

Chap. 7 : transfer and self-reliance in iron and steel technology (part ii. case-studies)

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Transfer and Self-Reliance in Iron and Steel Technology

Pre-conditions

The technology to manufacture iron and steel is the most representative of the technologies that were once imported and that are now being exported. Iron-manufacturing technology is a complex, large-scale technology that is not easy to transfer. Thus, approximately 40 years were required before independence in this technology was attained and, indeed, 100 years before technological exports could begin, after additional transfers had been made following World War II. The urgency of development today, however, does not allow such slowness. The only option then is to identify the most feasible measures from other countries' development experiences through field-work and dialogue. Following are a few suggestions regarding the technology choices to be made.

Unlike most developing countries today, Japan was in an advantageous position concerning the pre-conditions required for iron-manufacturing technology. Nevertheless, the technology that was transplanted to Japan was not the most advanced available at the time; it was merely the most widely used.

Japan's first reverberating furnace was constructed in the Saga domain in 1850 to forge big guns. Its technological level was pre-Industrial Revolution, and it was operated using charcoal, water-wheels, and cold blast. Since the reverberator converted pig-iron to malleable iron (wrought iron), obviously the supply of pig-iron had to be ensured. The pig-iron produced by traditional Japanese technology was not of a quality high enough, however, to be used for making big guns. Accordingly, unless the iron was produced using Western methods, the reverberator was useless. So it became necessary to construct a blast-furnace. This example demonstrates the need, when transferring technology at a point downstream, to go to the upstream source; the nature of technology is connective and cumulative.

Thus, in 1854, the Satsuma clan constructed the first blast-furnace in

Japan. While steam-power and coke were being used in blast-furnaces in Europe, in Satsuma, the furnace was designed to operate using a water-wheel and charcoal because of the scarcity of coal. Note that the furnace was designed to conform to the existing limitations. Like its predecessor, this blast-furnace was limited and could not be developed into a modern, full-scale industrial technology. Nevertheless, because the furnace rationally corresponded to the size of the market for the munitions industry the clan operated, its design and scale were appropriate.

A series of difficult problems relating to raw materials and ventilation marked these early attempts at iron manufacturing. This comes as no surprise when one learns that the Saga clan's reverberator and the Satsuma's blast-furnace were built using a single technical guide, Ulrich Haguénin's *Het Gietwezen in s'Rijks Ijzer-Geschutgieterij* (te Luik, 1826), without access to any models or instructors. Any similar attempt made today would be censured for its recklessness. Nevertheless, the projects achieved a certain, if limited, degree of success. The success meant that Japan had attained a level of technology comparable to that of Europe on the eve of the Industrial Revolution. At the same time, on a practical level, it became clear that the sand being used as the raw material for pig-iron in Japan was unsuitable for casting.

Although the technological level before the Meiji period was high, the gap between it and modern technology, including technology for developing raw ores, was great. The Meiji Restoration broke the shogunate's monopoly on the importation of technology and created circumstances in which technological guidance could be obtained directly from foreign engineers.

Failure and Recovery of the Kamaishi Ironworks

In its seventh year in power, 1874, the new Meiji government initiated construction of a modern ironworks at Kamaishi mine in present-day Iwate Prefecture. The orders for a plan were given to L. Bianchie, a German employed by the government, and Oshima Takato (1826–1901). Oshima, whose father was a medical doctor in the Nambu domain, studied medical science at Nagasaki and later concentrated on gunnery, mining engineering, and refining technology. He constructed a reverberating furnace and a Western-style blast-furnace at the Kamaishi mine in the Mito domain. Oshima was the translator of the Haguénin work, and as a member of the Iwakura Mission to Europe and America, he had an opportunity to further his knowledge of the West's technology.

The two proposals submitted by Oshima and Bianchie differed in basic design and location. Bianchie proposed a design for two large and highly efficient blast-furnaces (25-ton daily output) and a railway to transport the iron-ore; he even drew up plans for puddling and rolling.

Oshima's proposal was for five small furnaces (5 to 6 tons daily) and a horse-drawn tramcar for transportation. The Nambu domain was famous for its cast-iron goods, good-quality charcoal, and sturdy horses. Oshima's plan

was a capital-saving design well suited to the technological conditions present in the Tohoku area at that time and thus appropriate for starting up an enterprise (Iida 1979). Perhaps the lesson here is "start small and grow big."

Nevertheless, Oshima's plan was not adopted by the Ministry of Works, and he was posted to the Kosaka mine in Akita Prefecture, obviously a demotion.

The government-operated Kamaishi Ironworks imported not only the blast-furnace, air-heating furnace, and machines for the puddling plant, but also the locomotives, freight cars, and rails (and presumably the ties, which were made of iron) for the railway system that connected the port of Kamaishi with the mine and the place where the charcoal was produced. For engineering, construction, and operation, the government employed British engineers and foremen.

The works started operation in 1880, seven years after the plan was drafted. After 97 days of smooth running, operation of the blast-furnace ceased because of a fire in the charcoal-making shop that caused serious damage, necessitating that the fire-bricks lining the inner walls of the furnace be replaced, and a shortage of charcoal.

Firing resumed after more than a year's disruption, in February 1882. Because of the charcoal shortage, coke was used, but the coke's inferior quality brought on another stoppage in mid-September, after only 196 days of operation. This second failure, so soon after the first, compelled the government to close the works in December.

Although ostensibly the failure at Kamaishi was due to a shortage of charcoal, the area was famous for its production of good-quality charcoal. One must conclude, therefore, that other difficulties, for example problems with transportation and the procurement of raw materials, were also instrumental in the decision to shut down.

In other words, there were M_1 and M_4 difficulties. But was that all? If Oshima's plan, which had the advantage of diversification of risks, had been adopted, the failure could likely have been avoided. One can discern in the government's attitude and actions an excessive reliance on foreign engineers and at the same time a contempt for its own.

The government sold the remaining materials (charcoal and iron-ore) to Tanaka Chobei, a purveyor for the government. After repeated repairs to the blast-furnace, he succeeded, on his forty-eighth attempt, in producing iron. Tanaka's modifications of production and facilities resulted in an operation less like Bianchie's plan and more like Oshima's original proposal, and this undoubtedly contributed greatly to his eventual success. Foreign engineers and foremen were no longer in attendance, and the workmen were using ores that had been rejected by the previous management because of their "inferior quality." Making use of these ores was a key factor in Tanaka's success.

Tanaka has left a record of some of the problems regarding transportation and fuel problems that were encountered—what we're referring to as questions of technological links and support services. It is apparent that he had

correctly grasped from the manager's point of view what Oshima the engineer had reasoned. He agreed with Oshima's idea of starting a moderately sized operation and enlarging it gradually.

Tests showed that the iron produced at Kamaishi was equal to the world's best-quality iron, manufactured by Krupp in Germany, and that it was usable for military purposes. Kamaishi was thus able to acquire, for the first time, a stable market. However, the authorities forced Kamaishi to renovate its facilities, update quality control, and improve transportation. Noro Kageyoshi (1854–1923), professor at Tokyo University and a member of the first generation of recipients of a modern engineering education, was appointed as one of the technological advisers. One of the 25-ton blast furnaces was successfully put back into operation, and, for the first time, success was won in the technology of using coke.

Japanese engineers brought the technology of iron manufacturing in Japan into the modern age: In 1894, when the blast-furnace was restarted, the mill produced 13,000 tons, a 50 per cent increase over the previous year, and in its twelfth year, output exceeded total production from all foot-bellows-type iron mills.²⁸ But foot-bellow mills survived, and are a good example of the toughness of traditional industry.

In 1895, a British type of rolling machine that had been imported and operated at the plant was able to be repaired by workmen at Kamaishi. In addition, rails, plates, round bars, square bars, and flat irons were manufactured with Kamaishi's own pig-iron, though in only a small, 5-ton quantity. Only 40 years had passed since the Saga clan had groped for the technology for a reverberating furnace.

Thanks to good-quality charcoal and other advantageous pre-conditions, in 40 years Japan had caught up with modern iron manufacturing technology, which had a 200-year history. More recently, Korea has, through its efforts, done the same in 20 years.

Although Tanaka's operation eventually corresponded to Bianchie's plan, this is not to say it was in fact an appropriate starting point; Bianchie and the other foreign advisers were mistaken in regard to the scale and links of technology. Production only got under way successfully once the operation had been reduced to a smaller scale. The Kamaishi case clearly demonstrates how important the choice of a rational scale of operation and technological level and the management of technology are for technology transfer. The second lesson to be learned is that final responsibility for solving the problems should be left to the engineers of the importing country.

There are some technology historians who maintain that Kamaishi was technologically successful because it was able to operate for approximately 100 days. We do not support this position, for the simple reason that technological success is determined by the realization of the full potential, the full economic or physical life span of a technology or operation. Any industrial technology must be used to the limit of its physical or economic life span. What determines this is the technology of daily operation, maintenance, and administration. The foreign engineers at Kamaishi failed in the first stage of

technology transfer. Their failure highlights the differences in approach between Bianchie and Oshima, between a techno-scientist and an engineer.

Failure at the Yawata Ironworks

In late-nineteenth-century Japan, the consumption of steel and wrought-iron is estimated to have been less than one kilogram per capita. Considering that the capacity of a blast-furnace is more than 1,000 tons a day, an estimated annual per capita consumption of more than 20 to 30 kilograms is necessary for the stable operation of a mill with a blast-furnace system continuously manufacturing steel from pig-iron. If the population is small, obviously a great per capita consumption or foreign markets is required.

Although modern iron manufacturing had been achieved at Kamaishi, capacity remained at about 25 tons per day, and Japan had to continue importing pig-iron and steel. To meet the government's development target, therefore, a project was initiated to construct a modern ironworks for the continuous operation of pig-iron and steel manufacture. The result was the state-operated Yawata Ironworks in Kyushu, western Japan.

The impetus for the ironworks was provided by a snag in the delivery of weapons the government had purchased that occurred during the Sino-Japanese War. The weapons were held up in Singapore due to a diplomatic wrangle, and Japan realized that, in the government's words, "if the war were to be prolonged, it would face a situation of great difficulty in the supply of weapons." The importance and necessity of weapons independence was clear. In pursuing this independence, however, one problem that had to be faced involved standardization, a subject we will discuss in detail later because of its decisive importance for industrialization generally.

The new ironworks were to be managed by the navy, and after one upset, Blast-Furnace No. 1 began operation in February 1901.

The designer was W. F. Luhrman, and the nominal capacity of output of pig-iron was 160 tons. The actual output hovered around 80 tons, and, in addition, the pig-iron was unsuitable for making steel because of its poor quality. The coke consumption was at a deplorable 1.7 tons per ton of pig-iron. (Today, the average ratio is approximately 0.45:1.0; the expected ratio even back then was about 1.0:1.0.) In July 1902, after less than 20 months of operation, the first blast-furnace was shut down.

Considering that Japan's only previous experience was at the Kamaishi Ironworks, whose output was 60,000 tons per year (20,000 tons of open-hearth steel, 4,500 tons of wrought-iron, 500 tons of crucible steel for military use, and 3,500 tons of Bessemer steel for the railways), the Yawata plan was ambitious: It called for the construction of three 60-ton blast-furnaces, two 17-ton Bessemer converters, four 15-ton open-hearth furnaces, six puddling furnaces, and one crucible furnace, besides hydraulic forging and rolling machines. Moreover, once construction started, the original scale was enlarged: planned output was increased from 60,000 tons to 90,000; the blast-

furnaces went from three 60-ton units to two 160-ton units; and each of the four open-hearth furnaces from 15-ton units to 25-ton units. The budget was doubled, to the fantastic sum of ¥25 million, part of which would come from the indemnities of the Sino-Japanese War.

As indicated by its English name, the Imperial Japanese Government Steel-Works, Yawata was intended to be a symbol of the nation. Unfortunately, however, it merely repeated the failure at Kamaishi.

To give this some perspective, it might be mentioned that U.S. Steel, established in 1901, had a nominal capacity of 10.6 million tons; thus, even if Yawata's capacity could be raised to 90,000 tons, this was still less than one per cent of U.S. Steel's capacity. It was indeed a tiny mill, although the biggest in Asia.

When the attempt to enlarge the scale of operation failed, Noro, the technical adviser referred to earlier, was recalled. His investigation revealed the following:

1. Design flaws were found in the structures of both the blast- and open-hearth furnaces.
2. The suggested operational procedures were unsuitable for the raw materials available in Japan (the mixture of input materials was inappropriate and the coke being used was of poor quality).
3. There were serious problems with the ventilation facilities.

The production equipment was manufactured by the Gutehoffnungshütte Company of Germany. The company had sent approximately 20 skilled foremen, and the Japanese government hired 3 top engineers for the operation. But the results were disappointing. Besides the design errors mentioned, the operational guidance was poor: the planners repeated exactly the same mistakes as had occurred at Kamaishi in their inclination toward larger scale, the most up-to-date facilities, and blind faith in foreign expertise. Japanese engineers were able, after some effort, to correct the faults, and enough alteration was made to the design of the second blast-furnace under construction to enable it to start normal operations in 1904.

The success was attributable to the efforts of Hattori Susumu (1865–1940), Noro's pupil. The top-level group of engineers had been fired and, except for a foreman for the revolving furnace, had returned to their respective countries at the time of the Russo-Japanese War. They returned home, it seems apparent, because of their loss of confidence.

To give a simple example of some of the difficulties that were encountered, the open-hearth furnace used at Yawata and designed by a German by the name of R. M. Daelen (1843–1905), was characterized by Imaizumi Kaichiro, an associate of Hattori, "as having a most serious defect, the location of the jet, which could be corrected after experimentation, but because of space limitations, it was impossible to improve too short a jet and build a room for residue from the furnace." Imaizumi repaired the furnace, and, in discussing the problem with Daelen directly, is said to have been told by Daelen himself that the design was in fact "a totally untested desk plan."

This represents the sort of obstacles that had to be overcome before technological stabilization was attained.

No piece of equipment or machine can be expected to operate in the beginning at the level for which it was originally designed; newly designed equipment is more unstable. It is the engineer's job to bring the working level up to the intended level of operation. Not uncommonly, operational stability is reached at a lower level than the originally designed output level, and this low-level output often becomes a maximum-output level. Output greater than the design intended should not be attempted because it may cause problems or accidents. If a greater output than intended is attained, it means that technological potential and precision are being sacrificed in excessive concern for safety. Considering, however, that machinery exported to developing countries is used under diverse conditions, perhaps greater importance should be attached to safety, even at the expense of precision.

There are some specialists who argue that the Yawata Ironworks was wisely modelled on German rather than on American plants because the demand structure in Germany, with many types of steel produced in small quantities, was quite similar to the demand structure in Japan. In other words, the technology was carefully selected and transferred. Yawata's failures thus represented a degree of progress compared to those at Kamaishi.

In any event, Japanese engineers corrected the design and operational errors of the foreign experts, and, by 1910, the Yawata mill had gone into the black. Specialists point out that this, together with the introduction of the Solvay coke furnace and the newly acquired skills for making coke, were of great significance.

To conclude this section, it should be pointed out that, although the teachers were poor and the students excellent, the students were still no more than students. They did not have the skills and experience necessary to see a problem on paper or to create a design, and certainly not to implement a design.

From the point of view of the history of Japanese iron manufacture, Kamaishi represents the period of the establishment of technology and its operation, and Yawata the ability to correct and improve and introduce new methods and technologies. In sum, Yawata represented the fourth stage in Japan's technology transfer aimed at self-reliance.

Hoshino Yoshiro, who revised my five-stage theory, claims that the fourth stage, the "ability to design technology," has three substages: (1) complete imitation and additional testing, (2) partial design alteration, and (3) complete renewal of the design. Yawata's second blast-furnace indicates that it had certainly arrived at substage 2.

Iron-manufacturing technology arrives at the fifth and final stage when the technology for treating non-design-type problems has been developed, for example raw materials. Although the conversion to electricity as the power source had begun in the 1910s, the consumption of coal was 4 tons per ton of steel in this period. Only in 1932 was it reduced to 1.58 tons.

During this period, as a result of the increasing demand for pig-iron and steel products, private steel manufacturers appeared on the scene. They had no blast-furnaces; instead they used electric furnaces, and scrap steel and cheap imported pig-iron for steel making. Although the Yawata Ironworks had built up a technological potential, it was not successfully meeting civilian needs. It typified a state-operated mill that gave first priority to government and military needs.

The emergence of electric-furnace ironworks was a response to an increase in industrial demand, and also demonstrated the urgency of the problem of raw materials.

Technological Independence and Dependence on Foreign Raw Materials

The emergence of electric-furnace ironworks corresponded to the fact that Japanese iron manufacturers had a greater capacity for producing steel than for pig-iron. As a result, scrap steel was imported from the United States and pig-iron from India. However, importing from overseas was hindered by foreign exchange fluctuations and problems of unstable supply. Consequently, a solution was sought in establishing iron manufacturing in Japan's colonies and securing raw materials by colonialistic means.

The attempt to transfer technology to the colonies, however, encountered problems because of the low-quality iron ore and the technological difficulties in using these ores. The diplomatic problems that resulted are scarcely in need of mentioning. In this case, consequently, attaining technological independence entailed the need to initiate dependence on foreign suppliers in order to fulfil the first of the five Ms. In other words, the Japanese iron manufacturing industry gained technological independence, but only by virtue of a reliance on overseas supplies. Indeed, this was a paradox of Japan's technology.

Because iron is essential to nearly all industries, the entire network of technologies in Japan intensified its dependence on overseas resources, initially in the 1920s and then in the 1970s as the result of gaining self-reliance in technology at both the minimal and maximal scales.

Japan's independence in iron and steel technology was ushered in in 1920 at the Anzan (An-shan) Ironworks of the South Manchurian Railway Company when a group led by Umene Tsunesaburo (1884–1956) succeeded in discovering a method of pre-treating (i.e. magnetized calcination) low-quality iron-ore. This breakthrough immediately enlarged the range of available resources.

There were two other important technological developments in need of mention. One is the coke furnace developed by Kuroda Taizo (1883–1961). This furnace recovered by-products through a regenerative burning apparatus. It was invented by Kuroda in 1918.

The other is the strong magnetic steel (so-called KS Steel) invented by

Honda Kotaro (1870–1957) through his metallurgical study of alloys. Honda's discovery formed an important basis for Japan's world-leading position in this field.

Parallel to these developments in technology, the Ministry of Finance provided financial assistance to Han Ye Bing, the company that controlled the Da Ye Iron Ore Mine, in 1904, the year in which Yawata began stable operation, to ensure a dependable supply of good quality and low-priced materials.²⁹

This financing allowed Yawata Ironworks to import 500,000 to 600,000 tons of iron-ore every year, but it also spelled ruin for Han Ye Bing, China's most important coal and iron supplier (Nakura 1980).

The import of iron-ore and coal from this company once occupied 90 per cent of all imports, but in the 1920s, the supply became unstable, an increased indebtedness led to a loss of autonomy, and the political and social unrest worsened in the Yangtze River areas—all of which adversely affected the company's activities.

During this period, Ishihara Koichiro's Nanyo Kogyo Koshi (later, Ishihara Sangyo) entered the market to take the place of Han Ye Bing. By his own efforts, Ishihara developed the Sri Medam Mine in British Malaya in 1920 and later, he began transporting iron-ore by sea. During his lifetime, he also succeeded in constructing a small combine. In the 1930s, Ishihara was active as a proponent of development of southern Asian resources and of an anti-militarist reform of domestic politics.

In sum, it might be recalled that when Japanese technology arrived at the primary stage of self-reliance, the problem of resources became its Achilles' heel. In an attempt to remedy the problem, technology was transferred to Manchuria and resource development in Korea was undertaken.

One interesting outcome of this policy was that, since, generally speaking, no skilled labour force had formed in these areas, and despite exports of high-level technology, Japan had no greater effect beyond the creation of technological enclaves.

Formation of a Skilled Labour Force

In a study of technology, it is necessary to touch on the problems concerning the education of engineers and the formation of skills. Putting these issues aside for the moment, however, I wish to confine myself here to a brief discussion of the labour force in the steel industry.

The nucleus of skilled workers at Yawata was a group of less than 20 German foremen, who returned to Germany in 1904–1905, and 10 skilled workers dispatched from the Kamaishi Ironworks. The technological isolation peculiar to labour for iron manufacture (the difficulty of converting it to other types of industry) and the heavy physical demands made the transfer of a labour force unfeasible. There was an important difference between the labour force in the Kamaishi area—where heavy snowfall precluded farmers

from engaging in agriculture during the winter months, forcing them to take side jobs at the mine, for example—and the labour force recruited in the Kyushu area, where two-crop cultivation prevailed. (The percentage of the Yawata labour force recruited in Kyushu amounted to 80 per cent in 1920, roughly the same proportion as in the beginning.)

At Yawata, former coal-miners, transportation workers (who had worked in transportation on the Onga River until they lost their jobs to the railway), and villagers who had gained machine skills during construction of the ironworks became full-time workers and eventually skilled workers. In the beginning (1902), besides the 504 full-time workers, there were many who were indirectly employed on a subcontracting basis.³⁰ Indeed, the part-time workers outnumbered the full-time, a situation that holds true today. The total number of such employees in one year's time reached 600,000 (on the average, 1,500 persons per day).

Characteristically, more workers were assigned to the indirect production divisions than to the direct divisions. Because the major equipment was German made, importance was placed on maintenance and repair. Second, related machinery and equipment had to be designed and manufactured within the ironworks. This was inevitable since, at the time, the necessary technology had not been developed.

In the beginning, a majority of workers at Yawata had finished compulsory education (until 1900, four years were required, six years thereafter). Although the relationship between longevity and amount of schooling is not clear, the worker longevity rate at Yawata was low. The authorities of the Yawata Ironworks tried to increase longevity by enlarging lodgings and other welfare facilities, establishing a co-operative purchase organization, and introducing a retirement allowance system with progressive rates and a system of commendation for long-time workers.

In general, as operational stability grew, these measures and the salary system were expanded and refined, and the standards to select workers became stricter. In 1920, more than 90 per cent of the workers had finished compulsory education. This higher level of educational background in turn contributed to a strong self-awareness and a tendency among workers to view certain management practices critically and to raise demands for improved working conditions. From 5 to 9 February 1920, there was a major strike in which more than 10,000 workers participated. It was interrupted by the arrest of 19 leaders of the strike, but resumed on 29 February and continued until 1 March. The workers succeeded in obtaining a reduction of working hours from a 12-hour, two-shift system to a 9-hour three-shift system. The demand for a "dismissal of incompetent high-ranking managers" and the "promotion of able workers" resulted in an improvement in management and administration.

A system peculiar to the Yawata Ironworks, referred to as the *shukuro* ("veteran") system, was introduced by which highly skilled workers were treated as life-time staff. While by 1930 only seven workers had achieved *shukuro* status, this measure nonetheless helped make a small hole in the

hard wall between workers and administrative staff. Worker longevity did not thus, however, greatly improve. During the recession following World War I, the rate of those leaving the mill was stable at 10 per cent. (The national rate for all factory workers was 66 per cent.) The high rate of 36.1 per cent that occurred at Yawata in 1919 was the result of the disappearance of advantageous working conditions and wages along with the economic boom the war had generated.

Iron Manufacturing Technology and Weapons Self-Reliance

As mentioned, the desire for arms independence played a huge part in the development of iron manufacturing in Japan. Before moving on to mining technology, therefore, it will be useful here to consider this aspect briefly.

Japan was compelled to recognize the power of modern weapons when American gunboats forced the country to open its doors. The defeat in the Opium War of China—a country Japan had traditionally looked up to—came as a psychological blow and provoked arguments on coastal defence and a serious study of how to develop the technology for casting big guns and, in turn, for the construction of reverberating furnaces.

A basic problem was the inability of any clan to supply its own fire-bricks to construct reverberating furnaces, let alone the prerequisite blast-furnace; none, moreover, could supply its own iron-ore and coal necessary for operation. There was, clearly, a big gap between the aims of the shogunal regime and the demands of modern technology. To add to the problem, in retaliation against the criticism of the political system lodged by scholars of Western science and technology, the shogunate began a campaign of oppression of intellectuals. Thus, the Tokugawa regime was faced with the contradiction of desperately needing the help of scholars of Western science and yet staunchly opposing the reforms needed to gain and implement their knowledge. Some concessions, however, were unavoidable to adopt a new technology and its related system.

For instance, the Tokugawa shogunate decided to have its own navy; however, because high-ranking samurai, with their retinues of personal servants and retainers and aristocratic habits, could not practically be considered for duty, the government was compelled to select from among only lower-ranking samurai on the basis of ability rather than hereditary status. This rupture of a system based on social ranking that had been in force for hundreds of years in order to effect the transfer of a new, important technology represented a significant risk for the shogunate.

A further concession was the need on the part of feudal lords in hereditary vassalage to the Tokugawas and the shogun's direct retainers to relinquish their monopoly of military technology. They were forced to tolerate attempts by other clans to produce arms and build Western-type warships.

The defeat of the shogunate by the powerful anti-shogunate clans led to a period of ambitious, sometimes blind, technology transfer by the Meiji gov-

ernment. Although, in this period, there existed a national consensus for the transfer of technology for national defence, the burden was not light, neither for the government nor for the country as a whole. Nevertheless, the Meiji government promoted technology transfer based on this national consensus, and its success lent the government a measure of political stability.

To build an arsenal of modern weaponry for national defence required ironworks, for which, in turn, it was necessary to develop sources of iron-ore, coal-mines, and a transportation system. In other words, it was necessary to reverse the order of the "natural course of history" in development, an act fraught, however, with not a few difficulties. Even so, what enabled Japan to effectively reverse the order was the existence of the necessary pre-conditions and a technology that had generally developed to the level of manufacturing technology. Naturally, the pre-existing technology often had to be revised to mesh with the modern technology.

At the time, because Western technology consisted of assembled parts that could easily be disassembled once the principle involved in their construction had been mastered, similar component parts could be manufactured by a full mobilization of traditional technologies.

The technology for iron manufacture was the most complicated and the largest in scale at that time. Although Japan had attained a measure of independence, the difference in level between Japan's technology and the most advanced in existence was still great. Nevertheless, once a technological system—albeit on a small scale and low level—had been established, subsequent technology transfer became easier. The period leading up to self-reliance was marked by difficulties, but the creation of a firm foundation opened the way for future development.

As we noted earlier, underlying the important role attaining "independence in weapons" played in the establishment of a great modern ironworks was the bitter experience of weapons detention in Singapore during the Sino-Japanese War. The standardization of weapons was an important aspect to this effort toward independence. The perception of the need for the mass production of interchangeable parts and a system of standardization of modern weapons dated back to the experiences in the Seinan War (Southwestern Rebellion of 1877, the first civil war in Japan). Both the government forces and the rebels were fighting with imported weapons, but the many kinds of guns and the difficulty of maintaining a regular supply of ammunition created vast confusion.³¹

Consequently, a drive toward standardization in weapons was begun, and it was combined with efforts to establish an ironworks for the purpose of domestic production. Subsequently, domestic production, standardization, and mass production were being institutionalized—principally for small firearms—and, to return to the larger forces at play—in response to domestic and international political developments. These developments had a decisive influence on industrialization as a whole, and the heart of the problem regarding development and technology remains there even today.

Because the technology of iron manufacture was such an important force

in Japanese industrialization, I have allocated a disproportionate share of the discussion to its examination. The role of the technologies for textiles, railways, iron-ore, and coal-mines, however, was equally important. Also, ship-building technology played an important part in the domestic production of machines for metal and coal-mining and, later, in the production of machinery and machine tools.