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Development and Technology in Post-war Japan

Japan in the World

Japan's share in the total GNP of the world was 9.0 per cent in 1980, a position exceeded only by the United States and the Soviet Union.

Because at the beginning of the twentieth century Japan accounted for a mere 1 per cent of the world's total GNP, compared with 30 per cent for the United States and 20 per cent for the United Kingdom, this rapid structural change, and the Soviet Union's rise to second position, are remarkable. The changes in the scope and the structure of the world economy are readily apparent in the 1980 shares of world GNP held by the United States and the United Kingdom, 21.9 per cent and 3.6 per cent, respectively.

In terms of per capita GNP, Japan has achieved a level comparable to that of both the United States and the United Kingdom, inasmuch as its population is slightly more than half that of the United States and slightly less than that of the United Kingdom. In other words, over the past 80 years, the Japanese economy has grown 30 times as fast as the US economy and 20 times as fast as the UK economy. However, this is merely a matter of flows; in stocks, it should be noted, unfavourable gaps remain for Japan compared with either the US or the UK, the latter especially.

With regard to the power of a nation to influence the international community, the United States and the United Kingdom are in a far better position than other nations because English is a nearly universal language. The Japanese language, on the other hand, is not even treated as an official UN language. Thus, when it comes to the question of a country's international political influence, its economic power is not always the decisive factor; this is obvious in the examples of China and India.

Taking population as a criterion, a country with a population of more than 100 million may be regarded as big, but Japan has barely enough population to enable it to count itself among the big countries. Even the United States and the Soviet Union are far smaller in this regard than China and India.

A country with less than US$10,000 per capita national income and less than 100 million population may not be expected to make effective use of a full set of modern technologies because it cannot realize economic efficiency at a level these technologies would require.

Judged, then, in different aspects, Japan may fall outside the group of front runners, but it may be inappropriate to place it among the second-group runners considering the great distance between the two groups. Seen in terms of its industrial power and its governmental system, Japan is Western, but culturally it remains Asian.

Beginning in the 1960s and continuing for more than a decade, the Japanese economy was able to achieve what was then called a miraculous annual growth rate exceeding 10 per cent. Though this was in many ways ascribable to the previous low level of its economic development and to the nation's recovery from World War II, it also reflected the rapid expansion of the scope of production through technology transfer.

Worth noting here is the difference between Japan and the other industrial countries in how it coped with the oil crises of the 1970s, an epochal situation in contemporary history that threw most of the world into hard times. Whereas most countries viewed the crises as a stoppage of the oil supply, Japan saw them as signs of the need to rationalize through technological innovation.

When the economies of the industrially advanced nations were confronted by stagflation, and the United States, which had led the post-war world, suffered a growth rate that had declined to as low as 3.5 per cent (the EC countries had an average of 3.1 per cent), Japan managed to maintain a growth rate not lower than 5 per cent. By the end of the 1970s, much to the perplexity of the Japanese, the world looked to Japan and West Germany to play the role of locomotive, to pull the world economy out of its recession.

It is beyond my ability to fully answer the question of how Japan managed to surmount the crises of the 1970s. One answer that has been offered relates the Japanese success to its capacity for technological innovation, and without doubt, technology has contributed much to the high economic growth rates of Japan since the mid-1960s, a ratio of contribution calculated at 30 per cent. Just as it managed to tide over the oil crises that had brought the high-growth period to an end, Japan also managed to overcome the difficulties caused by industrial pollution that emerged in the 1960s and 1970s by developing technologies to control or prevent pollution and others to conserve energy. These accomplishments brought world recognition to Japan as a technologically advanced country.

Is Japan the front runner of the developing countries, or is it running on the heels of the developed countries? It may be that it has elements of both. In some technologies, though, it is without doubt a leader.[1]

From the time we undertook this project, and especially since 1980, an unusually keen world-wide interest has centred on technology. It seems that the second oil crisis, in 1979, and the ensuing economic difficulties compelled many countries to seek technological innovation as a way to change the status quo.

Something that made it less difficult for Japan than other industrial nations to cope with the oil crises was that industry largely accounted for Japanese oil consumption, thus relegating that portion used by individuals to a less important position than in other countries. This made it easier to develop energy-saving technologies and possibly easier to implement them with more resounding effects. Yet no one can say for certain that technology will be able at all times to play the lead role as a problem solver, as perhaps it has until now.

Indeed, technology alone has not the power to solve economic and related problems. Managerial skills are absolutely vital, as the Japanese experience shows; at the same time, Japan's strategy must be acknowledged as a general solution and not one that is peculiarly Japanese. Thus, it could be said that the Japanese solution is merely one form of the general solution. There have been some studies that pursue this perspective, but we need to examine the question further before coming to any conclusions.

Although technology is not all that counts, its importance is undeniable. In this context, it is not surprising that Japanese technology, with its peculiar history of formation and its unique structure, should have aroused interest among other nations. It is with this in mind that we decided to study the problem.

Our conception of technology and development may differ from the usual. While science is universal, technology is not. What may be called the internal and external links of technology cannot be broken when innovation occurs. In other words, although the internal logic or built-in mechanism of a technology is autonomic, the external conditions under which it must operate are not. Herein lies the dilemma of technology.

Economy and Technology in Post-war Japan

With the world's mining and manufacturing production index for 1975—the year after the oil crisis hit—given as 100, the corresponding figure for Japan in 1980 was 124. By 1980, the economies of all the industrialized countries except Japan stagnated, and the index for the United Kingdom fell below even the 1975 level.

The first to recover from this crisis was Japan, its corresponding index scoring 142 in 1981, followed by the United States (128), France, and West Germany. In terms of per capita GDP in 1980, ignoring the oil-producing countries of the Middle East with figures as high as US$30,000, the Japanese figure, at US$9,890, was 61.8 per cent of the Swiss figure and 89.9 per cent of the US figure. This placed Japan seventeenth among all countries (though fifteenth in 1975). Japan has the smallest personal income gap between rich and poor.

To give a fuller picture, we must consider that Japan depends on imports for 95 per cent of its energy consumption, for 90 per cent of the important raw materials for its manufacturing and mining industries, and for more than 60 per cent of its food requirements. It must be said, therefore, that Japan, though often called an economic superpower, is a vulnerable power—even a minor power in respect to natural resources—a nation that has no other choice but to keep itself going on the basis of technology and foreign trade. Despite the high economic figures for Japan in terms of flows, the livelihood of its people, if not poor, is still far from being rich if seen in terms of stocks. A European Community leader once aptly commented that the average Japanese is "a workaholic who lives in a rabbit hutch."

Even so, the Japanese living standard, not well-to-do but not badly off, is something enviable for people in the third world. The Japanese may live in rabbit hutches, but in the third world even a small dwelling would be satisfactory if clean and sanitary and supplied with tap water and electrical home applicances. For many people in the third world, beset with chronic underemployment or latent unemployment and lacking decent homes, Japan could be a not-so-far-away goal at which to aim. Note too that Japan grew nearly to what it is today in not much more than a quarter-century.

While Japan scored 124 in the mining and manufacturing production index in 1980, the Republic of Korea registered 210. Obviously, the movement of the production index, like that of the growth rate, has no direct bearing on amount in absolute value. The smaller the absolute value of production, the greater the index movement might be, and conversely, the greater the absolute value of production, the smaller the index movement. The continued rapid economic growth of post-war Japan indicates that, because of the great war damage the country suffered, its economic reconstruction had to start from limited, but deliberate, activity and a low level of living.

Post-war Recovery

The cities of Hiroshima and Nagasaki were each destroyed by a single atomic bomb. A great many Japanese cities, with the well-known exceptions of Kyoto and Nara, ancient capitals of Japan, suffered from bombing: in the 119 cities bombed, 2.2 million houses (about 20 per cent) were destroyed and 9 million people made homeless. Because few new houses were built during the war, in post-war urban Japan more than one family—sometimes several—would be jammed together into a house that was already past its prime.

The devastation affected everything connected with daily life, from factories, roads, bridges, electric lines, and waterworks to schools, hospitals, and communications systems. About 40 per cent of civilian national wealth was lost, and the few machines and pieces of equipment that survived were overused, poorly maintained, and short of parts and accessories.

For several years after the defeat, the nation's standard of living hovered at a level of 30 per cent of the top pre-war (1935–1937) level; mining and manufacturing production in 1946 stood at a mere 6.6 per cent of the pre-war high. The greatest losses were in shipping: from a total tonnage of 6.3 million, only 1.53 million (or 24 per cent) had survived.

The railroads were more fortunate, with track loss at 50 per cent and rolling stock loss at a mere 10 per cent, and hydroelectric power plants had suffered only slightly. But with 6 million Japanese being repatriated from overseas and with the presence of the Occupation forces, whose requirements had priority over everything else, the capacities of these two sectors, even if fully worked, could not meet the demand.

Before and during the war, Japan had been largely dependent on Korea for its supply of rice, beans, iron-ore, and anthracite; on Taiwan for rice and sugar; on Sakhalin for timber, wood-pulp, and coal; on Manchuria for iron-ore, coal, and soya beans; and on China for salt, iron-ore, and coal. The stoppage of their supplies as a result of the defeat badly affected Japan's mining and manufacturing industries, and the people suffered from a great shortage of daily necessities.

Extremely short in supply were textiles, with production at merely 33 per cent of the pre-war high; ammonium sulfate was at 42 per cent, paper at 46 per cent, and bicycles at 20 per cent. And manufacturing came to a halt after raw materials were exhausted. The shortage of goods went hand in hand with inflationary spirals.

Intending to materially disarm the militarist-fascist state, the Allied victors prepared a plan toward the end of 1945 for "reparations in kind" to be imposed on the defeated nation. This called for removing or dismantling 50 per cent of the machine tools, all manufacturing equipment of the light-metal and ball-bearing industries, 20 shipyards and naval arsenals, and all plants having a capacity to produce more than 2.5 million tons of steel (the total steel-producing capacity of Japan was 11 million tons). More than 1,000 plants were designated for reparations.

Industrial capacity left untouched at the time was meant solely to produce goods for reparations. It was intended that Japan would revert to a small agricultural nation governed by what Westerners then understood as Asiatic standards; it was to be kept at the level at which it had stood immediately after the 1929 slump.

In other words, Japan should never again rise above the levels of the Asian countries it had trampled underfoot by armed aggression. Its annual production of crude steel, for instance, was not to exceed 1.5 million tons, a level at which it had stood 20 years earlier (1926), and its production would rely solely on domestic ores.

The year of defeat happened to coincide with a very bad rice crop, the second worst in this century, which was further aggravated by typhoons and floods. The rice yield dropped to 60 per cent of an average year, and fears were strong that 10 per cent of the nation's 80 million population might die of starvation. Even through a food rationing system, the Japanese government could not ensure a per-capita daily intake of 1,300 calories.

One observer, an American journalist arriving in Japan at the end of 1945, described the aftermath this way:

> The closer we came to Yokohama, the plainer became the gravity of Japan's hurt. Before us, as far as we could see, lay miles of rubble. The people were ragged and distraught. . . . There were no new buildings in sight. The skeletons of railway cars and

locomotives remained untouched on the tracks. Gutted buses and automobiles lay abandoned by the roadside. This was all a man-made desert, ugly and desolate and hazy in the dust that rose from the crushed bricks and mortar.[2]

One scholar referred to the Gayn descriptions as a record of a situation characterized by "great heaps of useless war equipment laying about, with throngs of people running pell-mell for the few scraps of consumption goods that remained."[3]

Raw materials could not be imported, and a shortage of fuel greatly hampered transportation. As for electricity, voltage was so low that lamps barely shone. As the currency lost popular confidence, economic life became one based mostly on exchange and barter. A state of marginal existence under rampant inflation from an extreme shortage of goods lasted more than three years. The people were in constant lethargy. A judge, believing that "a bad law is still a law," refused to buy food on the "unlawful" black market and died of malnutrition in October 1947.

Priority Production System and the Dodge Line

Despite the economic difficulties, there were some improvements: The Occupation authorities steadily effected measures to demilitarize and democratize the defeated nation. The emperor myth was unveiled, and the forces that had operated under the aegis of the "inviolability of the Imperial prerogative" were politically ostracized. Women were enfranchised and workers given the right to organize. The education system was reformed. The special political police organization was dissolved, and freedom of speech and freedom of the press were assured.

One of the most important reforms was the land reform, which swept away the semi-feudal landlord-tenant relations. In the three years after 1946, a total of 1.87 million hectares, or 81 per cent, of tenant land, and 240,000 hectares of pasture-land were released from landlord ownership. Most tenant farmers became owner-farmers, with the maximum of landownership set at 1 hectare, excluding some provinces and forest land. Land reform was fundamental in expanding and deepening Japan's domestic market.

The House of Peers, whose membership had been restricted to high taxpayers and absentee landlords, was abolished. This collapsed the material foundation of the ultra-conservative forces that had been opposed to all reforms on the strength of the "inviolability" of the emperor. There are several reasons that explain the quick and successful execution of the land reform.

First, it was done under orders of the Occupation forces; second, the new farmers' unions throughout the country were a force to prevent landlords from sabotaging the reform; and third, landlord rule over tenant farmers had been on the wane through the war as economic controls such as fertilizer rationing and the rice delivery system were imposed. Also, since the 1910s, when tenancy disputes began to be frequent, the government had posted *kosaku-kan* (officials in charge of tenancy relations) with police power in all prefectures. The *kosaku-kan* had kept detailed accounts of the tenancy disputes they had handled, and these records were helpful in reform administration.

During the time of the reforms, the economic life of the nation, aggravated by inflation, showed no signs of improvement. A plan was drawn up to give priority in recovery to the basic industries, namely, steel, coal, fertilizer, gas, cement, and railroads. Under this plan, the "priority production system," labour and money were first to be put into coal-mines; then coal was to be produced for manufacturing iron and steel, and the steel materials were to be used for increasing coal production. It was hoped that in this way allied industries and others would be stimulated and the inflation resulting from the shortage of goods would gradually be overcome.

This recovery plan, though theoretically reasonable, was misguided. To begin with, the existing coal-mines had obsolete, worn equipment whose maintenance had been neglected in the wartime drive for more coal. Skilled miners were in short supply, 20 per cent of the total being inexperienced. Three to five years would be necessary before many of the mines could recover their pre-war levels of output. The annual coal output per miner was only 90 tons, versus the pre-war (1930–1934) average of 200 tons.

Second, although daily-necessity consumer goods were in extremely short supply, the demand for steel and other basic producer's goods was not great enough for their manufacturing capacities to operate profitably or for the labour force to be effectively employable. Hence, their market prices had to be even lower than their production costs. The government, therefore, subsidized these industries to cover the backspread.

Since the steel industry was more capital-intensive than coal-mining, it could recover faster than mining when supplied with imported raw materials and subsidized by the government. The priority production policy thus stimulated recovery in these industries, but it did not eliminate inflation.

Priority was also given to the increased production of ammonium sulfate fertilizer, needed for rice cultivation. As symbolized by the 1946 "Food May Day" demonstrations, the food shortage was an important part of the critical economic conditions and a key factor in the political and social unrest at the time. The government therefore treated the chemical fertilizer sector with special political care, and by 1949 it had recovered its pre-war level of production.

Although the estimated requirement of steel materials for use in coal-mines in 1946 was 98,000 tons, only 80,000 were allotted, of which 25,000 were illegally disposed. Only slightly more than half the required steel, therefore, was put to use in the mines. The Occupation authorities ordered the Japanese government to make available 2 million tons of coal monthly for the people, but the government was hard pressed to raise its target level even to 1.2 million tons. The actual monthly output of coal in November 1945 was only 554,000 tons.

The situation regarding cement was no better. Under the cement distribution sytem, at least 70 per cent of the requirement was to be made available, but what actually appeared was less than 50 per cent. Workers often blamed management for sabotaging production by concealing and illegally disposing of goods and materials. Struggles of the newly legalized labour unions sometimes even led to worker control of production.

A strong distrust of the management running the mines, in which a vast amount of state funds were invested, clouded their operations. This distrust was clearly evident in the proposal by the British representative on the Allied Council for Japan that the state take control of *zaibatsu* coal-mines for three years. There were even apprehensions about entrusting to the private sector the nation's post-war rehabilitation. The proposal for state control of the coal-mines was finally abandoned after a frantic resistance by management. And management soon regained control of the mines where production had come under worker control.

By 1949, thanks to the government's emergency aid in addition to the intended effects of the priority production system, industrial production had largely caught up with inflation. Then, however, the Occupation authorities ordered the Japanese government to change its policy: first, economic aid to Japan was discontinued; second, the price-offsetting subsidies were ordered discontinued; third, a balanced finance policy would be taken to cope with inflation; and fourth, Japan was brought back into the international economy by the introduction of a single exchange rate of US$1 : ¥360.

With this policy change, the coal industry, which had been allowed to operate with an overemployment of labour to increase coal output, was now compelled to raise its productivity and therefore to rationalize and mechanize its production system. It was imperative now not merely to produce more but also to realize lower prices through increased productivity. The steel industry and other basic industries, which, with the aid of government subsidies, had been able to buy coal for ¥1,000 a ton, were now forced to pay ¥3,344 a ton. These high prices formed a bottle-neck that impeded economic reconstruction.

As a part of the mechanization in the coal industry, coal diggers and loaders were imported from the United States with aid funds. But with pit conditions, coal-beds, and other production conditions being much different from those in US coal-mines, they were soon found awkward to handle and left unused. It is easy to see that this early case of technology transfer failed because of the casual handling under foreign aid. But it is important to note that the unusableness of the American machines (even though this pushed up the price of coal) gave impetus to manufacturing the machines domestically. Because the machinery industry had been very much munitions oriented during the war, it found itself in need of new markets in this period; consequently, the coal industry was a welcome customer.

The Japanese coal industry next turned to Europe for the necessary technologies, and in 1950 it introduced the Kappe method of coal-mining from West Germany. By the following year, this technology had begun to be adopted by the leading coal-mines, and, coupled with the successful development of shafts that had been in progress in some of the major coal-mines, it raised productivity. Coal output approached 50 million tons in 1951, and productivity became comparable with the levels of most European countries.

The steel industry began peacetime work with three operating blast-furnaces at the Yawata Ironworks (in its heyday, the industry had had a total of 37 blast-furnaces). The newest of the nation's furnances (affecting 22 plants, or the equivalent of three-fourths of total capacity) were designated for reparations, most chief executives were purged, and the biggest of the enterprises was dissolved under the economic democratization policy of the Occupation authorities.

The recovery of steel production was slow, but after a mere 560,000 tons in the year of defeat, it recovered four years later to 70 per cent of the pre-war level (or to 4.84 million tons in crude steel). Then came the government's abrupt changes in economic policy and, like the coal industry, steel suffered a serious blow. Although it had succeeded in introducing a technology enabling it to use ordinary coal instead of raw coal, the steel industry could not achieve marketability without the aid of price subsidies.

As we have seen, the government's abrupt policy change dealt a serious blow to the recovering economy. Major corporations were forced to dismiss their employees on a massive scale, and some were even driven to bankruptcy. The government's reduced budget policy came suddenly, at a time when industry had not yet managed to fully recover productivity and when many enterprises were unable to meet market needs because production costs were too high. The new policy, the so-called Dodge Line policy, quickly ended inflation, but it increased uncertainty about the future of the Japanese economy.

The strategy for economic recovery based on coal and steel thus had to be discontinued, and priority was shifted to shipping, electric power, and transportation. Of all branches of the economy, shipping had suffered most, and if Japan were to be brought back into the world economy, the recovery of this sector was urgent.

But a more important reason for a priority shift to shipping was that the Occupation policy, which had designated shipping for reparations of a punitive character, was now beginning to change. As the cold war progressed, the United States, which had played an almost exclusive role in the Occupation, was now increasingly in favour of using Japan and West Germany as factories to help rehabilitate their respective neighbouring countries. Also, many US politicians were beginning to feel that if the financial burden on the American taxpayer were to be lessened, the Japanese economy should be made to stand on its own feet.

The Korean War and Japanese Recovery

An unexpected turn of events came with the outbreak of the Korean War in June 1950; it galvanized the Japanese economy back to life. Social reforms that had been dragging amid the chaotic economic conditions began to show progress as the economic life of the nation grew active.

Within the first year of the war, the "special procurements" reached US$340 million; this more than cleared all the backlogs in the manufacturing industries that had been caused by the Dodge Line policy. Goods and materials for use by the UN forces ranged from locomotives, rails, trucks, steel materials, iron posts, electric wire, barbed wire, and other heavy-industry products to chemicals, processed foodstuffs, clothing, and medicines. The procurements reached into all branches of Japanese industry; three branches alone—metals, machinery, and textiles—accounted for 70 per cent of the special procurements.

Covering also the goods and materials for the post-war rehabilitation of South Korea, the special procurements amounted to a total of US$2.4 billion in the four years after 1950, which, even after deducting the cost of imported raw materials, left Japan with a big dollar surplus. The Japanese economy had thus struggled free of its worst difficulties.

The special procurements demanded that Japanese industry mobilize all its existing equipment, however worn and used, so that most of it soon needed replacement or renovation. And this was made possible by foreign currency earnings. Indeed, the first real impetus for Japan's post-war recovery came from the special procurements connected with the Korean War; in other words, the stimulus came from outside Japan.

For example, the steel industry, whose reconstruction based on the priority production system had been stopped by the Dodge Line policy, took advantage of the Korean War to expand its capacity by importing new equipment and realized not only lower prices for its products but also improved quality. What made this possible was the favourable conditions in the international technology market. Technology transfers were very liberal, and Japan's steel industry acted wisely in its choosing and importing of new technology. We will return to this point later in the discussion.

The strip mill is an example of the sort of technology transferred at this time. Compared with older types, it was automated and of far greater speed. Though new to Japan, the technology was already well established in countries with advanced steel industries. Japan had failed to introduce this technology earlier mainly because of the heavy military orientation of the steel industry and because the industry was under state control. The post-war transfer of technology was aimed just as much at the recovery of the steel industry as it was at overtaking the advanced nations.

Another new technology was the basic oxygen steel-making process, also known as the LD process, which was, at the time, the day's newest technology. As an Italian case later reveals, it had not yet been globally established. Nevertheless, the Japanese steel industry adopted and eventually improved the process by adding new ideas and devices, thus laying the foundation for the industry's future development.

Because a strip mill rolls steel in a continuous process at a high speed, mass production became possible. Moreover, the production of high-quality steel sheets had not been possible with the old rolling mills. Thus, Japan was now able to produce materials for use in cars, small electric appliances, and other durable consumer goods, and steel makers could now also mass-produce materials for the general machinery industries. This was all of great significance to the steel industry, which had functioned entirely under the limitations of steel-plates, bar-steel, and section-steel production. Also, with the introduction of LD converters, indispensable for the mass production of rolled-steel products, the two processes of input and output became well balanced. (In most developing countries, they tend to be poorly balanced.)

In another area of the steel sector, a plan for an innovative mill materialized at this time, and the result elevated Japan to a position of world influence among steel makers. Kawasaki Steel Corporation drafted plans for a seaside mill in which the continuous operation of pig-iron production and steel-making was possible. It was a completely new plan both in mill placement and layout. Raw materials (ore and coal) would be unloaded on a wharf at the mill site, undergo manufacturing processes, and emerge as manufactured goods for shipment from another wharf at the same site. At the Yawata Iron Mill—the oldest of Japanese iron and steel works, where a half-century of expansion had meant one new shop or facility after another—the seemingly endless adding-on of the intramill transport railroads extended some 400 kilometres. Plant redesign shortened this by 90 per cent.

Though a change in mill layout may appear to be an insignificant adjustment, when done correctly it can save immense transportation time and fuel costs, which grow in scale as production increases. The result of this amazing foresight soon became status quo as all other steel mills hastened to follow suit.

The idea had been developed during World War II, but the Japanese military had opposed it, and even during the post-war reconstruction, it had failed to materialize. Then came the Korean War, which helped move it from the drawing-board to reality. With the mill's new location and layout, Kawasaki Steel was able to produce 700 tons of steel a day. But there was still some opposition, this time from voices in government circles who felt Kawasaki's transition from a major manufacturer using electric furnaces to one using blast-furnaces might bring on an overproduction of steel. In 1950, Japan's annual output of crude steel had been only 5 million tons.

Overproduction did occur in the 1970s, when the productive capacity for crude steel in Japan reached 110 million tons a year. And a decade later, amid a drop in the world demand for crude steel, Japan's top steel manufacturer, with an annual crude steel production capacity of 50 million tons, had to curtail operations to 60 per cent of capacity.

One of our collaborators in this project, Professor Hoshino Yoshiro, has pointed to several factors that sparked the remarkable growth of the Japanese steel manufacturers, growth that saw the capacity of one soar to 10 times what the immediate post-war output level of all Japan had been.

According to Hoshino, at the time, steel manufacturers throughout the world were competing to enlarge the scope of production, and each country was developing components of technology with little regard for what other countries were doing. Under these circumstances, if a steel manufacturer were observant and could collect data on these various component technologies and integrate them into a single system, he could build the most advanced steel mill in the world. And indeed, Japan at the time was fortunately in a position to fully utilize the advantages of the late comer and ready to spend the time and expense necessary to do this.

This was true not only with steel-making technology but with nearly all other technologies, and here the Japanese experience can serve as an important and useful example. Collecting, examining, and appraising relevant information and bringing it together into a consistent whole should constitute a part of the technological development capability of all the technologically less-developed.

In the third world today, however, several factors make this difficult, if not impossible. These include factors inherent in current technologies and factors relating to the lack or immaturity of external conditions of certain technologies that might enable the less-developed to make use of advanced technologies.

Nevertheless, each developing country must work to overcome these obstacles by setting goals and executing plans based on its particular philosophy of development. Ultimately, development is a matter of national sovereignty.

Post-war Japan had an urgent need to rehabilitate itself, and there was an overwhelming national consensus regarding the indispensability of promoting science and technology through introduction from abroad. There was also the general feeling that Japan's defeat in World War II was due in large part to the antipathy of the Japanese military toward science.

There was a wide range of views, arguments, and counter-arguments in regard to the policies for rehabilitation, especially concerning whether Japan should follow an autarkic line of development or one that would make it an integral part of the world economic system. Throughout, however, a national confidence in science and in democracy prevailed and, indeed, characterized the nation's state of mind in the post-war years before the period of rapid economic growth.

From Recovery to Rapid Growth

Rehabilitation and Technology Transfer

As stated earlier, the Korean War was an unexpected shot in the arm for the Japanese economy, which, before it had managed to rehabilitate itself, was drowning in a stabilization crisis. It gave Japan a springboard for rapid recovery in the 1950s and for rapid economic growth in the 1960s. It may even be said that the Korean War changed the entire outlook of the Japanese economy.

Post-war Japan may be divided into five periods:

1. Post-war chaos (1945–1949)
2. Decade of recovery (1950–1959)
3. Decade of rapid growth (1960–1969)

4. Decade of adjustment (1970–1979)
5. Contemporary uncertainty (1980s)

There are those who contend that Japan's rapid economic growth began with the Korean War, because in the late 1950s its economy had already posted high growth rates, high even on an international scale. An official Japanese document concluded in 1956, only 10 years after the end of World War II, that "the post-war period is over."

Some indicators may in fact justify the belief that the special procurements during the Korean War enabled the Japanese economy to recover its pre-war levels. Under this line of argument, Japan entered the period of rapid economic growth in the latter part of the 1950s, a period that continued until the oil crisis of 1973. A similar view also characterizes the years from the late 1960s to 1973 as a period of uncertainty for Japan, pressured as it was to internationalize its economy.

For my part, however, I do not consider the post-war period to have ended in 1956, as the Japanese government declared. At that time, Japan's per capita national income was only US$220 (less than 7 per cent what it was in the United States and 50 per cent in West Germany); more than 45 per cent of Japan's population belonged to the primary industry sector; and as the special procurements came to an end, only light-industry goods such as textiles and sundries were competitive as exports.

To be sure, some economic indices for 1955 might compare favourably with those for 1930, but in the early 1960s the nation had really only recovered what it had lost in World War II. The 10-year income-doubling programme was officially declared in 1960, by which time full employment had been realized and there had developed a shortage of labour as the economy increasingly internationalized. Also at this time there were official plans for the liberalization of trade and capital transactions.

Technology transfer began to increase rapidly as Japan prepared for the imminent arrival of foreign capital and technology, considered a possible forerunner of another national crisis.

Furthermore, the technology transfers of the 1960s differed from those of the 1950s. Whereas the earlier effort was aimed at recovering pre-war production levels, the transfers of the 1960s aimed to prevent an influx of foreign goods and to strengthen Japan's position in the impending international commercial war in which Japan would be forced to compete. Thus, the enlarged scale of production was for much more than domestic demand, and, moreover, the technologies would be the world's most advanced.

The situation much resembled the one 90 years earlier, when the new Meiji government committed itself to building an industrialized country under the slogans "promotion of industry" and "prevention of imports." The great difference between the two times, however, was that the national consensus in the Meiji period was based on creating a "rich nation and a strong army," while in the 1960s it was restricted to non-military wealth and power.

Thus, technology transfer in the 1960s was characterized not so much by an intention to expand the scale of production, to mechanize and rationalize, as was the case in the preceding decade, but by the aim to transform the production system itself into automated high-speed mass production.

There had been a mass-production policy in the 1950s, at least in some industry sectors, but it did not stress high-speed production, much less automation, because a plentiful, good-quality, labour force was then available, making automation less attractive.

Technology transfer in the 1950s, the 1960s, and the 1970s may be characterized as follows:

1. In the 1950s technologies were transferred to bridge the wartime gap in such sectors as steel, shipbuilding, chemical fertilizers, and textiles, sectors that were already active in Japan.
2. In the 1960s technology was transferred in such fields as automobiles, small electric appliances, and petrochemicals, industries that were already well developed in the United States and in the industrialized European countries, but that were still in their infancy in Japan. As a result of the transfer, these products began to be mass-produced as domestic products and became highly competitive with foreign goods in Japan's home market.
3. Technologies transferred in the 1970s included electronics, high-polymer chemicals, and atomic energy, which had been developed during and after World War II. In these fields—except for atomic energy—and in particular electronics, Japan followed a painful path of quickly overtaking the advanced countries, then being outrun, overtaking them once again and, in some fields, taking the lead.

Even before Japan's international competitiveness in the most advanced technologies had become globally recognized, its steel-manufacturing technology was drawing foreign attention. In 1964, one of the biggest new steel mills in Europe, an Italian steel maker in Taranto, had newly completed construction of two blast-furnaces with a capacity of 2,000 tons each and a converter with a capacity of 3,000 tons. When it encountered problems in its blast-furnace operations, it turned to Yawata Steel for technological advice. Within six months, Taranto had been able to increase its output 15 per cent.

Later, Yawata exported converter technology to British Steel Co., in Wales, the birthplace of modern iron-manufacturing technology. Japan's export of such technology culminated in a series of plant exports to developing countries, including Brazil (Usinas Siderúrgicas de Minas Gerais, or Usiminas), Malaysia (Malayawata Steel Co., Ltd.), and the Middle East (Qater Steel Co.).[4]

In the 1960s, the world steel industry entered an age of large blast-furnaces and LD converters, although these plants were still at the planning level and were not yet practical as operational technologies. Thus Britain, a long-time iron-manufacturing country, had to seek help from Japan. This reveals that the components of a technology are usable only when they comprise equal elements of the technology. The question of whether a technology can be used is determined by the least developed of its components. This is where technology differs from science, which endeavours to uncover a new principle and theoretically build upon it. It is important to keep this difference in mind when discussing science and technology.

Although scientific creativity is directed toward the discovery of principle and theory, technological creativity lies in finding a new way to co-ordinate and direct a set of skills and devices toward a definite practical purpose of operation. In R. & D., or research and development, the R may be expressed as a total of ds: $R = d_1 + d_2 + d_3 + \ldots d_n$.

Japanese science and technology have sometimes been characterized with a small r and a large D, r. & D., but I believe they have both contributed their share to the world's Rs and Ds. All national experiences are different, none being superior or inferior to any other. The evaluation standards for pure science must not be applied to technology, which is for meeting the daily needs of the populace.

The post-war Japanese experience can be summarized by taking microelectronics as an example. Until recently, the vacuum tube was used in communications and computational equipment. In the mean time, the transistor was invented, just at a time when Japan was taking great pains to improve the performance of vacuum tubes and to mass-produce them. Nevertheless, Sony Corporation introduced the transistor into Japan—the first to do so—from the United States, where the technology had been used mainly for military purposes. After 1956 Sony began to develop and manufacture transistor radios, although they were too expensive then for most Japanese.

By 1960, Japanese transistor radios were finding their way into the American market. The transistor itself, as small as a grain of rice, was easier to put together and required the use of fewer hands to produce than the vacuum tube, but it required intensive labour to attach the reed wires to each tiny transistor, to set the resistor, condenser, coil, and variable condenser, and to run through the complicated process of wiring before a radio was completed.

Thus, "the greater the transistor radio industry grew in scale, the more hands were needed. It was the ideal growth industry for Japan at that time where a comparatively cheap labour force with fairly high technological ability was amply available."[5] Japan thus became the top transistor manufacturing country in the world by around the mid-1960s.

In 1960, Japan took another punch, the IC shock. The US corporation Texas Instruments invented ICs and sold them to the US Air Force, though at the high price of US$700 per circuit. The switch from transistors to ICs represented also a change in the substrate material, from germanium to silicon. In effecting this substrate change, the Esaki diode, a diode discovered by a Japanese scientist, was used, which in itself indicates the character of Japanese industry. As with the invention of KS magnetic steel by Honda Kotaro in 1933, however, it was not Japanese industry that put it to practical use. Science and technology will not be put to practical use where there is no need; even when a need exists, it might not always lead to a practical application. In any event, Japan had no military need for the new technology at that time.

ICs began to be manufactured in Japan in 1966. As is well known, the IC comes in two types: the bipolar type, which is good at quick calculation but not at minuteness, and the MIOS type, which shows just the reverse characteristics of the bipolar model. Though the bipolar type is preferred for aerospace and military purposes because of its high-speed logic circuitry, the MIOS type was chosen in Japan to develop IC manufacturing for civilian purposes because of its better storage capabilities.

One difficulty Japanese manufacturers were facing at the time arose from the fact that some leading US manufacturers were having their units built in South-East Asia, where cheap labour was available. The Japanese makers knew, however, that if they could double their output through mass production, they would be able to realize a 30 per cent lowering of cost; consequently, they introduced more than six times the number of existing automated lines to rival the US manufacturers.

Then in 1971, Japan was hit by the advent of the LSI. The Japanese-made IC would lose the war. Japanese manufacturers managed to cope with the difficulty, however, by increasing the integration density of IC components by one digit, which resulted in a one-digit cost decrease.

An important factor at the time was a curtailment of manufacturing processes. The existing equipment for SSIs and MSIs, including even what had been installed within the past two years, were scrapped to prepare for LSI manufacturing.[6] This heralded a fierce competition between the ability to develop technology and to manufacture it, a waste, it may be said, of human energy. This sort of battle is being fought even today in areas of product development between Japan and the United States and among Japanese manufacturers.

With the LSI, the efficiency and control of machines was greatly enhanced. Industrial technology, whose products in the 1950s and the 1960s were characterized as "big, long, heavy, and thick," was producing in the 1970s goods that were "small, short, light, and thin."

Due to the complexity of the LSI, manual labour had a limited part in its manufacture. Rather, highly complex equipment was necessary, which required heavy capital investment, and this, in turn, demanded a big market. Japanese LSI manufacturers chose non-military areas in which to sell their goods.

IC manufacturers in the United States tended to be venture businesses with a specialty line, but in Japan the chief manufacturers of instruments had their own IC branches, thus their comparative advantages in capital investment, marketing, and product development.

The Effects of Technology

What will the rapid development of semiconductor technology bring to mankind? One argument made in response to this question at a UN University meeting underlined that the development of micro-electronics (ME) would radically change the information and communications networks in the developing countries. The effects of using ME for educational purposes were also discussed and opposing arguments heard. A situation might arise, it was argued, in which a country's central government would make use of ME for monopolizing information so that central needs might be met at the cost of provincial needs.

Does the LSI signal a new industrial revolution? The arguments began when the IC was first used to operate machine tools (the advent of the numerically controlled, or NC, machine tools). More interest was aroused when the machining centre (MC) made its appearance, followed by robots for welding and painting. The NC machine tool in its early years differed from today's in output and price as greatly as the IC and the LSI did.

In 1980, the NC machine tool almost doubled its built-in capability, compared with its predecessor of a year earlier. The machinery industry prompted the appearance of these automated machines in its call for higher-speed mass production and greater product precision. In the automobile industry, for example, the structure of which is shown in figure 1, each car required about 30,000 parts, constituting 5,000 different types. Even the largest car makers manufactured an average of only 30 per cent of these parts. The rest were supplied by small independent manufacturers, and that is where the need for NC machine tools was felt the most.

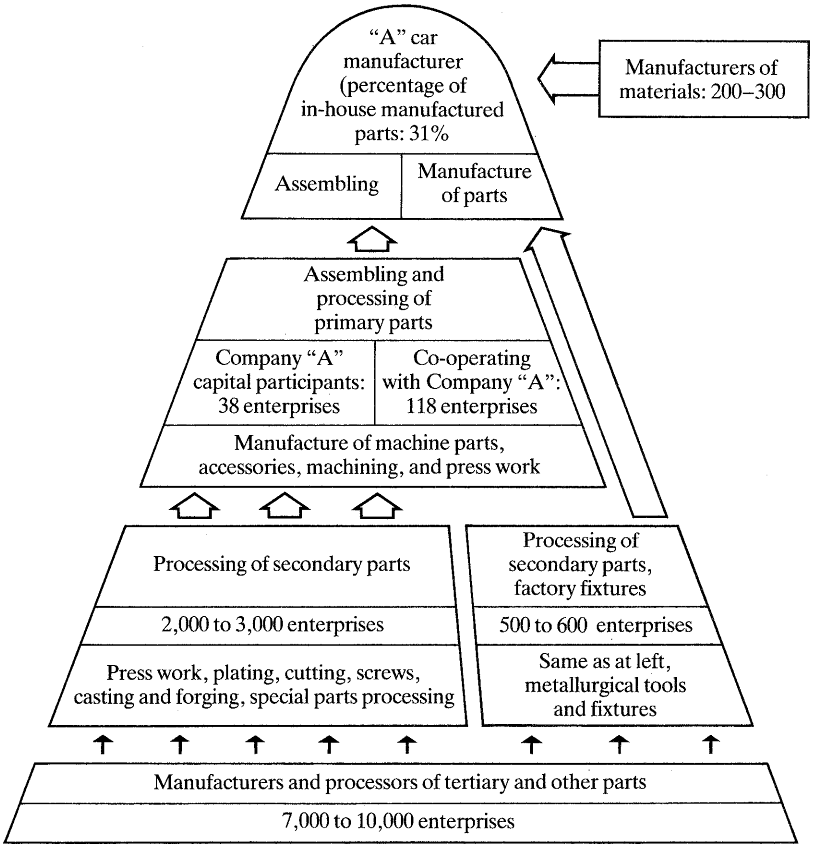
The adoption of robots in Japan (initially in the small- and medium-scale industries) to weld and paint was encouraged by a labour shortage and the lower prices of LSIs. The introduction of the robot was, it should be noted, a labour-saving device only at this stage, since the intention was to meet the existing tact of the production line; consequently, there was no time savings or loss.

The appearance of the NC machine tool represented an important innovation for the machine tool in the machinery industry. As noted earlier, machines were changed in the 1960s, and in the 1970s, factory layouts were altered. Furthermore, to be able to handle the new machines well, the workers were required to have the basic mechanical and mathematical knowledge of a technical high school graduate. Today's machines, however, require less ability to operate. It is clear, though, that higher educational standards are a prerequisite for higher technology.

Though the NC and MC revolutionized the parts-manufacturing processes, some 75 per cent of the labour and working hours in the machinery industry were in assembly. Consequently, assembly process automation was the next object of rationalization. The Japanese machinery industry is currently testing assembly automation, referred to as factory automation (FA), and the flexible manufacturing system complex (FMSC). It is estimated that, if such automation can be successfully implemented, labour productivity could be enhanced 30 to 40 times. At the same time, workers would be expected to have the skills of a multi-skilled mechanic, skills far exceeding in quantity and quality what they have today. That would require additional investment for education, whether public or private.

Complex manufacturing systems result in lower prices and diversification. The LSI has already changed the character of the mass-production system,

Figure 1. Division of labour in the Japanese automobile industry



Notes:

1. Percentage of in-house manufactured parts =

$$\left(1-\frac{\text{Purchasing cost}+\text{Amount paid to sub-contractors}}{\text{Total manufacturing cost}}\right)\times 100\%$$

2. Sub-contracting manufacturers of primary parts do not necessarily work for Company "A" alone.

3. In Japan, parts manufacturers are, as a rule, affiliated with one or more controlling companies; in the United States, they are vertically integrated with automobile manufacturers; in Europe, there is a horizontal division of labour between the two. With Japanese auto makers, despite the comparatively low percentage of parts made in-house (25% to 30% for Japan versus 50% to 60% for the United States and Europe), quality control and cost control are well maintained because they control their sub-contractors' technologies, capital, and personnel.

Sources: Chūshō kigyō hakusho (White paper on small- and medium-scale enterprises), 1980 edition; Industrial Bank of Japan, Research Department, ed., *Nihon sangyō dokuhon* (A reader on Japanese industry), Tokyo, Toyo Keizai Shimpo Sha, 1984, p.163.

allowing, as it does, the production of a uniform product through the assembly of a great many standard and exchangeable parts.

Computers enable mass-production lines to meet the specifications for more than 200 parts that go into the manufacture of a particular car model. Thus, mass production has undergone immense qualitative change, from the mass production of a single kind of Colt rifle (the first mass-produced product) to that of highly diversified products. What has made this possible was the development of the electronics industry in the 1960s and thereafter and the introduction of its products into the manufacturing process.

The development of the electronics industry has caused great concern about how the advances would affect employment. In Japan, this worry has so far proved unfounded, according to an official survey.[7] The appearance of the quartz watch is an example: Technological innovation in one of the manufacturing processes increased productivity four times. But, rather than simply decreasing the number of workers by four times, it was the policy of Japanese business to transfer those displaced to another process. Here we see a great difference between management practices in Japan and those in the United States and Europe, where management is characterized by functionalism.

The enhanced productivity called for an expanded market, and the rapid economic growth of Japan at that time provided it. Without enlarged markets resulting from product diversification, enhanced productivity as a result of technological innovations will reduce employment.

In Japan, increased productivity, a realization of full employment, and wage increases led to an enlarged and deepened market, which proved the government's growth-oriented income-doubling policy effective. As a result, the world-wide reputation of Japanese goods being cheap but poor changed in the 1960s to cheap and good, and since the 1970s they have been regarded as expensive but superb. After IC manufacturing became automated, the cost performance of the Japanese electronics industry began to be highly regarded in the American market.

Besides changing the nature of its products, Japanese industry has now begun to change its employment structure. The total number of employees in the manufacturing sector is on the decline, while in the non-manufacturing sector, especially in sales and in R. & D., it is increasing. In manufacturing, the technology is mature, and the use of ICs and LSIs has generally had a great skill-saving effect, resulting in differences in the quality and efficiency of goods between major and minor manufacturers being almost indiscernable. To use our terms, M_3, M_4, and M_5 have become weightier.

In the case of a certain calculator manufacturer, 1,000 of 3,500 employees are engaged in R. & D. at a technology centre. At a motor cycle manufacturer, salesmen participate in meetings for technological development so that the company's manufacturing technology may better meet market needs, and in the manufacturing department, workers are encouraged to acquire skills not directly related to those required for their current employment. For example, an assembly-line worker may be encouraged to qualify as a maintenance technician, as a plumber, or as an operator of high-pressure machines or instruments. Though this practice may pose a risk to the employer that skilled workers will resign their jobs, it is considered desirable that a single-craft worker should become an all-around worker: hence, the big investment in employee education. Current technological development and innovation require the convergence of a wide range of engineering and scientific knowledge, and, likewise, it is necessary for workers, at all levels, to have a proficiency in several areas, and this represents a new means of skill formation.

It should be noted, however, that the development of technology in Japan was not without cost. First, it widened regional gaps in development; second, it aggravated industrial pollution. The underground water pollution caused by LSI factories has recently attracted attention.

Growth-oriented economic calculations, with their peculiar values, disregard such social problems. If a pollution victim loses all income because of illness, the case will be counted a negative in the economic calculation, but if the victim receives medical care, it will be counted a plus. In the same sense, the building of antipollution facilities will mean an increase in GNP. This should be taken into consideration when one makes use of macro-economic calculations.

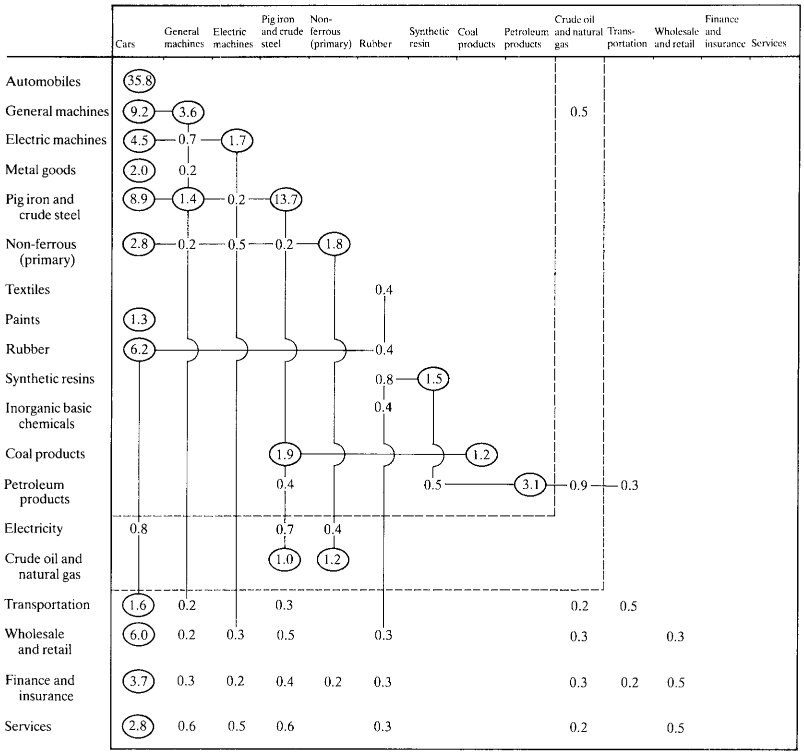
Between the periods of recovery and rapid economic growth, Japan's industrial picture underwent radical change. The four major industrial centres of pre-war Japan combined to form a single long belt. This concentration widened the income gap between the urban and rural sectors, which further intensified the concentration of population in the cities, aggravated the urban housing problem, and pushed up land prices to result in the mushrooming of "rabbit-hutch" dwellings. At the same time, the exodus of young people from the remoter towns and villages created areas of underpopulation.

When a community's population decreases below a given level, the community cannot continue to exist; once its working-age inhabitants are gone, its social balance is lost. The phenomenon of village disintegration (*mura-tsubure*) appeared in many parts of the country, brought on by the decline in the primary labour population because of industrialization. This went hand in hand with mechanization, which also contributed to a decreased labour force.

The middle-aged and the elderly, unable to adapt to the changes brought on by the rapid economic growth, were placed at a disadvantage. This may be said to parallel the problems arising in third world countries in their development. Their problems today and the problems facing Japan during post-war industrialization are essentially the same in character and structure.

The pollution problems Japan faced also parallel the situation in the developing countries. In the period of rapid economic growth, which was strongly oriented toward the heavy and chemical industries, little attention was paid to the problem of pollution.[8] Aside from automobile exhaust fumes, the noise and vibration from the Shinkansen (superexpress bullet trains), and the smoke and dust from the growing steel mills, air pollution caused by petrochemical plants gave rise to asthma and related disorders among the

Figure 2. Transactions in automobile production (for every 1 million yen, based on 1975 prices)



Note: Numbers in circles correspond to the size of transactions; the structural relations shown here indicate the structure of transactions between different branches directly and indirectly necessary for producing a unit of automobiles.

Source: Prepared by Watanabe Toshio and Kajiwara Hirokazu on the basis of Ozaki Iwao, "Reaction of Economics to Changing Structures: Technological vs. Economic Systems," *Kikan Gendai Keizai*, no. 40 (1980). Taken from *Ajia suihei bungyō no jidai* (Horizontal division of labour in Asia) (Tokyo, JETRO, 1983).

populace in the areas around the plants, and the heavy-metal effluence from fertilizer plants, ingested by fish, eventually culminated in the tragic outbreak of Minamata disease.

It should be noted here that the "experts" in the mercury poisoning cases denied, on the basis of data from oversimplified laboratory experiments, any causal relationship between the probable sources of the pollution and the illness of the victims. Even when they were unable to deny the facts any longer, these "experts" aligned themselves with those responsible for the pollution in minimizing the harm. Political parties and labour unions failed to act effectively for the relief of the victims, and in the end, only unrelenting protest and demands for respect for human rights by the victims proved effective.

If primary industry was a victim of the heavy and chemical industries in the period of recovery, it was the creator of victims in the period of rapid economic growth. Heavy and constant applications of chemical fertilizers polluted the soil and water, and agricultural chemicals made the users both victim and the source of pollution. In addition, farming based on mechanization and chemical fertilizers caused a rapid decrease in the fertility of the soil, which in turn required more fertilizer to make up for the loss; in sum, a vicious cycle that prompted many people to forecast gloomy times for the agriculture industry and for the food economy of Japan, which was already dangerously far from being self-sufficient.

Some scholars look to genetic engineering and say that new fertilizer-free crop varieties may and should be mass-produced. Not all people, however, are optimistic about attempts to solve agricultural and ecological problems through engineering. Indeed, the pollution problems have made people increasingly sceptical about the nineteenth-century notion that what is born of science and technology can be remedied by new science and technology: the problems have, in fact, made scientists and technologists even less self-confident. Although many scientists, especially those in the United States, are unwilling to recognize ecology as a science on the grounds that it lacks objectivity and cannot be quantified, it is now the object of a great deal of attention. Science and technology began to be openly questioned in the 1970s, and the century-old philosophy of modern science is now being critically re-examined.

Keeping this in mind, let us refer to tables 1 and 2, which present the Japanese government's view of future prospects for Japanese technological development in comparison with the industrialized West. Table 2 includes findings from a survey of Japan's neighbouring countries in regard to technological development. From table 2 it is apparent that the Asian countries have developed their light, labour-intensive industries at an extremely rapid pace. Although for the time being these industries can be supported by domestic demand, eventually they must depend on export markets for their products, and their international competitiveness will greatly depend on an acquisition of high-level skills.

The long time needed traditionally to acquire skills is now being remarkably shortened by the introduction of new and efficient machinery. Industries whose raw material requirements are met domestically can remain internationally competitive through the introduction of new machines and technology. On the other hand, labour-intensive industries that depend on imported raw materials will quickly lose their international positions. As the introduced technologies become obsolete, the value of technology will come to depend on the locations of either resources or markets, and the advantage of cheap labour might be lost. Thus, it is very likely that developing countries will need to creatively reorganize their markets.

Table 1. Levels of technology and potential for its development in Japanese industries in comparison with the United States and Europe (1978: actual; 1985, 1990: estimates) (Japan is: ◎ = Higher; ○ = Comparable; △ = Lower)

		1978				1985				1990			
		Level		Development potential		Level		Development potential		Level		Development potential	
	Industry	US	Europe	US	Europe	US	Europe	US	Europe	US	Europe	US	Europe
Textiles	Synthetic fibre	○	○	△	○	○	○	○	○	—	—	—	—
	Spinning	○	○	○	○	○	○	—	—	—	—	—	—
	Weaving	△	△	△	△	△	△	△	△	—	—	—	—
	Apparel	△	△	△	△	○	○	○	○	—	—	—	—
General printing		○	○	○	○	○	○	○	○	◎	◎	○	○
Paper, pulp		△	○	△	○	△	○	△	○	—	—	—	—
Cement		○	○	○	○	○	○	○	○	○	○	○	○
Packing		△	△	○	○	○	○	○	○	○	○	○	○
Daily necessities		○	○	○	○	○	○	○	○	○	○	○	○
Flat glass		○	○	○	○	○	○	○	○	○	○	○	○
Fine ceramics (electro-magnetic, biochemical, optional functions)		○	○	○	○	△	○	△	○	○	○	△	○
Fine ceramics (mechanical, thermal, chemical functions)		△	○	△	○	△	○	△	○	○	○	○	○
Chemical	Chemical fertilizers	○	○	○	○	○	○	○	○	△	○	△	○
	Petrochemicals	○	○	○	○	○	○	○	○	○	○	○	○
	Fine chemicals	○	○	△	△	○	○	○	○	○	○	○	○

Table 1. (continued)

Industry	1978				1985				1990			
	Level		Development potential		Level		Development potential		Level		Development potential	
	US	Europe	US	Europe	US	Europe	US	Europe	US	Europe	US	Europe
Light alloy rolling	△	○	△	○	○	○	○	○	○	○	○	○
Aluminium refining	△	○	△	○	○	○	○	○	—	—	—	—
Non-ferrous metals	○	○	○	○	○	○	○	○	○	○	○	○
Ferro-alloys	○	○	○	○	○	○	○	○	○	○	○	○
Pig manufacturing	○	○	○	○	◎	◎	○	○	○	○	◎	◎
Steel manufacturing	◎	◎	○	○	◎	◎	○	○	—	—	—	—
Iron Rolling	◎	◎	—	—	◎	◎	○	○	○	○	○	○
and Special steel	○	○	○	○	○	○	○	○	○	○	○	○
steel Surface-treated steel plate	○	—	○	—	○	—	○	—	○	—	○	—
Steel pipe	○	○	○	○	○	○	○	○	○	—	—	—
Oil refining	○	○	△	○	○	○	△	○	◎	◎	○	○
Coal Production	○	○	△	○	—	—	—	—	—	—	—	—
Coal Use	△	○	△	○	—	—	—	—	—	—	—	—
Crude oil, natural gas	△	○	△	○	○	○	○	○	—	—	—	—
Non-metal, non-ferrous mining	—	—	△	—	—	—	△	—	—	—	△	—
Gravel	—	△	—	—	—	—	—	—	—	—	—	—
Thermal-power generation	○	○	△	○	○	○	○	○	○	○	○	○

Electricity	Hydraulic-power generation	○	○	○	○	○	○	○	○	○	○	○	○
	Transmission	○	○	○	○	○	○	○	○	○	○	○	○
Gas		○	—	○	—	○	—	○	—	○	—	○	
General machinery	Chemicals	○	○	△	○	△	△	△	△	△	△	△	△
	Large showcases	○	—	△	—	○	—	○	—	○	—	○	—
	Food processing (meat)	△	△	△	△	△	○	△	○	△	○	△	○
	Food processing (cereals)	○	△	○	○	○	○	○	△	○	△	—	—
	Packing	○	○	○	○	○	○	○	○	○	○	○	○
	Metal working	○	○	○	○	○	○	○	○	○	○	○	○
	Business	△	○	△	○	△	○	△	○	—	—	—	—
	Printing	○	○	○	—	○	—	○	—	○	—	○	—
	Forging and compressing	○	○	△	○	○	○	○	○	—	—	—	—
	Sectioned materials	○	○	△	△	○	○	○	○	○	○	○	○
	Textiles	○	○	○	○	○	○	○	○	○	○	○	○
	Construction	○	○	△	○	○	○	△	○	○	○	△	○
	Agricultural	○	○	○	○	○	○	○	○	○	○	○	○
	Freezing and air conditioning	△	—	△	—	○	—	—	—	○	—	○	—
	Export and engineering of plants	△	○	△	△	○	○	△	○	○	○	○	○
	Atomic energy (light water reactor)	△	○	△	○	△	○	△	○	○	○	○	○

Table 1. (continued)

	Industry	1978				1985				1990			
		Level		Development potential		Level		Development potential		Level		Development potential	
		US	Europe	US	Europe	US	Europe	US	Europe	US	Europe	US	Europe
Electric machinery	Electrical equipment (for medical use)	△	○	△	○	○	○	△	○	○	○	○	○
	Electrical guages	△	○	△	○	△	○	△	○	△	○	△	○
	Electrical materials	○	○	○	○	○	○	○	○	○	○	○	○
	Semiconductors and ICs	△	○	△	○	○	○	○	○	○	○	○	○
	General electronic parts	△	○	△	○	△	○	△	○	△	○	△	○
	Household electric appliances	○	○	○	○	○	○	○	○	○	○	○	○
	Microcomputers	○	○	○	○	○	○	○	○	○	○	○	○
	Information processing (software)	△	—	—	—	○	—	—	—	○	—	—	—
	Power generators	○	○	△	○	○	○	○	○	○	○	○	○
	Lasers	△	○	△	○	△	○	△	○	○	○	○	○
	Data bases	△	○	△	○	△	○	△	○	—	—	—	—
	Computers	△	○	△	○	△	○	○	○	○	○	○	○
	Aeroplanes	△	△	△	△	△	△	△	△	△	○	△	○
	Automobiles	○	○	△	○	○	○	△	○	—	—	—	—
	Cameras and other optical applicances	○	○	○	○	○	○	○	○	○	○	○	○

	Ocean development	△	△	△	△	—	—	—	—	—	—	—	—
	Housing	○	○	○	○	—	—	—	—	—	—	—	—
	Atomic-energy industry	○	○	△	○	—	—	—	—	—	—	—	—
Other	Social system (medical information system)	△	○	○	○	△	○	○	○	—	—	—	—
	Social system (audio-visual daily information system)	△	○	○	○	△	○	○	○	—	—	—	—

Source: Institute of Industrial Technology, Ministry of Trade and Industry, *Sōzō-teki gijutsu rikkoku o mezashite* (Toward self-reliance in technology) (Tokyo, Government Printer, 1981), pp. 72–79.

Table 2. Levels of technological development of Asian countries (1978)

Manufactured good	Thailand	Indochina	Philippines	Malaysia	Singapore	Hong Kong	Taiwan	R. of Korea
Atomic energy equipment	1	1	1	1	1	1	1	2
Washing machines	1	1	1	1	2	3	4	4
Refrigerators	2	1	2	2	3	3	3	4
Lighting equipment	2	2	2	2	2	3	4	4
Communications equipment	1	1	1	1	1	1	2	2
Radios	3	3	3	3	3	4	4	4
Televisions	2	2	2	2	3	3	4	4
Computers	1	1	1	1	1	1	1	1
Electrical instruments	1	1	1	1	2	2	2	2
Resistors, condensers	1	1	1	1	2	2	3	3
Semiconductors	1	1	1	1	2	3	3	3
Batteries	3	3	3	3	—	4	3	4
Cars	1	1	1	1	1	1	1	3
Buses, trucks	1	1	2	1	1	1	2	3
Car parts	2	1	2	1	1	1	2	3
Motor cycles	1	1	1	1	—	—	3	—
Bicycles	1	—	—	—	—	—	3	3
Railway cars	1	1	1	1	1	1	3	3
Shipbuilding	1	1	1	1	3	1	3	3
Aeroplanes	—	—	—	—	—	—	1	1
Cameras	2	2	2	2	2	3	3	2
Boilers	1	1	1	1	1	1	1	2
Power shovels	1	1	1	1	1	1	2	2
Valves	2	2	2	2	2	1	3	3
Tanks	1	1	2	2	2	3	3	3

Bearings	—	—	—	—	—	—	—	1
Pumps	2	2	2	2	2	2	2	3
Waste-water disposal equipment	1	1	2	2	3	3	3	3
Agricultural machinery	2	2	2	2	2	1	3	3
Lathes	1	1	1	1	1	1	2	2
Textile machinery	1	1	1	1	1	1	2	3
Sewing machines (for home use)	1	1	1	1	1	1	2	2
Desk calculators	—	—	—	2	3	3	3	3
Electronic registers	1	1	1	1	1	2	2	3
Integrating watt meters	—	—	—	—	—	—	3	3
Wrist-watches	1	1	1	1	2	3	2	2
Lighters	—	—	—	2	—	—	—	—
Generators	1	1	1	1	1	1	2	3
Motors	1	1	1	1	2	4	3	3
Transformers	1	1	1	1	2	1	3	3

Notes: 1*a*. Figures 1, 2, 3, and 4 denote, respectively, that it would take "more than 10 years to catch up with Japan," "5–10 years," "less than 5 years," and "already comparable with Japan."
b. Enterprises covered here include those of native capital and joint ventures with advanced industrialized countries. For those items of which appraisals varied widely, figures are based on the majority of answers received.
c. Sixty-five Japanese manufacturers operating in Asian countries were interviewed about the 40 items shown in this table.

2. I would make no comment on this survey except to point out that it was conducted before the second oil crisis. The situation has changed, especially after 1985, because of the decline of the US dollar. Technology transfers were carried out in these countries on an unprecedented scale, which pushed up their position in the world.

Source: Nihon Keizai Shimbun Sha, *Asu no raibaru—Oiageru Ajia no kikai kōgyō* (Tomorrow's rival: The Asian machine manufacturing industry in pursuit) (Tokyo, Nihon Keizai Shimbun Sha, 1978).

Since technological innovation usually reduces employment, it is important that new markets be developed to absorb increased productivity. Second, the labour saved through innovation should be absorbed in the same branch of technology, which would require a new investment capacity.

A situation where investment is made for technological innovation and there is still capacity to invest is a typical picture of prosperity, a phase in which each investment calls for another. This situation, rarely seen, was experienced by Japan only in the period of rapid economic growth.

Such prosperity brings on inflation, which widens the gaps in the rates of growth between enterprises and industries. Gaps of this kind can pave the way for technological and managerial dualism, even on an international scope. In countries where social integration is not sufficiently high and a national consensus on the goals and means of development are lacking, political and social disorder and unrest may arise, which might paralyse technology and even bring on the loss of capital and technology. Consequently, countries responsible for their own development should be prepared to proceed carefully with technological innovation and should seek effective international co-operation.

Technology Transfer in Post-war Japan

I have dwelt upon aspects of the technological history of post-war Japan because my impressions, after having spoken with people from both developing and developed countries, lead me to believe that there is a great deal of interest in Japan's post-war technological, especially high-technological, development. There is a misunderstanding, however, that Japanese attainments in high technology have been due solely to technology transfer from the advanced countries. Anyone acquainted with the history of technology should be aware that this cannot be true, but not all people want this acquaintance, and further, people tend to expect too much of technology, without first learning exactly what technology is, especially what its internal logic or internal mechanisms are.

Technological change in post-war Japan has been remarkable, undergoing a radical change nearly every decade. Machines were renewed within a period of 10 years, and within the next 10, factory layouts were also changed completely. Some say that this is unprecedented. If so, it should be encouraging for those now struggling to develop their countries, because obviously it is not unattainable.

Of course, Japan did carry out a number of technology transfers from abroad, but many other countries have also had such possibilities. The first question we might ask, then, is, Why was it that some did not try to introduce advanced foreign technologies? And if they did try, but the technologies failed, why did they fail? By way of response to these questions, let us return to the Japanese case.

We may first of all point to Japan's need to recover from its heavy war damage, an urgent need obvious to anyone. But not all industries were successful in introducing new technologies, nor earnestly willing to do so.

To take the most successful case, the steel industry chose to introduce rolling technology, the final manufacturing process. That was logical, since at the time rolling was where Japan lagged farthest behind the other industrial nations. Any other country in a similar situation would have done the same, and in fact that is what some South-East Asian countries are now doing. This kind of technology transfer makes it possible to economize in construction, operation, and fuel costs (the Japanese steel industry economized on construction costs by 30 per cent) compared with technology requiring new construction, such as that for sintering, blast-furnace, or converter processes in the continuous operation of iron and steel production.

When the LD oxygen furnace was introduced, for example, it represented an optimal choice, making full use of the advantages of the late comer. In 1979, the ratio of LD converters to total furnaces was 81 per cent for Japan, compared with 66 per cent for West Germany, 56 per cent for the United States, and 21.4 per cent for the Soviet Union. As for blast-furnaces with a capacity exceeding 3,000 m^3, in 1985 Japan had 12, the Soviet Union 2, West Germany 1, and the United States none.

Japan began using LD converters in the 1960s. The US steel industry had built many open-hearth furnaces in the 1950s, which made it unnecessary and untimely to switch over to the LD converter. Besides, because American iron-ores are highly sulfuric, the open-hearth furnace is better at making high-quality steel.

At the time, most LD converters were operating at an average rate of 40 charges per day, and Japan's Yawata was running them with 50 tons per charge; the corresponding figures for an open-hearth furnace were 5 or 6 charges per day at 200 tons per charge. The productive capacity gap (2,000 tons versus 1,000–1,200 tons per day) was obvious. Moreover, the former had the advantage in fuel costs (6 to 10) and in construction costs (1 to 2).

According to a view dominant in Japan, theoretical innovation in this branch of technology did not take place globally in the 1960s, and, consequently, competitiveness naturally depended on a factory's scale of operation. In Japan at the time, there were few obstacles in the way of enlarging the scale. And, as the scale grew larger, the Japanese steel industry proved to have advantages over others in the operational skills needed to handle the growing capacity. Thus, Japan turned out to be the rare case in which the late starter had the advantage.

The Japanese industry's own efforts toward innovative design of the entire manufacturing process, from factory layout to factory location, were another contributing factor. Thus one can see that an accumulation of modifications in operation and processing or both, minor as they might appear from the point of view of engineering, can have effects that are not at all minor. It also becomes evident how standardized the technologies were in this industrial branch and how much steel technology had matured. Factors such as operational skills and factory layout, what may be called soft technology or technology management, can greatly increase competitiveness in this branch of industry. Strangely enough, however, little attention has been paid to this fact. There seems to be an unfortunate tendency for engineering-oriented technologists to neglect the question of the extent of maturity of the relevant technologies when discussing the ability to develop technology.

As for the failure of technologies to transfer successfully, the second of our two questions posed above, it should be pointed out that modern technologies differ from pre-modern technologies in that they are freely transferable on a commercial basis. However, they cannot be freely joined; they require related technologies and the availability of supporting services. So, when a technology fails to transfer successfully despite the enthusiasm and serious efforts of the parties concerned, or when a technology, once transferred, does not meet expectations, most likely it is because it lacks the necessary pre-conditions and supporting services. In other words, the cause of failure can be found in inadequate feasibility studies concerning optimal type, level, and scale of transferable technology or in a lack of efforts in preparing the necessary conditions for the transfer, such as enhancing the levels of fringe technologies and services.

Japan succeeded because it already had the right conditions; the related technologies had been sufficiently readied to make the transferred technology operative and thus it could further develop the transferred technologies.

This being the case, it is perhaps worthwhile to look back on Japan's history of technology to find out how those pre-conditions and supporting fringe technologies were built, because they were not brought into being on short notice after the war, nor were they provided by foreign countries. Indeed, Japan won its success at tremendous social cost. The problem of occupational diseases was and is even now very serious. In addition to the problems of pollution and such phenomena as *mura-tsubure*, there is another problem perhaps worth mentioning.

In the old-style ironworks, rolling was a process that required skills that could be acquired only through many years of experience. Half-naked, muscular workers, with sweat glistening on their skin, would toil long, and yet in a high-spirited manner, creating a sight that would make any observer stand in awe of human labour. This way of work has already passed into history.

Yet, it later turned out that the latest computerized factories had to consult the old skilled workers for advice; despite automation, their skills and knowledge were still needed, as automation demanded highly and multi-skilled workers. Automation may have displaced the value of single-craft skills, but the latest automated processes often reveal themselves to be inferior to the human skills of former days, as will be discussed later. Suffice it to say that the skills of management and workers constituted important factors in the success of Japan's technology transfer.

The Japanese steel industry, with its highly matured technology, is now being pressed to choose for its survival among three alternatives: (1) to remain as a supplier of materials, not only iron but also new materials; (2) to change over to a compound-processing technology that ensures higher value added; or (3) to try to survive in a new general engineering field. The Japan Steel Corporation, for example, while emphasizing the development of new materials and electronics, continues to develop new iron-manufacturing technology.

The equipment of the Japanese steel industry is now nearing the last phase of its life in an economic sense, but capital investment for its renewal has not been active. Because the location merit of technology tends to shift globally from consumption to resources, developing countries are planning to build their own steel mills. For an output of 1,000 tons per annum, 1,000 tons of steel will be required for construction and equipment, which would mean that demand for steel would be on the rise for a long time to come.

However, it is now down, which compels the existing steel manufacturers to cut back in their operations. For the cut-back not to cause a great income loss, it becomes necessary for the manufacturers to develop and invest in higher technologies different from those of the production expansion period, and this acts as a brake on capital investment for equipment renewal. Steel technology is now said to be in its last stage of glory. Whether or not this is true, we may be sure that steel technology is no longer the leading technology.