Chapter 5
Meiji Japan: progressive learning of Western technology

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This draft: April 25, 2018

Abstract

In the second half of the nineteenth century, Japan transformed itself from an agro-based feudal society to one of the leading industrial nations of the world. This was attained by aggressive learning and local adaptations of Western technology. Meiji Japan's learning began with simple methods such as book study and turnkey projects directed by foreign advisors, but in time progressed to the generation of a large number of proficient Japanese engineers and technicians, analysis and copy production of imported machinery and selective acquisition of frontline technology through licensing, technical cooperation agreements and joint ventures with foreign giants. In most cases, the Japanese side quickly mastered the technology and graduated from foreign help. Country ownership in executing technology transfer also increased over time. Private dynamism inherited from previous periods was the main driver of technology learning while policies of the Meiji government were mostly appropriate and supportive of private effort.

Key words: Japan, Meiji period, technology transfer, industrialization, industrial policy

1. Rapid industrialization and westernization

From the early seventeenth century to the middle of the nineteenth century, Japan was ruled by the samurai (warrior) government of the Tokugawa family who governed from Edo (present-day Tokyo). Japan then was an internationally isolated feudal society based on peasant agriculture. As the nineteenth century dawned, Western powers began to approach Japan for diplomacy and trade but the samurai government refused to deal with them. Then, in 1853, an American military fleet ("Black Ships") commanded by Commodore Matthew C. Perry entered the Bay of Edo to demand the opening of Japanese ports with the display of cannon fire. In the following year, Japan was obliged to sign the treaties of "amity" with five Western powers which permitted port calls by foreign ships. Four years later, in 1858, Japan was forced to conclude "unequal" commercial treaties with the West which lacked the rights to set its own tariff rates or judge foreign criminals. Through this humiliating experience, Japan found itself a backward nation which was no match for Western economic or military might. A decade of political struggle and military conflicts ensued, which toppled the samurai government and established a new one that regarded rapid westernization and industrialization as paramount national goals. The new Japan was officially ruled by Emperor Meiji but actually run by former young samurais who ended the feudal rule by military means.

Meiji Japan (1868-1912) set itself the targets of political modernization, industrialization, military buildup and correcting the unequal commercial treaties, and eventually attained all of them. In less than half century after the forced opening of ports, it succeeded in vigorously importing Western systems and technology, thereby transforming itself into a "modern" state boasting a Western style constitution, parliament, laws, court, cabinet, ministries, military, police and local governments (Banno & Ohno, 2010, 2013). In the economic arena, an industrial revolution in light manufacturing was achieved in the 1890s (Minami 1986, Hara 1999). By the early twentieth century, Japan overtook the UK as world's top exporter of cotton textile products. In the military sphere, Japan defeated the Qing Dynasty of China (1894-95) and the Romanov Dynasty of Russia (1904-05) and secured control over Korea and part of Northeastern China. As Japan's political, economic and military standing rose, Europe and America agreed to revise the unequal commercial treaties in steps with the complete restoration of tariff and court rights attained in 1911. After WW1 (1914-18), Japan was invited to major international conferences as one of the Big Five along with the UK, the US, France and Italy.

Meiji Japan's emergence from an agro-based backward latecomer to one of the most advanced nations in the world was accompanied by a fast and broad absorption of Western technology and its local adjustments, and the high-quality human capital that made this possible. This chapter examines how this was done.

The most prominent aspect of Meiji Japan's technology absorption was progression from easy to complex in both content and method of technology learning as domestic capability steady rose (Uchida

1990). This situation will be amply and concretely demonstrated in the rest of this chapter. Another essential feature was a happy blend of strong private dynamism and (mostly) appropriate industrial policy. This was true not only in the late nineteenth century, but also in the post-WW2 period when Japan recorded another rapid growth, this time based on heavy industries and high technology (Ohno 2018). In both periods, private dynamism was the main engine of growth while policy played an important supporting role. Another unique fact was the long co-existence of traditional and modern industries and their parallel development and interaction (Nakamura 1997, Odaka 2000). Old industries from the Edo period were not wiped out by the intrusion of superior Western technology. This was possible partly because Japan and the West belonged to entirely different cultural spheres with dissimilar food, clothing and housing, and also because Japanese industries selectively adopted new technology to improve and scale up production.

2. Historical background

The natural question is, where did Japan's private dynamism and relatively wise government come from? For this, a historical perspective is crucial. The answer must be found in the periods leading up to the Meiji period, not just in what the Meiji government did in technology transfer or engineer training. Before delving into concrete ways of technology learning, this section reviews the pre-conditions of Japanese industrial revolution prepared before Meiji. It also explains why today's developing countries are advised not to directly copy the policy menu of Meiji Japan—not only because external conditions have changed greatly since the late nineteenth century but also because many of the latecomers today lack internal preparation for technology learning which Meiji Japan had.

Umesao (2003) advances a hypothesis that Japan's unique geographical position generated social dynamism throughout its recorded history of almost two millennia[1]. According to him, Japan—just as Britain—is physically separated from the Eurasian Continent by a narrow strait. This allowed it to import the culture and systems of high civilization with relative ease while avoiding or minimizing military invasion from outside. Enjoying external stimuli under protection, society could evolve continuously without being destroyed or severely damaged by foreign invaders. The Japanese state, which first emerged in the fourth century AD, evolved sequentially from strong central power to decentralization, feudalism, a rise of local economic activities and finally capitalism, unlike societies on the Eurasian Continent which were prone to attacks and even annihilation by violent nomadic peoples every few centuries. Umesao believes that Japan's unique geography and the resulting cumulative history prepared conditions for strong economic growth, and that its industrialization proceeded in parallel to that of the West rather than by just copying others.

[1] Umesao's hypothesis was first presented in a Japanese article published in 1957. He terms it an "ecological view" but, as explained here, it is more concerned with Japan's particular geography which permitted an uninterrupted social evolution.

Shiba in his historical essays, published over 1986-1996, also points to Japan's status as an island nation as the major shaping factor of Japanese people, making them curious and eager to accept foreign ideas and objects but only after adjusting them to Japanese tastes and mindset. The other shaping force identified by Shiba is the samurai spirit whose highest value is honor, not personal gain or family prosperity. Japanese people want to live and die honorably, avoiding shame.

Maegawa (1998) observes that, in general, an encounter with the powerful West may weaken or even destroy an indigenous society but it may also lead to activation and dynamism of such society. In the World System, the Center (large nations and international organizations) imposes its rules on the Peripheries (latecomer societies), forcing them to adopt the norms created by the strong. The Peripheries look helpless and passive in front of external pressure. However, Maegawa argues that a latecomer is not really weak if it controls the type, terms and speed of importation of foreign things, using them to stimulate the existing society for new growth. Even as foreign elements are added, the basic social structure remains intact. Such a nation is said to manage global integration adroitly. Meiji Japan is regarded as a prime example of this feat which he calls *translative adaptation*.

What is the mechanism by which long and evolutionary history forges a nation capable of adsorbing foreign elements effectively without losing national identity? Umesao is reticent on this question, and we can list only some hints (Ohno 2018). Frequent mergers of domestic and foreign elements make the society unafraid of and resilient to external shocks, and at the same time flexible enough to change. Moreover, the mindsets of both the ruler and the ruled are inculcated by the institutional memory of the long past which recognizes behaviors and social ethos that preserve the nation against short-term crises. Heroic deeds are told and re-told through books, poems, songs and theatrical arts in which the hero laments the cruel fate but selects the action that best serves the nation and its future generations. Japanese people adore Yoshitsune, a young and splendid samurai leader in the twelfth century who won dazzling victories but was cornered by his jealous brother to his tragic death, as a model samurai who performed duties without clinging to self-interest. Spiritual values such as hard work, honesty, patience, high aspiration, sacrifice and long-term vision are esteemed. Japanese national leaders, government officials and business people are naturally affected by such social atmosphere.

When feudal Japan was confronted by Western powers in the middle of the nineteenth century, this time-generated national mindset was fully at work.

In politics, the previously uncontested authority of the Tokugawa family began to crumble after the unequal commercial treaties were signed with the West and domestic opponents of the treaties were brutally suppressed through execution and imprisonment. From around 1860, the legitimacy of the Tokugawa government was openly challenged, leading to several years of intensive debates and fights over political leadership and the wisdom of foreign trade. Even in this fierce competition, opposing camps often cooperated for a common goal of avoiding colonization by adjusting strategies and re-forming partnership rather than insisting on rock-solid positions with an intention on mutual annihilation

(Banno & Ohno, 2010). Transition from feudal Edo to modern Meiji was achieved with surprisingly low casualties of about 10,000 warriors and soldiers. In contrast, the French Revolution and the Napoleonic Wars resulted in five million deaths, and post-WW2 conflicts in Korea, Vietnam, Nigeria, Cambodia, Afghanistan, Mozambique and Sudan each claimed over one million lives. One Meiji journalist wrote: "Although both [Japan and France] go from one extreme to the other, our people do so within certain bounds while the French do so outside these bounds" (Tokutomi 1889).

Moderation in political and military showdown was possible due to several reasons. Fights over political leadership and international trade were restrained by rising nationalism against foreign colonizers, emergence of rich and intellectual classes, and general discontent with outdated policies and governance of the Tokugawa rule. These in turn were the results of the peaceful and steady development of Edo society which nurtured the sense of national oneness for common goals. For these reasons, nineteenth-century Japan could keep subtle balance between fierce political competition (dynamism) and ultimate national unity (stability).

In socio-economic fields, Edo Japan spawned many important developments which facilitated technology learning and industrialization in the subsequent Meiji period. First, small-holder family agriculture grew in both area and land productivity. Public and private projects in opening new fields and water management were active, and new farming methods, tools and organic fertilizers (dried fish) were introduced to boost quality and yields. Second, nationally-integrated markets and transport systems for rice (tax base) as well as various cash crops and manufactured products developed. Third, commerce, finance and a wealthy merchant class emerged with Osaka as a national economic center. Fourth, a large number of pre-modern manufactured goods such as sake, kimono, ceramics, cutlery, processed food and natural dye were produced in virtually every city and province via private effort and public support. Fifth, some provinces even succeeded in systematically promoting agriculture and manufacturing in their domains even though the central Tokugawa government was largely uninterested in and incapable of such promotion (Ohno 2018).

On top of all this, education became a national fad from top samurai to commoners. For adults, official and private classes were offered in ancient Chinese literature and philosophy as well as (later) in western languages, medicine and navigation. For children aged roughly seven to thirteen, *terakoya*, unregulated for-profit private primary schools, popped up all over Japan to the tune of 20,000 establishments where self-appointed teachers taught reading, writing and arithmetic (abacus) with flexible and individualized curriculums.

Thus, when Japan was pried open by the American Black Ships for diplomacy and trade in the 1850s, its people and institutions were able to absorb and internalize the new technologies and systems presented by the West. It can be said that Japan's re-encounter with the advanced West occurred just at the right time when the Japanese society had evolved sufficiently and was ready to take up a new challenge for transformative growth. The old policies and systems imposed by the Edo government had become constraints for such growth.

3. Early attempts in technology learning

In 1854, the Edo government made its first conscious effort to import pragmatic foreign technology by installing Western-style armaments for coastal defense. Some provinces (called *hans*) also tried to replicate foreign technology by building furnaces to smelt metals for casting cannons. Scholars of Dutch studies and traditional craftsmen built such furnaces relying solely on descriptions in imported Dutch books, which however were already outdated by the time they were translated. Haphazard copy production of steel and arms generally failed. Some hans also test-produced Western-style ships and steam engines from Dutch texts, but the technology gap between their results and the actual foreign ships visiting Japan was so great that this effort had to be abandoned. Realizing the limits of learning technology only from books, the central government and some hans reverted to directly importing ships and firearms manufactured in the West after Japan opened up for international trade in 1859.

The results were not so dismal in cases where technology was transmitted in the presence of foreign instructors. The construction of a Western-style wooden ship at Heda port in the Izu Peninsula in 1854, where Japanese carpenters worked under Russian naval officers and shipwrights to build a new vessel for Russians to return home, can be regarded as the first successful attempt of on-site technology transfer. The Japanese carpenters absorbed the technology so well they later became skilled workers at Japanese naval arsenals and private shipyards.

Another notable case was the Nagasaki Naval Training Center. Established in 1855, it trained the crew of Japan's first Western-style battleship, the *Kanko Maru*, which was a gift from the Dutch government. This training project was a joint undertaking of the Dutch navy and the Edo government with daily management entrusted to the former. Five Dutch naval officers trained 167 samurais who had been competitively selected from all over Japan. Courses focused on standard naval training such as navigation, artillery and the care and maintenance of steam engines. The Japanese crew also received on-the-job training through exercise navigation to Kagoshima. Between 1860 and 1870, the Edo government and a number of han governments imported a total of 166 ships from the West. It was the graduates of the Nagasaki Naval Training Center and two similar centers subsequently set up in Edo and Hyogo who operated them. The importation of different types of ships enabled Japanese to compare and enrich their knowledge of warships, engines and gunnery. Similarly, the army of the Edo government acquired skills both through the artillery it imported and foreign military advisors who trained students.

The Edo government also built the Nagasaki Steel Mill and Shipyard in 1857 and the Yokosuka Steel Mill in 1866 as ancillary facilities for the Nagasaki Naval Training Center. These facilities, which later became Mitsubishi Nagasaki Shipyard and Yokosuka Naval Arsenal, replicated Western mechanised factory production and transferred technology to Japanese under the supervision of foreign engineers and technicians. Kagoshima Spinning Mill, established in 1867 by Satsuma Han, adopted a similar approach. These early factories became a model for the Meiji government's program which hired foreign advisors for construction and guiding factory operation.

4. Foreign experts and turnkey projects

In the early years of Meiji, the new government hired foreign advisors to the tune of 300 to 600 in any year on a project contract basis, at considerable fiscal cost, to establish Western style state-owned enterprises in railroad, telegraphy and silk reeling (Umetani 1968). Some foreign advisors received salaries higher than that of the Japanese prime minister. Each project recruited a team of foreigners usually of the same nationality with various functions, who imported virtually all materials to create an exact replica of a foreign model (Kasuya 2000). These were turnkey projects with a foreign director supervising his fellow countrymen and Japanese workers, with the Japanese side overtaking operation and maintenance after project completion[2]. Yokosuka Shipyard, Tokyo-Yokohama Railroad, Imperial Mint and Ikuno Silver Mine were such examples. There were also foreign advisors hired individually to fill specific technological needs at government bureaus and agencies as well as industrial, mining and agricultural projects run by the Home Office and the Hokkaido Settlement Agency. Such individual employment required greater ownership and involvement on the Japanese side than projects entirely entrusted to foreign teams.

These turnkey projects hired Japanese to perform only unskilled or auxiliary works. The Imperial Mint was directed by William Thomas Kinder who was dispatched, along with other experts, by the British Oriental Bank to create and manage the mint under a Japanese government contract. Its annual reports were published in the name of Kinder. Meanwhile, in the case of Telegraphic Service of the Ministry of Industry, the official report was submitted in the name of the Japanese second-in-command. The Japanese edition of the report claimed that Japanese and foreigners shared duties equally but the English edition stated that the Japanese worked under the supervision of foreigners. It is suspected that the latter was closer to the truth while the former story was made up to please the higher-ups in the ministry.

The primary aim of establishing a mint, telegraphic service, railroads and shipyards was to rapidly introduce modern industrial infrastructure comparable to Western models. Given the speed with which the Meiji government wished to build them, it is not surprising that these enterprises were run by a large

[2] Technology transfer at state-run enterprises under turnkey projects proceeded on a trial-and-error basis rather than as a well-planned process. Masahide Yoshida, a former samurai serving the Edo government, recounted that he had been recruited as one of the first Japanese staff of the Telegraphic Bureau in 1869 simply because he was studying English in Yokohama. On the third day he was asked to send and receive telegrams for which he had no previous knowledge. He somehow learned the skill but eventually chose to become an interpreter of the foreign advisor who laid telegraphic cables between Tokyo and Nagasaki (Uchida 1990).

number of foreigners who managed them in the same way as the establishments at home. These early projects did not always consciously aim at transferring technology to Japan.

Western countries also considered it highly desirable that Japan build infrastructure by Western standards. For foreign diplomats, merchants and shipping companies, Nagasaki and Yokosuka Steel Mills were indispensable for the repair of their ships. Nagasaki Kosuga Dock and Takashima Coal Mine were additionally created to repair foreign ships and replenish fuel (charcoal) under the management of British merchant Thomas B. Glover. The construction of lighthouses and telegraph service was requested by British Consul General Harry Smith Parkes to the Meiji government. By 1874, British engineer R. H. Branton was commissioned, who assembled an 88-men strong team of British, Chinese and Filipino workers that included builders, lighthouse keepers and boat crews. Branton undertook construction and maintenance with all costs borne by the Meiji government. These lighthouses ensured safe passage for foreign and Japanese ships alike.

In the area of telegraphy, the Edo government signed an agreement with the French government to build a telegraph service in 1866. However, this decision was overturned by the Meiji government which chose, through the mediation of the British consul general, a domestic service provider. Okita Telegraph Company, owned by the Danish, was awarded a contract for sole agency. By 1866, two international telegraph lines had been laid from Europe to the Far East via Russia and via the Indian Ocean, and the Japanese telegraphic cables connected them at the end and extended them to Nagasaki and Yokohama, the two port cities with large foreign settlement. This enabled foreign diplomats and merchants in Japan to have easy contact with home.

Japanese government orders of machinery, equipment and materials brought handsome profits to foreign merchants, who also mediated technology transfer. Jardine Matheson & Co. and the Oriental Bank competed over an order to build and equip the Imperial Mint. When the latter won the contract, it not only imported second-hand equipment from the Hong Kong Mint and sold gold and silver for minting but also provided Japan with management expertise by hiring a British team headed by Kinder as mentioned above. For any such project, foreign merchants would act as middlemen for importing management and technology by mobilizing engineers and technicians from the home country.

International migration of Western engineers was also behind the prevalence of turnkey projects abroad. As British industrial infrastructure was nearly completed by the 1850s, the pace of building railroads, ports and other facilities slowed down to produce a surplus of civil engineers in Britain. Needing work, many chose to migrate to the Continent, then British colonies and foreign lands such as Canada, India, Australia, South Africa and South America. Machinery and equipment makers also turned to overseas markets. For British railroad contractors, it was customary for a supervisor who received an overseas order to secure all equipment and materials needed such as train tracks and locomotives at home, hire subcontractors and a team of skilled workers, then travel with them to his destination. In 1857, a team of 160 Britons travelled to Argentina to build a railroad. A similar team came to Japan thirteen years later to lay its first railroad between Shimbashi and Yokohama.

As noted above, technology transfer was not the main purpose of turnkey projects, but the method did provide a good training ground for Japanese workers. It fostered new machine operators, steam engine drivers, steelworkers and electricians. They often migrated from state-owned enterprises to the private sector or set up their own factories, spreading Western technology that they had acquired and contributing to the creation of Japanese enterprises with modern management knowledge from the 1880s onwards.

As the absorption of Western technology and management progressed, turnkey projects conducted by large foreign teams came to an end in the relatively early years of Meiji. From around 1875, state-owned enterprises stopped hiring such teams and, by 1880, foreign engineers had disappeared from all but a few workplaces. Factories and facilities that had been created under management contracts were now run by Japanese. This shift resulted partly from the strong desire of the Meiji government to "import substitute" engineers so it no longer had to foot the expensive bill. But more important is the speed with which Japanese workers absorbed new practical skills. Japanese enterprises did not need continued foreign help in operating modern and complex equipment which Japan first saw only a decade or so ago. There were already competent Japanese managers and engineers who could easily replace foreigners.

5. Engineering education

After the departure of foreign advisors, Japanese engineers assumed the role of internalizing and diffusing Western technologies in Japan. They understood the core of Western technology and could put this knowledge to practical use. They collected latest technical information from abroad and instructed appropriate models to purchasing missions dispatched to European and American manufacturers. After a factory was built, they supervised its operation. This smooth transfer of Western technology owed much to the fact that Meiji Japan trained a large number of Japanese engineers to an exceptionally high standard in a short period, a feat that few latecomer countries have been able to emulate. Apart from turnkey projects mentioned above, industrial training was realized by sending students abroad as well as by establishing domestic institutions for technical education and training.

Early engineers studied Western technology before a formal university and technical education system was established. They can be divided into three types. First, there were scholars of Dutch studies from the late Edo period who had relied on imported technical books and journals. They worked for Western style establishments owned by the Edo government or various hans, and later served as engineers for the Meiji government. Oshima Takato, who built the first blast furnace in Japan, Takeda Ayasaburo, who built the star-shaped fort in Hakodate, and Utsunomiya Saburo, who became Japan's first cement manufacturer, were among them.

Second, there were graduates from technical schools managed and taught by foreigners. They included the Nagasaki Naval Training Center (1855), Yokosuka Shipyard School (1870), the Telegraphic Service Technical Training College (1871), the Imperial Naval Academy's Institute for Maritime Studies (1873), and the Railroad Engineer Training Center (1877). These institutions taught in foreign language—usually English and sometimes German—and transmitted knowledge necessary to perform assigned functions so workers could run the business after foreign management left. The graduates later worked as foremen or junior technicians in Japanese army, telegraphic service, railroads and shipbuilding. For instance, graduates from the Railroad Engineer Training Center supervised and successfully completed the construction of a railroad from Kyoto and Otsu which included tunnelling through Osaka Mountain, in 1878-1880.

The third group of early Meiji engineers were those who were sent abroad to study by the government. The Ministry of Education and the military selected best graduates from educational or training institutions for continued study abroad. They proved to be extremely good and hardworking students despite the meagre stipends provided by the government. On returning to Japan, they worked as senior technical experts for government ministries or for the private sector. The very first overseas students were seven men sent to the Netherlands by the Edo government to learn military navigation in 1862. The navy later sent many trainees abroad from the Yokosuka Shipyard School and the Naval Academy to learn shipbuilding and arms manufacture. There were also some who chose foreign education at their own will and cost, and even others who went abroad without official permission.

By the end of the 1880s, the government had dispatched around 80 students abroad to be trained as engineers as far as the records show. Among them, 21 studied shipbuilding, 17 studied mechanical engineering, 13 studied civil engineering, 10 studied mining and metallurgy, 6 studied arms manufacture and 4 studied chemistry. By destination, 28 were sent to the UK, 20 to the US, 14 to France, 9 to Germany, and 8 to the Netherlands (excluding unknowns, Uchida 1990). They not just took formal courses at universities but also went to renowned technical schools, received on-the-job training at factories or had private lessons for broader knowledge.

Not many Western universities at that time acknowledged or offered pragmatic technical education. In the UK, only universities in Scotland and London had mechanical and civil engineering chairs prior to the 1840s. It was customary for a British engineer to be trained on site, first working as an apprentice and then as an assistant. Many of the British engineers who migrated abroad had been trained in this way. In France, there were some notable technical institutions such as *École Polytechnique*, *École d'Application,* and *École Centrale*. In Germany, each state boasted a number of technical and vocational schools, including the mining school of Freiberg established in 1765. In the US, there were few technical education institutions until the first half of the nineteenth century. Boston Tech, which later became Massachusetts Institute of Technology, was founded in the 1860s, and at around the same time Columbia University and Cornell University first offered civil, mechanical, mining and materials engineering courses. However, these technical institutions and courses were still considered a rank below universities until the end of the nineteenth century. It can be said that the first wave of Japanese overseas students were sent to the right institutions for absorbing pragmatic technical knowledge, and received first-class training on par with European and American engineers. It is no surprise that they could easily replace foreigners upon their return to Japan.

Meiji Japan accepted engineering, along with medicine and law, as one of the new subjects to be studied vigorously. Unlike Western Europe, it did not look down on engineering as an inferior subject with less academic quality. The early establishment of faculties of engineering at Japanese universities contributed greatly to the country's technological advance. Meiji Japan selectively imported the latest and the best of engineering education which the West had created through a century of trial-and-error, and combined them for the best practical—not academic—results. This was initiated with the founding of the Institute of Technology (*Kobu Daigakko*) in 1871 and the courses in applied science and civil and mechanical engineering at the University of Science.

The Institute of Technology was established by the Ministry of Industry to train a cadre of engineers for its bureaus of mining, railroad, telegraphy and construction[3]. As the ministry did not possess needed technical expertise, it hired Henry Dyer, a British engineer, to run the Institute under a management contract. As the rector of the Institute, Dyer was in a fortunate position to be able to design a program which he considered ideal by integrating theory and practice, a feature that British engineering education lacked. The six-year program of the Institute included basic training in English and mathematics in the first two years, specialized classroom instructions in the next two years, and internship at various bureaus of the Ministry of Industry under the supervision of foreign engineers in the final two years. On graduating, young engineers were expected to assume positions within the Ministry of Industry. At the University of Science, a smaller number of graduating students found employment at the Home Ministry, the Imperial Mint and others. Three other imperial universities established in the Meiji period—Kyoto, Tohoku and Kyushu—were equipped with a faculty of engineering from the outset.

These faculties of engineering were not research-oriented but dedicated solely to transmitting Western engineering knowledge to Japanese soil. Textbooks were all foreign, and many of the lectures and examinations were conducted in English or German. The journals published by the Societies of Industrial, Mechanical and Electrical Engineering devoted many pages to overseas mission reports and excerpts from foreign journals.

Establishment of schools for supplying mid-level industrial instructors and factory supervisors was proposed by Gottfried Wagener, a hired German engineer, and Tejima Seiichi, a Ministry of Education official. *Tokyo Shokko Gakko* (Tokyo Craftsmen School, later renamed to *Tokyo Kogyo Gakko* or Tokyo Industrial School) was established in 1881 as the first of such schools. It selected students aged 16 to 17

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3 In 1871, *Kogaku Ryo* (School of Engineering) was created within the Ministry of Industry, which was upgraded to a university in 1873. The university was renamed to *Kobu Daigakko* in 1877. It was merged with the University of Science to become the Faculty of Engineering of the Tokyo Imperial University under the Ministry of Education in 1886.

through exams and past school records. Courses were first offered in mechanical engineering and chemical engineering with other subjects added later. In early years, special courses were also taught on how Western technologies should be adapted to upgrade indigenous Japanese industries such as textile, ceramics and brewing. Unlike the Institute of Technology, all instructors were Japanese except Wagener who taught ceramics and glass making. The school initially faced administrative and financial problems but they were overcome around 1890 as Tejima took over the top management. In 1897, under the Technical Schools Act, it was formally recognized as an industrial high school. Tokyo Kogyo Gakko became Japan's leading institute for producing industrial instructors, factory managers, engineers and entrepreneurs. When its campus in central Tokyo was destroyed by the Great Kanto Earthquake in 1923, the school relocated to O-okayama which is now the Tokyo Institute of Technology.

Apart from the Tokyo campus, publicly-run industrial schools were created in Osaka (1901), Kyoto (1902), Nagoya (1905), Kumamoto (1906), Sendai (1906), Yonezawa (1910) and Akita (mining course only, 1910) with a total of eight schools by the end of Meiji. Subsequently, twenty-three more industrial schools were opened by the 1940s. After WW2, most of them were converted to faculties of engineering of national universities, and many privately-run industrial schools were also established. Education offered at industrial schools was more limited in scope than that offered at the faculties of engineering at universities, but student quality was high. They attracted good students who could not receive university education for financial reasons. While university graduates normally assumed official or academic positions, industrial school graduates went to factories and became core engineers.

Table 1. Number of Japanese Engineers by Type of Education

Employer	Category of engineer	1880	1890	1900	1910	1920
Government departments and agencies	Early Meiji-era engineers	61	72	-	-	-
	University graduates	25	183	474	1,075	1,795
	Industrial school graduates	-	45	263	1,160	1,999
	Subtotal :	86	300	737	2,235	3,794
Private organizations	Early Meiji-era engineers	-	17	54	34	-
	University graduates	-	131	385	846	3,230
	Industrial school graduates	-	34	389	1,963	7,138
	Subtotal :	-	182	828	2,843	10,368
Total	Early Meiji-era engineers	61	89	54	34	-
	University graduates	25	314	859	1,921	5,025
	Industrial school graduates	-	79	652	3,123	9,137
	Grand total :	86	482	1,565	5,078	14,162

Source: Uchida (1990), p. 281.

Table 1 shows the number of Japanese engineers by type of education from 1880 to 1920. In early Meiji, the number of recognized engineers was fewer than one hundred which caused a severe scarcity of experts who could comprehend and adopt Western technologies. Subsequently, university-educated engineers and industrial school graduates grew greatly in number. By the turn of the century, engineers employed in the private sector outnumbered those in government offices.

Leading industries of Meiji is known by the sectoral distribution of engineers. In 1911, at end Meiji, 513 engineers (18.0%) were in the mining sector, 300 (10.6%) were in textile, 250 (8.8%) were in shipbuilding, 231 (8.1%) were in power and gas, 186 were in commerce (6.5%), 149 (5.2%) each were in railroads and food processing, 106 (3.7%) were in general machinery and 104 (3.7%) were in electrical machinery, among all engineers employed in the private sector.

It is noteworthy that the commercial sector also employed engineers. During Meiji, *sogo shosha*, or general trading houses such as Mitsui, Okura and Takada played a crucial role in transferring technology to Japanese corporate customers. They made foreign trips, established overseas branches, collected technical information from academic journals, helped their customers to choose appropriate technologies and foreign manufacturers and assisted in ordering, transporting, installing and operating the equipment. They also mediated technical cooperation agreements between Japanese and foreign firms as explained in the next section. To perform these roles, general trading houses needed many industrial engineers.

6. Import of machinery and foreign partnership

In middle to late Meiji, Japan began to expedite technology transfer by learning from imported machinery as well as through technical cooperation agreements. With a growing number of Japanese engineers, it became possible to absorb sharply targeted foreign technologies by enterprises owned and operated solely by Japanese. Concrete examples are given below.

To set up a national telephone network, engineers at the Ministry of Communications including Oi Saitaro, a graduate of the Institute of Technology, collected publicly available technical information, visited the UK, the US and Germany to compare their telephone systems, negotiated with foreign telephone equipment makers and selected the kind of system suitable for Japan. Advanced equipment had to be imported, but Japanese laid the lines and managed operations without any foreign assistance. Compared with the time when Japan introduced telegraph service through a turnkey contract in early Meiji (section 4), its capacity as a receiver of foreign technology had improved remarkably.

In the navy, early Meiji-era engineers trained in Britain and France, as well as shipbuilding and armaments engineers who graduated from naval technical schools, were similarly instrumental. Throughout the Meiji period, principal battle ships were imported mostly from the UK. Upon ordering, Japanese naval shipbuilding and armaments engineers travelled to Britain as observers while state-of-the-art battleships were built and readied for delivery. This provided them with ample opportunity to learn about ship design and construction from the British Navy and shipyards. Their knowledge proved invaluable to the domestic production of arms and support vessels by Japanese naval arsenals. Over time, Japan acquired capacity to build even principal ships. Private shipyards such as Mitsubishi, Kawasaki, Osaka Steel Works and Ishikawajima also gradually improved their ability to construct steel-hulled ships by importing machinery and equipment. These enterprises relied on imported steel materials and components that could not be produced domestically. Sometimes they also procured designs from Britain (Arisawa et. al. 1994).

In the textile industry, the government imported ten sets of cotton spinning machinery, each equipped with 2,000 spindles, from the UK. After installing and test running the equipment at state-owned mills in Aichi, the government sold these concerns off to the private sector as ten separate cotton mills. Engineers and technicians from the Ministry of Agriculture and Commerce assisted commercialization of these factories. Graduates of the Institute of Technology, employed as master engineers, built and managed Owaribo and Miebo, two dominant mills of that early period. In the next phase, the large-scale private cotton mills of Osaka, Amagasaki and Kanebo were built. For this, university educated engineers designed factory plans, and travelled to the UK to purchase machinery and acquire practical skills and technology needed (Hanai 2000).

As these examples illustrate, technology transfer from middle Meiji onwards occurred mainly through importing machinery and acquisition of know-how that accompanied such machinery. As Table 2 shows, machinery imports rose significantly throughout the Meiji period. It should also be noted that foreign machinery entered Japan with a uniform low tariff of 5 percent which was imposed by the "unequal" commercial treaties until Japan regained tariff rights in 1911.

Table 2. Machinery Imports in the Meiji Period

(Unit: 1,000 yen)

	1878-1882	1883-1887	1888-1892	1893-1897	1898-1902	1903-1907	1908-1912
Telegraphic & telephone equipment	11.8	19.3	35.8	43.1	65.1	113.5	78.0
Railway carriages	-	29.0	355.8	518.5	1,045.6	1,771.7	2,336.0
Locomotives	-	72.2	408.2	1,505.4	1,963.5	1,705.8	1,156.8
Steamships	81.9	718.5	841.7	4,744.5	3,562.2	4,692.1	2,215.6
Steam engines	-	81.7	329.1	586.2	759.8	1,208.8	797.2
Internal combustion engines	-	-	-	-	102.5	262.2	873.9
Dynamos & electric motors	-	-	-	-	322.6	1,546.0	2,275.4
Machine tools	-	3.0	4.5	106.1	649.1	2,404.2	2,687.9
Spinning machines	-	71.9	784.5	3,012.1	1,330.3	1,840.8	3,608.0
Looms	-	25.6	99.0	206.1	199.8	391.5	1,060.8
Total	1219.2	12,066.4	5,755.0	16,427.7	19,145.1	30,354.8	37,381.6

Source: *Nihon Boeki Seiran* (Japanese Statistics of International Trade), Toyo Keizai Shimposha (1935).
Note: Import of steam engines for 1883-1887 does not include the value for 1883.

Along with machinery imports, domestic production of machinery had also emerged. Not surprisingly, Japanese machinery in the Meiji period was inferior in quality to those of the West. Moreover, in design, nearly all machines manufactured in Japan were copies of imports. This was the means by which Japanese producers acquired technology arduously, gradually and through trial-and-error that led, in some cases, to commercially viable domestic production.

The early days of electric equipment production give an example. Tokyo Light Company, a distributor of imported electrical machinery, tried to encourage domestic production of dynamos and light bulbs which it was procuring. The company's Senju Power Plant test-purchased dynamos from Ishikawajima Shipyard that were designed and copy produced from a catalogue under the supervision of a certain professor, but the heat they generated distorted their shape. Similarly, Miyoshi Electric Machine, a pioneer firm in electrical machinery, supplied dynamos to Kobe Light Company and tram motors to the Municipality of Kyoto. In both instances the products were returned as defective. Through such failures, Japanese industries learned that they could not rely on amateurish copy production and that Western technology had to be absorbed more systematically with repeated trial production until it was successfully internalized.

From the 1900s, technical cooperation agreements offered a new way of transferring relatively new technology from large foreign firms of various nationalities. In some cases, such as Japan Steel Works, Nippon Electric Company (NEC), Tokyo Electric and Shibaura Engineering Works, these contracts included establishment of joint stock companies between Japanese owners and the foreign firm.

Let us look at the case of steam turbine technology. This was a new technology invented in 1884 by Charles Parsons in the UK. Within a decade, this technology spread to ship engines and thermal power plants throughout the West. Meanwhile, Japanese navy yards and private shipyards were producing their own reciprocating steam engines and boilers. In 1905 the Japanese navy learned that the British navy planned to adopt steam turbines in their principal ships for increased speed. This news prompted the Japanese navy to import Curtis turbines from the US and install them on the *Ibuki* and the *Aki*, battleships that were under construction at the time. Besides this, 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 began their own turbine production for future ships while continuing to import turbines for ships under construction. This was a complex way of technology transfer combining learning from imported products, the rights to patent execution and copy production.

Steelmaking was an area in which the Ministry of Industry had difficulties in transferring technology during the 1870s and 1880s. State-owned steel works at the Kamaishi Iron Mines with the assistance of hired foreign engineers, which was later privatized, did produce pig iron and steel but the quality was not up to expected standards. By that time, the US and Germany had improved technology greatly with open-hearth furnace and basic oxygen furnace which permitted the construction of large integrated mills combining iron making, steelmaking and rolling processes. There was a strong petition from the Japanese military that urged the government to import a complete set of integrated steel mill. In 1901, the state-owned Yawata Ironworks, with technology of Germany's *Gutehoffnungshütte*, was constructed. This was a turnkey contract consisting of confidential mill design, imported machinery and equipment and provision of German engineers and technicians. However, unlike turnkey projects in the early Meiji period, metallurgy engineers were Japanese. Moreover, the Japanese side chose the factory site and the type of technology to be adopted, and made the decision to procure raw materials from China. When initial operations using the German technology failed, it was Japanese engineers who adjusted the technology to local conditions and allowed the mill to operate successfully (Suzuki 2000).

The creation in 1907 of Japan Steel Works, a joint stock company owned by Mitsui and two British companies, Armstrong and Vickers, also originated from a request by the Japanese military for domestic production of armour plating and large-calibre guns for its lead ships. In this case, equipment and know-how were entirely British, but the Japanese engineers and skilled workers, who came mostly from naval munitions factories, quickly learned and assimilated the technology transferred.

In electrical machinery, the following three historical circumstances led to the establishment of joint ventures with American firms. On the Japanese side, the revision of commercial treaties with the West around 1900, based on the principle of equal treatment of domestic and foreign nationals, permitted foreign direct investment in Japan for the first time. Furthermore, as the modified Japanese law guaranteed the patent rights of foreigners, Japanese manufacturers were no longer allowed to copy-produce latest imported goods for free. On the American side, leading electrical equipment manufacturers had adopted a strategy of manufacturing new products at overseas subsidiaries.

In 1896, the Japanese government decided to adopt the system of American Telephone & Telegraph (AT&T) under its First National Plan to Expand Telephony. As the government intended domestic production of telephone equipment, Western Electric, which was the manufacturing arm of AT&T, first tried to form a joint venture in Japan by acquiring the stock of Oki Electric Industry. However, negotiations with Oki failed, prompting Western Electric to establish Nippon Electric Company (NEC) in 1899, which was the first subsidiary of a foreign firm in Japan, by holding 54 percent of the shares. Western Electric and NEC were bound by a technical cooperation agreement that gave NEC the right of sole agency in Japan and a monopoly on the patent re-execution rights in the future. Western Electric offered technical guidance to NEC, for which the latter paid roughly 2 percent of its sales revenue. NEC initially distributed imported telephones, then built a manufacturing plant with imported designs and equipment from Western Electric and produced telephones by using materials and processes satisfying international standards under the supervision of an American foreman. All internal documents were written in English. Thus, the products and production methods of NEC were identical to those in the US.

In 1905, General Electric (GE), another American giant, concluded a technical cooperation agreement with Tokyo Electric which was similar to the one between Western Electric and NEC, with GE acquiring 51 percent of Tokyo Electric's shares. The latter had evolved from Hakunetsusha, a light bulb manufacturer established in 1890. As the company had been unable to establish a viable production technology or compete with imported light bulbs from Germany, it sought management assistance from GE, a world leader of that industry. GE's policy to allow its subsidiaries to produce light bulbs under their own patents was another reason why Tokyo Electric selected GE as a business partner. Equipment and materials were imported from GE, and American engineers came to Japan to teach manufacturing methods. Tokyo Electric engineers were well-trained and able to quickly master any latest technology developed by GE. Unlike NEC which was newly founded, Tokyo Electric was an existing company acquired by GE as an overseas factory. But the method of technology transfer of the two cases was quite similar.

Business collaboration between GE and Shibaura Engineering Works in 1907 was different from the above two and was more incremental and partial. GE acquired only 24 percent of Shibaura's shares while the remainder was held by Mitsui. Technical assistance was provided through patent licensing agreements which was supplemented by sharing of R&D results, exchange of engineers and access to the blueprints for production equipment. In return, Shibaura paid royalties amounting to 1 percent of sales revenue. Mitsui opted for this technical cooperation to catch up with rapid technological advances abroad under the constraint of the Universal Patent Convention that now protected the patents of foreign manufacturers in Japan. Through this collaboration, Shibaura was able to design heavy electrical equipment by executing its rights on the GE patent and obtain new technical information through the exchange of engineers. But this did not introduce a large technology leap to Shibaura unlike the cases of NEC and Tokyo Electric. GE's technology was added to the existing technology of Shibaura without fundamentally changing the character of the latter. Large-size dynamos continued to be imported from GE which competed with Shibaura products. This was a case of a patent licensing agreement supplemented by a purchase contract of machinery and know-how.

These cases provide examples of how the latest Western technology was introduced to Japan in the late Meiji period. Whether technical cooperation agreements entailed an acquisition of dominant shares by foreigners depended largely on the corporate strategy on the foreign side. Some transfers of technology were selective and partial while others were guided by foreigners in every aspect. The latter may look like a repetition of wholesale purchase of Western technology practiced in early Meiji, but there were important differences. First, at the end of Meiji, Japan imported frontline technologies which were simultaneously developed and adopted in the West rather than buying common and mature technologies as in the early Meiji period. Second, the existence of domestic engineers and technicians allowed Japan to take a significant lead in selecting, adjusting and internalizing imported technologies instead of remaining a passive student.

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