad to study, they were sent primarily by the Ministry of Education or the military once they had graduated from a Japanese university (Watanabe 1977). A small number of engineers, however, continued to choose an engineering education abroad rather than study at a domestic university.

It is widely accepted that Japan's industrial success is owed largely to the development of the technical educational system (Umetani 1974: 59-94). Here, I would like to look at the distinctive characteristics of Japan's engineering education, comparing it to education in Western Europe.

Unlike Western Europe, Japan had no tradition of universities and thus engineering was not excluded as an unsuitable subject for study at the highest educational institutions. Like the study of medicine or law, engineering was considered a new subject of academic enquiry from the West, and as such, was treated with equal interest and respect. Therefore, the early establishment of faculties of engineering at Japanese universities became a distinctive feature of the education system, and the large number of engineers they produced greatly contributed to the country's technological advance. The beginnings of engineering faculties lie with the founding of *Kobu Daigakko* or Imperial College of Engineering in 1871 and the courses in applied science and civil and mechanical engineering offered at the University of Science.

The role played by the Imperial College of Engineering is highly (often excessively) appreciated. The institution was created by the Ministry of Public Works as an internal training centre to train a cadre of engineers for each of its bureaus; mining, railways, telegraphy and construction. As the ministry did not possess the technical know-how to provide an engineering education, it hired a foreign engineer by the name of Henry Dyer to run the college, using a management contract. As the principal and professor of engineering of the college, Dyer was in the fortunate position to be able to create a school that realised his own ideals, by combining the strengths of British technical education (e.g., empirical knowledge) with what Britain itself lacked (i.e., a systematic education). Thus, within the six years of engineering training the college offered, students received a basic education in English and mathematics during the first two years; the next two years were spent attending classes in science and engineering; and the final two years were devoted to placements at various bureaus of the Ministry of Public Works under the supervision of foreign engineers. On graduating, the engineers assumed positions within the Ministry of Public Works (Umetani and Yamanaka 1976-78, Miyoshi 1983: 15-43, Kita 1984: 93-142). On the other hand, and as Table 3-6, shows, a small number of students who took engineering related courses at the University of Science found employment in the Home Ministry and the Imperial Mint.

This division disappeared once the Ministry of Public Works was dismantled in 1885. The engineering courses at Imperial College of Engineering and the University of Science were combined into a three-year course offered by the Faculty of Engineering at Tokyo Imperial

University (known at the time as the National Tokyo Technical College). By the end of the Meiji period, each of the other imperial universities founded in Kyoto, Tohoku, and Kyushu possessed a faculty of engineering from the very beginning.

The faculties of engineering at Meiji-era imperial universities did not resemble the research-oriented institutions of today. Rather, they were dedicated solely to transmitting Western engineering knowledge. The textbooks used were all from abroad, and many of the lectures and the examinations were conducted in a foreign language. Even the journals published by the Societies of Industrial, Mechanical and Electrical Engineering, formed mainly by imperial university engineering graduates, devoted many of their pages to overseas mission reports or excerpts from foreign journals. The science education offered by high schools in preparation for university entrance, too, devoted a considerable amount of time to helping their students master English and German as well as mathematics.

The faculties of engineering of imperial universities were able to prepare Japan for the introduction of Western technology on a massive scale, and Japan benefited from fortuitous timing in designing its curriculum. Britain during the industrial revolution had gained experience in various areas of industry but had not yet systematised it into a body of technical knowledge. This step first came when engineering was ordered into a system of knowledge based on natural sciences, as it was at various technical schools in France and Germany. And it took until mechanical engineering and electrical engineering were taught at universities in Scotland in the latter half of the nineteenth century before standard textbooks for these subjects appeared English. Thus, the technical higher education system that emerged in Japan from the 1870s was able to benefit from an engineering education system that had just been established in Western Europe, and, as a result, the country spared itself a hundred years of trial and error that Western Europe had invested in this field. Japan’s experience with educating engineers presents a noteworthy example of the advantage conferred upon Gerschenkron’s latecomer industrialised countries. Yet, we should remember that Japan managed this feat at a considerable cost; having also had to master a number of foreign languages.

The technical and vocational schools that trained middle-ranking engineers contributed more to Japan’s industrialisation than the faculties of engineering of imperial universities. In 1881, the *Tokyo Shokkô Gakkô* (the Tokyo Workers School) was established to train worksite foremen. What it in actual fact did was to train engineers. In 1897 under the Technical Schools Act, it became a technical high school along with Osaka Technical High School, which had been established a few years earlier. The technical and vocational school system was further expanded during the Taisho and early Showa periods and Tokyo and Osaka Technical High Schools were upgraded to university status (Tokyo Technical University and Osaka Technical University). Under further educational reform conducted after the World War II, these colleges and other schools became the engineering faculties of universities created under the new system.

The education offered at technical high schools was more limited than that offered at the university faculties of engineering, but the quality of the students was outstanding. The students had enrolled in these schools after completing junior high school because they could not afford to attend a university. And while graduates from the university faculties of engineering were chiefly employed as engineers by government offices or family-controlled conglomerates (*zaibatsu*) or worked as teachers in schools, technical high school graduates became the core engineers of many private-sector enterprises. As I will discuss in Section 3, these early technical high schools also offered specialist courses that were corresponded closely to indigenous Japanese industries like textiles, ceramics and brewing, and they proved instrumental to introducing Western technologies into these industries. During the first half of the Meiji period, university engineering graduates outnumbered technical high schools graduates. However, by the latter half of the period the opposite was true, and the technical higher education system contributed many more engineers than the university system did.

The three tables 3-7, 3-8 and 3-9 show how the number of engineers employed by the government and the private sector increased between 1880 and 1920 (Uchida 1988: 289-291). The total number of engineers employed in 1880 is estimated to be fewer than one hundred, implying a scarcity of people who could comprehend and use Western technologies early in the Meiji period. A large proportion of these engineers comprised of the first Japanese overseas students. They, along with institutions that offered on-the-job training, made an enormous contribution to the introduction of Western technology to Japan at a time when the Imperial College of Engineering had produced only two batches of graduates. However, with time, the number of the university-educated engineers began to grow and graduates from technical high schools, which appeared in the 1890s, added to their numbers. With this kind of output, the total number of engineers increased exponentially, tripling every decade. By 1910, there were more than 5000 engineers in Japan, with the number of technical high school graduates exceeding that of university graduates. At the same time, the number of engineers employed by the private sector overtook that employed by government offices. As mentioned earlier, technical high school graduates accounted for seventy per cent of the engineers employed by the private sector while roughly equal numbers of university and technical school graduates were employed by government offices. Examples of government agencies that employed large numbers of engineers in 1910 are the Japan Government Railways, schools, local government offices and the navy. Looking at the private sector, the biggest employers of engineers were the mines, the textiles industry, shipbuilding, and power generating enterprises. These four industries, which depended on the major Western technologies of the time, employed forty per cent of all the engineers engaged in the private sector. It may be surprising to find that commerce occupies fifth place, but the reason will become apparent in the next section.

Table 3-7 Number of Engineers Employed by the Pubic and Private Sector During the Meiji Period (by Category)

Employer	Category of Engineer	Year				
		1880	1890	1900	1910	1920
Government Departments & Agencies	Early Meiji-era engineers	61	72	-	-	-
	University graduates	25	183	474	1,075	1,795
	Technical college graduates	-	45	263	1,160	1,999
	TOTAL:	86	300	737	2,235	3,794
Private Organisations	Early Meiji-era engineers	-	17	54	34	-
	University graduates	-	131	385	846	3,230
	Technical college graduates	-	34	389	1,963	7,138
	TOTAL:	-	182	828	2,843	10,368
GRAND TOTAL	Early Meiji-era engineers	61	89	54	34	-
	University graduates	25	314	859	1,921	5,025
	Technical college graduates	-	79	652	3,123	9,137
	TOTAL:	86	482	1,565	5,078	14,162

Source: Uchida (1988: 290).

Table 3-8 Number of Engineers by the Public Sector Employer

Year	1880	1890	1900	1910	1920
Home Ministry	8	39	64	61	206
Local government offices	3	33	89	295	624
Hokkaido Settlement Bureau	-	-	23	160	179
Ministry of Finance	6	18	43	169	208
Schools	-	53	169	349	594
Army	6	14	9	98	163
Navy	14	54	90	248	418
Ministry of Agriculture and Commerce	-	31	83	198	400
Ministry of Communications	*49	13	57	120	222
Japanese National Railways		39	105	514	751
Others	-	6	5	23	29
TOTAL:	86	300	737	2,235	3,794

* Ministry of Public Works

Source: Uchida (1988: 291).

Table 3-9 Number of Engineers by Private Sector Employer

Year	1890	1900	1910	1920
Railways	34	153	149	496
Maritime Transport	3	15	28	85
Construction Industry	16	10	23	131
Commerce	2	34	186	745
Mining	46	177	513	1,779
Metals Industry	-	8	47	635
Shipbuilding	16	69	250	1,071
Machine Manufacture	6	38	106	554
Electric Machinery Manufacture		23	104	770
Electric Power Generation / Gas Industry	20	34	231	861
Ceramic Industry	11	24	90	302
Chemical Industry		12	93	570
Paper Manufacturing	1	14	68	207
Food	-	17	149	180
Textiles Industry	18	77	300	1,103
Others	9	123	506	879
TOTAL:	182	828	2,843	10,368

Source: Uchida (1988: 291).

As we have seen in this section, technical high school and university-educated engineers worked in government offices to build modern infrastructure such as railways, ports and roads and to create the basis for a Western-style professional military. In the private sector, they played a pivotal role in privatised mines and shipyards and in emerging industries like spinning and power generation. They were the central figures acting as receivers of technology transfer in Meiji-era Japan. In this role their task was twofold; to digest and manage the Western technologies introduced in each area of endeavour, and to select technologies that could be adopted to create new industries.

2-4 Importing Machinery and Collaboration with Foreign Businesses

From 1880 onwards, new industries in spinning, paper manufacture, processing sugar, shipbuilding, telephony, electric power generation and electrical instruments and equipment production grew from technologies transferred from the West. How did the transfer of technologies to these industries take place? The most common means was the transfer of the technology embodied within the capital goods Japan imported, in this case machinery and equipment. Returning to our classification of technology transfer, this method of transfer encompasses types G (the technology embodied in goods) and H (purchase contracts for goods and services). From the 1900s, Japan employed a second method to facilitate technology transfer; it entered into technical collaboration agreements with Western enterprises to introduce technology to specific industries. Contracts were drawn with companies that offered people and know-how as well as providing machinery and equipment so this method of transfer can be classified as type A, C or E (affiliates, subsidiaries, joint ventures or turnkey contracts) (Minami 1987: 9-10).

These two methods of transfer were established and implemented at a time when growing number of engineers had improved Japan’s capacity to absorb technical information, select technologies and assimilate them. At the same time, there existed a global environment, where technological advances resulted in a widening knowledge gap and large Western businesses began to adopt these new technologies as tools in their technology transfer strategies.

When the Ministry of Communications, which took over the Telegraphic Service from the Ministry of Public Works, set up a telephone network, a group of engineers, including Saitarô Ôi, a graduate of the Imperial College of Engineering, collected publically-available information, visited Britain, the US and Germany to study their telephone systems, negotiated with telephone equipment makers and selected the kind of system Japan should adopt. That is to say, there was an inflow of foreign information during the first stage of the transfer process as shown in Figure 3-1, and this flow was increased through the movement of people from the recipient (country) to the supplier. Goods such as telephones and telephone exchanges were imported, but domestic workers, without any foreign assistance, laid the lines and managed operations. Compared to the time when Japan created a telegraph service, its capacity as a receiver had improved remarkably and this case of technology transfer belongs to type G or H, where the purchase of equipment acts as the means of technology transfer.

As for the navy, early Meiji-era engineers trained in Britain and France along with shipbuilding and armaments engineers, who graduated from naval technical high schools from 1883, were key figures in designing plans to reinforce and expand the naval fleet. Throughout the Meiji period capital ships were imported chiefly from Britain. It was an age when the “all-big-gun mixed calibre ships” principle reigned and countries pushed to build ever-larger steel-armoured battleships and revolutionise their architecture. In this context, the decision to depend on imported battleships to keep apace of advances in Western military technology proved a sensible choice. Furthermore, Japanese naval shipbuilding and armaments engineers made it a custom to remain in Britain as observers while the battleships were being readied for delivery, and thus learned a great deal about ship design and construction technology from the British Navy and shipyards. Their knowledge proved invaluable to the domestic production of arms and support vessels by Japanese naval arsenals. And with time, Japan was able to build its own capital ships. Along with the technology embodied within these state-of-the-art battleships, shipbuilding know-how and the design and manufacture of arms were all transferred to Japan (Uchida 1986: 206-209, Yamauchi 1914: 52-60). Privately-owned shipyards also gradually improved their ability to construct steel-hulled ships through importing machinery and equipment. These enterprises relied on importing steel materials and parts that could not be produced domestically; sometimes they also procured designs from Britain as a means to adopt technology.

Finally, in the period when privately-owned cotton mills began to emerge, the government imported ten large-scale sets of ‘spinning machinery’ equipped with 2,000 spindles from Britain. After installing and test running the equipment at government-run mills in Aichi, the government sold these concerns off to the private sector as ten equipped cotton mills. Engineers and skilled workers from Ministry of Agriculture and Commerce assisted in the privatisation of these factories. Meanwhile, graduates of the Imperial College of Engineering, employed as master engineers, built and managed *Owaribô* and *Miebô*, the two dominant mills of that early period (Okamoto 1973: 101-104). In the next phase of development, the large-scale private cotton mills of *Osakabô*, *Amagasakibô*, and *Kanebô* were built. Here, the university educated engineers who designed the factory plans and imported the spinning machinery were sent to Britain to select machinery and acquire the practical skills and technology needed.

As these typical examples show, technology transfer from the middle of the Meiji period onwards occurred chiefly through importing machinery (type H) or the transfer of know-how that accompanied imported goods (type G). From Table 3-10, we see how the amount of machinery imported for communications, transport, and automotive industry as well as for equipping factories increased throughout the Meiji period.

Table 3-10 Major Machinery Imports During the Meiji Period

(Unit: 1000 yen)

Period (5-year)	Telegraphic & Telephone Equipment	Railway Carriages	Locomotives	Steamships	Steam Engines	Internal Combustion Engines	Dynamos / Electric Motors	Machine Tools	Spinning Machines	Looms	TOTAL VALUE OF MACHINES
1878-1882	11.8	-	-	81.9	-	-	-	-	-	-	1219.2
1883-1887	19.3	29.0	72.2	718.5	*81.7	-	-	3.0	71.9	25.6	12,066.4
1888-1892	35.8	355.8	408.2	841.7	329.1	-	-	4.5	784.5	99.0	5,755.0
1893-1897	43.1	518.5	1,505.4	4,744.5	586.2	-	-	106.1	3,012.1	206.1	16,427.7
1898-1902	65.1	1,045.6	1,963.5	3,562.2	759.8	102.5	322.6	649.1	1,330.3	199.8	19,145.1
1903-1907	113.5	1,771.7	1,705.8	4,692.1	1,208.8	262.2	1,546.0	2,404.2	1,840.8	391.5	30,354.8
1908-1912	78.0	2,336.0	1,156.8	2,215.6	797.2	873.9	2,275.4	2,687.9	3,608.0	1,060.8	37,381.6

Source: *Nihon Bôeki Seiran* [Japan: A Statistical Survey of Foreign Trading] (1935, Tôyô Keizai Shinposha).
*Average for 1884-1887 years.

Reliance on imported machinery usually means that its domestic production is delayed. Yet, an industry will naturally continue to import machinery even if that machinery is available domestically, if it seeks to obtain the Western technology embedded within it. Also, in the case of Japan, imported machinery entered domestic market at virtually no cost until the tariff reforms of 1910. Tomokichi Yoshida, an engineer who worked at *Suzuki Kikai* (Suzuki Machines & Co), a rather unusual company that developed and produced a range of industrial machinery at the end of the Meiji period, remarked that at the time, “most machinery to make paper, process sugar or spin cotton was imported even though Japan had the technology to produce it. There was no domestically produced machinery because buyers opted to import less expensive machinery.” (Yoshida 1910: 69-72). Under these circumstances, it is remarkable that Japanese companies ever produced machines like steam engines and internal combustion engines to compete with imports.

The production and design techniques of the Meiji-era domestic machinery industry were less sophisticated than those of other countries. The main cause for poor production technology was the lack of skilled machine operators. It is no exaggeration to say that forty-five years of the Meiji period were spent on building up sufficient numbers of skilled operators. As for design techniques, nearly all of the machinery manufactured in Japan was copied from imports. Therefore, we see that the gradual growth of domestic machinery production was only possible through the technology transferred by copy production (type J), accompanied with an increased machinery imports.

The early days of electric equipment production in Japan provide a good example of how the capacity of a domestic machinery manufacturer affects the technology choices made by an industry. In the beginning, pioneering enterprises like Tokyo Light & Co attempted to support the domestic production of dynamos and light bulbs while still relying on imported goods. Senju Power Plant purchased dynamos from Ishikawajima Shipyard that were designed and copy produced from a catalogue by the National Tokyo Technical College professor, Hatsune Nakano. However, the dynamos proved unreliable as the heat they generated distorted their shape. Similarly, Miyoshi Electric Machine & Co, a pioneer electromechanical manufacturer, supplied dynamos to Kobe Light & Co and train engines to Kyoto City. In both instances the goods were returned as defective. Through experiences like these, Japanese industries learned that they could not yet rely on domestic machine manufacturers (Uchida 1980: 149). Thus, imports of machinery that embodied Western technological progress continued to increase, and the mechanical engineering technology they contained was gradually transferred to Japan through copy production.

In this light, it is important to examine the role of the importer, who acted as a mediator of technology transfer through the movement of machinery (i.e., goods) during the Meiji period.

There were two kinds of importers: foreign businesses, which acted as agents for foreign machinery manufacturers, and domestic general trading companies such as Mitsui & Co, Takada & Co and the Okura Group. Importantly, these trading companies acted not only as middlemen, but also provided information and technical services to domestic producers. As mentioned earlier, a relatively large number of graduate engineers were employed by the commercial sector, and their employers were private trading companies. In 1910 Mitsui & Co employed 42 engineers, Takada & Co employed 36 engineers and the Okura Group employed 12 engineers. A considerable number of these engineers either lived in Europe and the US or travelled there on business. As well as interacting with manufacturers in the West to keep abreast of new trends and circulating manufacturer catalogues domestically, these engineers performed some of the functions of a recipient company, such as providing local investors with business plans and selecting and installing mechanical equipment.

From the 1890s, when spinning mills were being set up in fast succession, Mitsui & Co, acting as the Japanese agent for Britain's Platt Bros & Co, provided most of the equipment. In the case of electrical machinery, Bagnal Hills, an American trading company, was the agent in Japan for General Electric, and Britain's Healing & Co represented British manufacturers. The Okura Group acted as the agent for *Allgemeine Elektricitäts-Gesellschaft* (AEG) and Takada & Co was the agent for Westinghouse. Siemens had its own branch office in Tokyo. Mitsui & Co was in charge of sales for *Shibaura Seisakusho* (Shibaura Engineering Works) and it competed with the other agents over electrical equipment sales to the Japanese market. Japanese trading companies facilitated the building of new hydroelectric power plants that appeared throughout the country at the end of the Meiji period. Agents actively provided domestic entrepreneurs with basic knowledge needed for the electricity business, helped choose locations, and set up the imported machinery (Maeda 1914: 314-317, Uchida 1989: 166-167).

From the 1900s, technical collaboration agreements offered a new model for the transfer of relatively new technology between large foreign enterprises from various countries. In some cases, such as Japan Steel Works, Nippon Electric Company (NEC), Tokyo Electric and Shibaura Engineering Works, these contracts were accompanied by the acquisition of stocks by the foreign enterprise.

First, let us look at the introduction of steam turbine technology. The steam turbine was a new technology invented in Britain in 1884 by Charles Parsons. Within a decade, this technology had become the basis for ship engines and thermal power plants throughout the West. Navy yards and private shipyards in Japan were producing their own reciprocating steam engines and boilers. However, in 1905 the Japanese navy learned that the British navy planned to use steam turbines to make their capital ships faster. In response, it quickly imported Curtis turbines from the US and installed them on the *Ibuki* and *Aki*, battleships that were under construction at the time. Furthermore, the navy acquired the patent for turbine technology from Curtis and encouraged Mitsubishi Shipyard to acquire the Japanese patent for Parson's turbines. Thereafter, Mitsubishi and the Japanese navy continued to import turbines for those ships under construction, but, at the same time, they began their own turbine production for future ships (Uchida 1986: 208, Matsumoto 1989: 140-146). This was an ingenious way to acquire technology, by combining types H (transfer through importing goods), I (the rights to patent execution) and J (copy production).

During the 1870s and 1880s, the Ministry of Public Works had failed in its attempt to introduce steel manufacturing technologies to Japan through setting up the Kamaishi Mines using hired foreign experts. Transferred into private hands later on, the mine succeeded in producing pig iron and steel, but it still continued to rely on importing the steel necessary for shipbuilding, arms manufacture, railways and civil engineering projects. In 1901, the government-run Yawata Ironworks, which had adopted technology from Germany's *Gutehoffnungshütte* (GHH), opened for business. At that time, technology in the US and Germany had made great strides. Improved open-hearth furnaces and basic oxygen furnace (BOF) steelmaking methods, enabled the establishment of large-scale mills which integrated ironmaking, steelmaking and rolling processes. Strong petitioning from the Japanese military led the government to import a complete set of technologies available from a German integrated steel mill, just like the ironworks introduced at the beginning of the Meiji Restoration. The transfer of technology included confidential information about the design of the integrated mill, goods in the form of imported machinery and the provision of German engineers and skilled workers (Iida 1973: 225). This type of technology transfer is classified as E (a turnkey contract). Although the mill's set up resembles the *oyatoigaikokujin* system, it differs in one significant respect; the metallurgy and materials engineers involved were Japanese. Furthermore, the Japanese chose the location of the factories and the type of technology to adopt as well as taking the decision to rely on China for the raw materials. In addition, when operations at the mill using the technology imported directly from Germany at first failed, Japanese engineers demonstrated their skill by adjusting the technology to local conditions allowing the mill to operate successfully.

The creation in 1907 of Japan Steel Works, a joint stock company owned Mitsui & Co and two British companies, Armstrong & Co and Vickers & Co, also originated from a request by the Japanese military, which sought locally-produced armour plating and large-calibre guns for its lead ships. In this case, equipment and know-how were transferred completely from Britain through a joint venture or type C technology transfer; but the Japanese skilled workers and engineers, who came mostly from naval munitions factories, quickly learned and assimilated the technology transferred (*Nihon Kogyô Ginkô Gaikokubu* 1948: 87-94).

With regard to the three electromechanical manufacturers, each was the recipient of technology transfer as a joint venture of an American company. The following circumstances led to this development. First, in accordance with treaty revisions of around 1900, Japan's commercial code permitted direct investment by foreigners on the principle of equal treatment with nationals. Furthermore, the code upheld the patent rights of foreigners, and domestic manufacturers were no longer allowed to reproduce the latest imported goods. Meanwhile, major electromechanical manufacturers in America were investing in technological development and had begun to adopt a corporate strategy of manufacturing new products in overseas subsidiaries.

In 1899 America's Western Electric & Co founded the telephone manufacturer Nippon Electric Company (NEC) as the first subsidiary in Japan by obtaining fifty-four per cent of the shares. Western Electric and NEC were bound by a technical collaboration agreement that gave NEC sole agency in Japan and a monopoly on the patent re-execution rights in the future. Under the agreement, Western Electric was obliged to offer NEC technical guidance. In return NEC paid Western Electric roughly two per cent of the value of its sales. Western Electric was the manufacturing department of American Telephone & Telegraph Corporation (AT&T). In 1896 the Japanese government had decided to adopt AT&T system under its First National Plan to Expand Telephony. As the government intended to produce telephone equipment domestically, Western Electric first tried to form a joint venture in Japan by acquiring the stock of Oki Electric Industry Co Ltd. However, negotiations with Oki Electric failed, paving the way for Western Electric to establish NEC. NEC began by selling and repairing imported telephones. Later, it built a manufacturing plant by importing designs and equipment from Western Electric and produced standard telephones, purchasing materials of standard specification and using standardised processes supervised by American foreman. All documents within the company were in English (Okamoto 1965: 59-87, Elliot 1923: 95-106, *Nihon Kôgyô Ginkô Gaikokubu* 1948: 57-72, *Nihon Denki Kabushikigaisha* 1962: 56-67). That is to say, this manufacturer made the same products as in America and in the same way as in America, but in Japan. This means of technology transfer belongs to type A (overseas factories founded through direct investment by suppliers).

In 1905 America's General Electric (GE) entered into a technical collaboration agreement with Tokyo Electric that was nearly identical to the one between Western Electric and NEC. The agreement was accompanied by GE's acquiring fifty-one per cent of Tokyo Electric's shares. Tokyo Electric had evolved from Hakunetsusha, a light bulb manufacturer that had started business in 1890. The company had fallen into difficulty because it could neither establish a viable production technology nor compete with imported light bulbs from Germany in terms of quality or price. As a result it sought management assistance from GE, a world leader in terms of scale and the technology at the time. Tokyo Electric chose to enter into this collaboration because GE had a policy that allowed subsidiaries to manufacture light bulbs under their own patents. On conclusion of the contract, equipment and materials were imported from GE, and GE engineers moved to Japan to demonstrate manufacturing methods. Under the agreement, Tokyo Electric engineers were also well placed to master any new technology as soon as it emerged from other GE factories (*Nihon Denki Kabushikigaisha* 1940: 99-101, *Nihon Kôgyô Ginkô Gaikokubu* 1948: 35-44). Unlike NEC, Tokyo Electric was not a new company, but acquired by GE as an overseas factory. Nevertheless, as a means of technology transfer it belongs to type A, where technology is transferred through direct investment by the supplier to create an overseas factory.

The business collaboration between GE and Shibaura Engineering Works in 1907 differed in style from the above two cases. GE acquired only twenty-four per cent shares in Shibaura, well below the fifty-one per cent needed to give it majority control. Technical assistance came chiefly through patent licensing agreements, but GE also offered the transfer of know-how through reciprocal reporting of research results, the exchange of engineering personnel, and access to the blueprints for factory machinery. In return for these services, Shibaura paid GE one per cent in royalties on the value of sales. Conscious of research and development advances abroad, the heads of Mitsui & Co, who were the owners of Shibaura, proposed this technical collaboration because of the fear that the technology gap with Japan would grow ever wider. The kind of copy production used previously was no longer possible as Japan had signed onto the Universal Patent Convention that protected the patents of overseas electromechanical manufacturers for their new technologies (*Mitsui Bunko* 1971: 83, Ôtaguro 1910). Through this business collaboration, Shibaura was able to design heavy electrical equipment by executing its rights on the GE patent and also obtain technical information on research topics through the exchange of engineers. But, it did not enjoy the introduction of revolutionary technology in the production process as NEC and Tokyo Electric did. Large-scale dynamos continued to be imported from GE and competed with the Shibaura products. Although Shibaura became a joint venture company of Mitsui and GE, the existing technology of Shibaura did not fundamentally change. GE just added its technology to the outdated technology of Shibaura. In this light, it is more appropriate to treat this example as type I (a patent licensing agreement) and to some extent type G (a purchase contract for machinery and know-how), rather than type C (joint venture).

Introducing integrated production technology to government-run ironworks, the production of steel for arms manufacture by Japan Steel Works, the manufacture of steam turbines by the navy and Mitsubishi Shipyard, the production of telephone equipment by NEC, light bulbs by Tokyo Electric or heavy electrical machinery by Shibaura—all are examples of how the latest technology was introduced to Japan from the West. Whether technical collaboration agreements included foreign investment depended largely on the corporate strategy of the supplier involved. Except for the Shibaura example and the cases involving steam turbines, foreign experts guided every aspect, right up to the technology available on site. In this respect, the examples seem to be a repetition of the early Meiji period’s system for hiring foreign experts. However, there are important differences. First, the various technologies that were introduced to Japan in the early Meiji period had already spread across Western Europe over the proceeding several decades, and were introduced to Japan in the same way as they were to the colonies. At the end of the Meiji period, however, with the exception of steel, the spread of technology to Japan and advanced Western nations occurred simultaneously. Japan was not the only latecomer country. Second, Japanese engineers assumed responsibility at the workplace, and the excellence of Japanese enterprises, including the talent of their skilled workers, was one of the reasons why Tokyo Electric was chosen by GE as a partner for a business collaboration. As mentioned earlier, Japanese engineers at Yawata Ironworks were competent enough to adapt foreign technology to local conditions. When the first steam turbine was developed, Japanese engineers were quick to comprehend its potential from publically available information. After carefully examining the test results from abroad regarding its application to shipbuilding, they selected the most appropriate foreign partner through which to acquire the technology, and the appropriate timing too (Matsumoto 1986: 193).

Thanks to these improvements in domestic manufacturing potential, many Japanese enterprises were in a position to produce machinery, electrical goods and steel using a variety of means, including copy production, when the outbreak of the First World War stopped the import of goods.

3. Traditional Industries and Technology Transfer

The previous sections have focused on how technology transfer from the West led to the development of new, so-called modern industries. However, according to research that makes use of the information within the statistical yearbooks for agriculture, commerce and prefectures as well as the directory of Japanese factories from the period, the scale of these new modern industries was rather small. Throughout the Meiji period, traditional industries such a weaving, brewing and ceramics, which had existed from before the Tokugawa period, still accounted for an overwhelming proportion of the employment and output in manufacturing and mining (Matsuda, Arita, and Satô 1987: 279). Estimates by Takafusa Nakamura show that even in 1920, modern industry represented less than twenty per cent of employers in non-agriculture and forestry sectors and that most people were employed in traditional industries (Nakamura 1985: 188). Modern industry was still a small island afloat on the ocean of traditional industries.

This was to be expected. People’s tastes and habits in food, clothing and housing during the Meiji period were much the same as they were during the Tokugawa period. Traditional industries from around the country supplied the type of goods that consumers desired, and leaving aside exceptional periods like wartime, household consumption accounted for seventy to eighty per cent of GNP. Traditional industries continued to occupy a major position during the Meiji period, and because the Japanese economy belonged to a different cultural context, a limit was imposed on the growth of the new modern industries that emerged through the transfer of the Western technology. Thus, the export-oriented industries that grew out of the Meiji period were extensions of traditional industries such as silk reeling and ceramics.

Traditional industries were far from stagnant during the Meiji era. They increased output in response to the demands of a growing consumer population and the expansion of exports, and by 1910, factory production systems had spread to even rural traditional industries (Furushima 1966: 399-474). During this period, many traditional industries achieved not only a quantitative expansion, but also achieved technological advances that created new product types and improved production processes. To highlight these developments, Takafusa Nakamura adopts the term ‘new’ traditional industries.

Naturally, traditional industries employed native technologies dating back to the Tokugawa period. The Western technologies introduced in the Meiji period did not replace them, but rather co-existed with them.

Here two questions arise. First, were these home-grown technologies applied to any of the modern industries that had been developed through technology transfer from the West? Second, were the technological advances within traditional industries a result of the Western technology that had been introduced? If so, did the means of technology transfer differ from that employed to develop new industries?

In terms of the content of technology transfer, some industries that are understood as deriving from the Western technology introduced at the beginning of the Meiji period, were in fact 'new' traditional industries.

The first one of these examples is mining. Nearly all the metal ore mines that the Meiji government took over and modernised with the advice of foreign experts had been in operation since the Tokugawa period. With the exception of Ikuno Silver Mine, foreign employees were limited to a small number of engineers working under a chief engineer. These engineers did not completely overhaul existing mining technology, but rather they designed and installed a modern system for the mine. This included test boring the entire mountain to map the veins by using their knowledge of geology, creating a comprehensive system of shafts and tunnels, and making it possible to mine deeper into the ground by using steam engines to drain the tunnels and operate hoists. They also collected the ore at selected mine locations transporting it through galleries using rail (Yoshishiro 1979). The main activities of the mine; the digging and refining of ore, were still conducted using traditional methods. Furthermore, the organisation of mine labour remained intact. Tokugawa mining technology had already reached a fairly high standard, and Japan already had a body of skilled miners. With the addition of a new mine design, steam engine power and dynamite, the existing mine now could be called a Western-style mine.

The construction of railways, ports, flood controls and hydroelectric power plants all made use of traditional civil engineering technology. We have seen how the blueprints for their construction were designed first by foreign engineers hired under the *oyatoigaikokujin* system and later by Japanese university graduates. However, the plans were transformed into structures by craftsmen's guilds (*kumi*) of masons and construction workers, who employed traditional techniques that had been in existence since the Tokugawa period. The care and attention to detail that we observe in the water channels and port structures built by Meiji craftsmen that remain today is truly impressive. From the facades of these structures, we notice that the construction practices used were no different to those employed by the craftsmen who built the sluices and castles of the Tokugawa period (Iizuka 1982: 115-130, Iizuka 1988: 104-110). In a report produced on his return home, William Potter, a English engineer who worked in railway construction commended 'Japanese workers as quick witted and hard working', noting that railway construction in Japan used masons and traditional methods for boring holes (Harada 1979: 57-63, Potter 1878-79: 6).

Now let us turn our attention to silk reeling. The government-run Tomioka Silk Mill and the *han*-operated Maebashi Silk Mill appear even in high school textbooks as typical examples of enterprises that introduced Western technology through the hiring foreign experts. Yet, the silk-reeling technology introduced from France and Italy was not as transformative as shift from handlooms to mechanised ones in the cotton textile industry. That is to say, the actual reeling process, which consisted of a series of steps: *shaken* (boiling the cocoons), *sakucho* (picking up filament ends from the basin), *seccho* (feeding the ends), *yorikake* (twisting several filaments into thread), and *rakkô* (reeling onto a spool), still relied on the dexterity of an individual reeler, as it had done with the earlier techniques of hand reeling (*tebiki*) and or sedentary reeling (*zaguri*). As such, a single reeler could still only extract one or two ends of filament from the cocoon for a reel. The same basis is used for silk reeling technology even today and it had already been established by the Tokugawa period (Okonogi 1989: 62). The Western technology introduced to Western-style silk mills made the following changes: It allowed for steam to be distributed to individual basins from a boiler via pipes and the spooling of silk to be powered by the steam engines or watermills. No doubt silk reelers could easily recognize the machines imported as a mechanised version of the hand-held or sedentary devices that they used earlier for crossing and twining several silk filaments. The transfer of Western technology to the silk-reeling industry was essentially the improvement of a traditional industry. Thus, the mechanised-reeling technique quickly spread nationwide, through silk reelers seeking employment at government-owned silk mills. The core information transferred in this instance was the concept of a factory as a system, rather than any hard technology (Kiyokawa 1986: 241).

In Shinshu, imported silk-reeling machines were simplified to an extent that allowed local blacksmiths and carpenters to produce them and a Japanese-style waterwheel to propel them. In this way an adaptive technology was born. In more rural Joshu, sedentary reeling remained the norm, but the re-reeling process was motorised within a co-operative, bringing about a revolution in industrial organisation. It is interesting to note that these kinds of adaptations of Western technology by traditional industry were absent in Chinese society, which imported mechanised reeling technologies at around the same time (Yoshida 1985: 58-61).

Furthermore, while the silk reeling technology of France and Italy remained unchanged at the beginning of the Meiji period, in 1903 Naosaburo Minorikawa invented the first multiple-spool machinery that allowed a single operator to extract more than 10 filaments of silk (Minami and Makino 1987: 57, Kiyokawa 1977: 340-342). Through Minorikawa's invention, Japan became the world leader in silk reeling technology.

The weaving industry, including the dying industry, was the largest traditional industry in Japan. After Japan opened its ports, cotton imports increased dramatically, but this was just for a brief period and in the end the traditional weaving industry revived. One reason its comeback was that the kind of cotton cloth imported did not match the types demanded by the Japanese market

(Kawakatsu 1977: 184). The West could not supply dyed-yarn, narrow-width cotton fabrics in traditional patterns such as *shima* (stripes) and *kasuri* (Japanese *ikat*) used for traditional Japanese clothing. Another reason was that Japan's indigenous weaving industry identified useful elements of Western technology and quickly assimilated them.

It is well known that the flying shuttle (system attachment) and the Jacquard (control mechanism) are two Western technologies that were adopted widely throughout the weaving industry in the early Meiji period. These two inventions, which were brought to Japan by a delegation of weavers from Kyoto who visited Lyon in 1872 and could be copied by blacksmiths and carpenters of any weaving districts within a decade, spread through the country as attachment devices for handlooms. There were significant differences between flying shuttle and the Jacquard. The flying shuttle was a device that doubled productivity because it enabled the weaver to work faster, by using just one hand and completing a pick in fewer movements. It could be used for the production of any type of cloth. The Jacquard, on the other hand, was a special device used only in the production of high quality, patterned textiles. It also raised productivity by automating the role of the assistant, whose job had been to lift the warp threads to make the pattern, and enabling operation by just one person.

While the adoption of these two technologies was rapid, that of the power loom was slow. It is easy to understand why. In the case of cotton thread production, the shift from manual to mechanised production raised productivity between fifty to one hundred fold, but the shift from manual production to motorised production (without automation) only raised productivity two to four fold. Furthermore, because power looms were expensive, they could not offer the same economic efficiencies that the flying shuttle could. An additional consideration was the design; the imported power looms had a broad warp beam and could not be used to produce the narrow-width fabrics that were in demand domestically. Therefore, the adoption of power looms in Japanese weaving industry was not just simply slow, but delayed until inventors from various weaving districts, like Sakichi Toyoda, had developed an affordable narrow-width power loom that could mass produce fabrics like calico (*shiromomen*) and *Habutae* silk (Ishii 1986: 107-127).

Technological advances in the weaving industry not only contributed to process innovation that improved labour productivity, but also, and more importantly, to product innovation, which created new fabrics and fashions. The weaving industry created new types of casual wear made from printed flannels, Meisen silks and muslin by using Western technologies and inventions such as chemical dying, silk spinning and worsted yarn, thus improving the quality and choice of clothing available (Uchida 1988: 167-169).

As the above examples show, traditional Japanese industries did not introduce Western technologies wholesale, but adopted them through a judicious and selective process. And, by combining indigenous technologies with new, they developed new home-growth technologies. To consider the Meiji period as a time of blind imitation of Western technologies, is a view that could only be applied to a portion of its industries. For traditional Japanese industries, it was a time when the spirit of innovation was continually given new impetus through the stimulus it received from Western technology. Between the enactment of the 1885 Patent Monopoly Act and the end of the Meiji period (1912), close to 23,000 patents and 26,000 utility models (patent protections), mostly related to native industries, had been registered (Kiyokawa 1988: 355). The majority of inventors were connected to traditional industries, and they were grassroots inventors who worked as craftsmen or employees of small and medium-sized commercial and manufacturing enterprises, rather than engineers who had exposure to Western technology through formal university or technical college education. If looked at closely, many of the inventions were relatively simple but contained practical ideas, and it is possible to argue that they were an extension of Tokugawa innovations such as the *Hacchô*, a device to twist thread (Kameda 1972: 3-20) and a spring device for cutting tobacco leaves (Okuda 1989: 5-16). Still, we can also recognize the influence Western technology had on the innovations of the Meiji period. For example, the wheels of imported bicycles added to rickshaws that were invented before the 1885 Patent Monopoly Act and refinements to the throstle spinning frame or *garabô* (Ishida 1989: 105-113, Tamagawa 1986: 1-19), whose divided branches and rotating spools were influenced by imported cotton spinning machines. Kenzô Takabayashi, who invented a tea processor (Shintani 1987: 33), and obtained one of first few patents to be granted, had lived in Yokohama. We could speculate that the extrusion mechanism on Terusato Mazaki's noodle-making machine, which was patented in 1888, was inspired by imported inventions like the metal rolling mill, printing press and fabric printing machines and was not just another application of the native Japanese cotton gin (Uchida 1982: 60-63).

As mentioned above, the inventions based on the power loom in Japan began in the 1890s, and patent registrations for them peaked in 1910 (Ôtsuka 1987: 123). Of course, these spin offs were not fundamentally different from the transfer of technology embodied in the imported power looms, even if there were some differences in the detail of the mechanism. However, if we believe accounts by Sakichi Toyada which describe his visits to factories in Tokyo and the Yokosuka Shipyard as well as daily visits to the Third National Industrial Exposition in order to see imported machines (Tanaka 1933: 66-84), Western technology must have had an indirect influence on the small improvements he made to various looms.

Viewed in this way, the transfer of the Western technology to traditional Japanese industry can be understood not only as type H (the transfer of the technology embodied in imported machinery or devices) but also type K (the in-house development of technology) in response to market conditions. None of the examples used imported machinery as was, nor did they involve copy production.

From the 1890s engineering graduates of technical high schools began to play the role of mediator, transferring Western technology to traditional industries in districts all around the country. Technical high schools possessed specialist departments in textiles, ceramics and brewing that corresponded to major traditional industries, and which were absent from the faculty of engineering of universities. The sons of those men who ran these traditional industries attended these high schools, and after graduation, many of them applied the Western technologies they had learned to their businesses at home. Others became engineers who worked at the Ministry of Agriculture and Commerce or at testing centres in various prefectures training dyers, weavers and ceramics manufacturers. Yet others became teachers at technical high schools located in industrial areas, advising the successors to traditional industries on the basics of Western engineering and the handling of imported equipment (Uchida 1982: 58-60, Imazu 1987: 247-252, Kobayashi 1981: 198-207).

The transfer of the Western technology to Japan during the Meiji period gave the country the opportunity to modernise its economy and evolve into a fully-fledged capitalist system. Whether the transition from Tokugawa to modern Japan took place gradually or in leaps is a major issue in Japanese economic history. We accept that there was at least a disconnect between traditional technology from Tokugawa period and Western technology because they derived from different techno-cultural complexes. However, as we have discussed in this paper the process of technology transfer that began at the end of the Tokugawa Shogunate developed gradually from a model that procured management expertise through hiring of foreign experts to one that demanded a higher degree of independence on the part of the receiver. Here, the training of domestic engineers was key. We can also clearly recognise the continuous series of changes in traditional industries or innovations in indigenous technology achieved through absorbing selected elements of Western technology. Furthermore, by the end of the Meiji period, business collaboration and foreign investment from the West enabled the transfer of the latest technology. Taken from this perspective, the transfer of technology from the West to Japan proceeded gradually over half a century from the end of the Tokugawa Shogunate to the end of the Meiji period, and the change it brought to the Japanese economy was continuous.

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