TECHNOLOGICAL INNOVATION IN POSTWAR JAPAN

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I. TECHNOLOGICAL IMPACT IN POSTWAR JAPAN

That Japan has recently been noticed for her "economic vitality" is symbolized by her nickname "the economic animal." We can see this "economic vitality" in various aspects: postwar Japan has achieved great economic growth; she has accomplished rapid industrialization equipped with the latest science and technology; the Westernization of her economy and society is rapid; her exports have increased with great rapidity; and today she has attained an export market of high standards and stability from the international point of view.

Economic and social change in postwar Japan has been drastic and dynamic: this change is defined as technological innovation, which may be compared to "the Industrial Revolution." By industrial revolution we mean the industrial changes caused by the occurence of drastic technological progress and the rationalization in the economic and social structure caused by the former.

Early stages of industrial revolution, led by the invention of the steam-engine by J. Watt in 1765 and blossoming during the period from the 1760's to 1830's, meant transition from a society dominated by an agricultural economy to one dominated by an industrialized economy. The transition helped establish industrial capital and social change; it provided the momentum for change into a society based upon the principle of the machine and technology—to industrialization.

According to W. W. Rostow, the beginning of the process of industrialization may be conceptualized as take-off.[1] Take-off begins with active, continuous, and self-sustaining responses toward international political stimuli and technological progress. While Japan's take-off into modern, industrialized society took place during the period from 1878 to 1900 when both international and internal political stimuli provided momentum, the economic and social changes which took place in postwar Japan were in-

1 W. W. Rostow, *The Stages of Economic Growth*, Cambridge, Cambridge University Press, 1960.

fluenced by the scientific and technical impact of technological innovation.

Japan's economy took off into modern, industrialized society decades later than developed European countries; and yet it accomplished the process quite rapidly. In Japan, GNP (estimated) grew at a rate of 4–5% a year during the period from 1880 to just before World War II. However, economic growth after World War II has been more rapid and marvelous. Today, Japan's GNP is $141.9 billion, next largest to the United States among the free countries. Her real economic growth was 8.8% during the 1947–1954 postwar revival period, 10.1% during 1955–1964 and 11.0% during 1965–1968: quite high among the industrialized countries of the world.

Also, Japan has achieved internationally high standards in the production and export of such products as ships, steel, automobiles and plastics. The percentage of Japan's exports in world exports grew from 1.5% in 1950 to 6.2% in 1968.

We may consider the factors which enabled such rapid growth as this from two different points of view: quantitative and qualitative. Major quantitative factors are (1) high savings rate, (2) increase in domestic private capital formation, (3) increase in the demand for durable goods, (4) relatively abundant labor force and, recently, (5) increase in exports.

Such quantitative factors reflect the influence of qualitative factors. Major qualitative factors are (1) quality of labor power, i. e., manpower, and (2) technological innovation. That is to say, the energy and adaptive ability envinced by the Japanese people on all levels played a great role in the nation's economic growth. The policy of "investment for further investment"[2] from around 1960—when economic growth was accelerated through a cyclical growth of increased capital investment to expand means of production caused by the increasing demand for capital goods, investment goods and production means which in turn had originally been due to expansion of capital investment—may be said to have been generated through the severe competition among private enterprises under a system of free competition. Entrepreneurs developed sufficient experience under severe competition, scientists and technicians were sufficiently able to adopt new technology, and laborers had enough education for growth to be sustained. On the other hand, these people were avid consumers, seeking for higher material standards, and were eager to adopt innovations.

It is valid to consider technological innovation (strictly speaking, different from the "innovation" of Schumpeter, or "technological progress"),

2 Keizai kikaku-chō (Economic Planning Agency), *Keizai hakusho 1956* (Economic White Paper 1956).

which we may call technological progress, as a factor which has strongly supported Japan's economic growth since the postwar revival period. Scientific, technological progress and invention were the results and by-products of planned, systematic research developed in Western countries during World War II. The process of "innovation" and the changes in economic and social structure and high economic growth that have been brought about by technological progress have been world-wide phenomena in the postwar period.

Innovation in Japan has been prominent in its rapidity, scale and permeability: the diffusion effect of technological progress was characteristically rapid and wide spread. Japan, just after the War, suffered from a great technological gap compared with Western countries because of her economic and technological isolation during the War, or else from technological backwardness since before the War. This gap must be filled, and the developing technological standards of Western countries must be adopted up by Japanese industry, science and technology. The competitive character of Japan's market tends to stimulate the introduction of new techniques and the formation of new industries. This competitive character, which achieved innovation, enabled Japan to adopt developed foreign technology with relative ease over a short period. As a result, the Japan's postwar catching-up with developed technology yielded a profound impact; and this has greatly influenced the development of and change in the economic and social spheres as well as in the spheres of science and technology.

II. PROCESSES OF TECHNOLOGICAL PROGRESS

The leading sector in Japan's technological innovation in the postwar period has been, as well known, the secondary industries. In the case of mining and manufacturing industries, the ratio of value added showed a drastic change around 1953; and it may be assumed that technological innovation started around this year. In fact, it was after the establishment of the Dodge Line (balanced finance) that the reconditioning of old machines worn out during the war, and rationalization of industries, began on a full scale.

In 1950, the Korean War broke out and Japan received special procurements and rapidly accumulated capital. Also in the same year, the enactment of the Foreign Investment Law enabled resumption of the introduction of foreign techniques, which has increased since then. Looking back on the condition of industrial equipment at that time, we may note that 44% of all blast furnaces and about 52% of open-hearth furnaces were old enough to have been built before 1937; almost 99% of the sheet rolling mills were set up before 1938; and, in the automobile industry, most of the machine-tools had been used more than 20 years.

Though one of the reasons why the reconditioning of antiquated machines began some years after the end of the War was the extremely low level of living standard due to World War II, we might say it began too late. However, because of that very lateness, the introduction of foreign techniques was more effective.

That it was possible to introduce new techniques and automated plants, which had been developed almost to perfection in Western countries, is clear because Japan began to introduce them as late as several years after the War. Strip mills in the iron and steel industry, transfer machines in the automobile industry, automatic control systems in new steam-power stations, and catalytic cracking in oil-refining industries were among such technological innovations.

Here, we would like to give an overview of several different aspects of the process of technological progress in the postwar period.

1. Economy of Scale

One of the characteristics of postwar industrial technology is that the economy of scale is an aim. The development of such new techniques and new plants increased the economy of scale and greatly contributed to the expansion of industry and the raising of production efficiency. In the iron and steel industry, which is the leading industry in economic growth, the newly-introduced strip mills increased the supply of thin sheets quite rapidly. The production of ordinary rolled steel by hot strip mills increased from 586,000 tons in 1953 to 2,250,000 tons in 1958 and 12,620,000 tons in 1964: it was 10.8% of total production of hot-rolled steel in 1953, but in 1964 it increased to 43.0% (73% of steel sheets). Hot strip mills as well as cold strip mills are excellent for speeding up automation of production processes and standardization of products: they contribute greatly to mass production and cost reduction. They became stars in technological innovation, because the demand for thin sheets increased with increasing demand for automobiles and domestic electric appliances. In the automobile industry, the introduction of big automatic presses next to transfer machines increased the production of automobile bodies to a greater degree. This exemplifies a typical case of the economy of scale caused by new technology expanding from material sectors to manufacturing sectors—from the iron and steel industry to the automobile and related industries.

When a mass production effect is raised by new technology, the scale

Table 1. International Comparison of Equipment and Techniques

		Japan	United States	West Germany	England	U.S.S.R.	Year
Growing-Scale of Blast Furnace	Daily Output per Blast Furnace (ton)	1,962	1,297	789	796	—	1967
Iron Ore	Ore (and iron content) necessary for production of one ton of blast furnace pig iron (ton)	1,652	1,704	1,827	1,978	1,927	1967 (U.S.S.R. 1966)
Ratio of Sintered Ore	Percentage of processed ores to the above output (%)	62.8	59.3	61.1	61.7	82.3	1967
Ratio of Coke	Amount of coke necessary for production of one ton of pig iron (kg.)	501	572	599	674	616	1967 (U.S.S.R. 1966)
LD Converters	Number	62	58	29	15	22	As of June 30,
	Annual Output (thousand tons)	53,720	46,500	16,640	6,960	12,180	1968
Hot Strip Mills	Number	15	44	6	6	13	As of March 31,
	Annual Output (thousand tons)	26,372	78,651	10,500	8,460	19,200	1968
Cold Strip Mills	Number	56	128	27	19	14	As of March 31,
	Annual Output (thousand tons)	13,405	48,869	7,494	5,385	4,920	1968

Source: Tsūshō sangyō-shō (Ministry of International Trade and Industry), *Tsūshō hakusho* (White Paper on International Trade), 1969.

of production can be expanded to the most technologically appropriate degree and the economy of scale will increase. For example, the most economical size for a pig ore process plant was 1,000,000 to 2,000,000 tons of blister steel per year around 1951; recently it has become more than 6,000,000 tons. The most economical production capacity for one hot strip mill was 200,000 tons per year in 1953; it was 1,700,000 tons per year in 1968: this improvement owes much to the development of operational techniques. Table 1 shows the condition of equipment in the iron and steel industry. Japan maintains the internationally highest standard in blast furnace and, in 1969, possesses eight out of the ten largest operating blast furnaces in the world. The ratio of oxygen convertors is 74% in Japan, while it is 37% in the United States and 36% in West Germany. Oxygen converters, compared with the open-hearth furnaces used hitherto, are capable of high efficiency production and quality. These contribute to raising the international competitive ability of Japan's steel goods. The average daily production of a plant for ammonium (a semi-processed material for chemical fertilizer) used to be 100–200 tons. However, since the recent introduction of the ICI system, plants of 500–750 tons of production per day have appeared, and the unit production cost was lowered by about 30%. In steam-power stations, the maximum power output was 66,000 KW in 1955 and, since the adoption of super-critical pressure turbine generator, has been increased to ten times as much.

The synthetic fiber industry offers a typical example of how changes in raw materials, mass production, reduction of cost and raising of product's quality can be brought about by technological innovation. This has been one of the leading industries in Japan's postwar economic development. Production of chemical fibers goes back to French Count Chardonnet's success in the industrialization of artificial silk manufacture in 1891. Manufacture of synthetic fiber began with the production of nylon in 1938. However, it was after the 1950's that the production of these fibers increased rapidly. Production increase has been possible through incessant improvements in product quality, reduction of cost and invention of new fibers. It is especially true that in the production of chemical fibers which are relatively free from natural limitations, the results of scientific discovery and technological development can be adopted immediately to industrial production: mass production can easily be undertaken and production costs will be greatly reduced by the expansion of production scale. For example, the gross cost for a plant with a production capacity of 30 tons of acrylonitric fiber per day is about 30% of that of 10 tons; the gross cost of a plant with a production capacity of 30 tons of polyester fiber per day is less than 50% of that of a 5 ton capacity plant.

As shown above, high economic growth in postwar Japan has been supported by the development of industrial productivity based on technological progress. The process of technological innovation in Japan has taken the form of development of industrial productivity and industrialization of the agricultural sector, with the tertiary sector influenced by the former two. It has five characteristic aspects: mass production, mass sales, mass advertisement, mass transportation and mass consumption. On the other hand, we should note that the adoption of mass production, the economy of scale, and scientific technology into industries are possible when capital accumulation increases and is concentrated. In this sense, while development of scientific knowledge raises the ceiling of economic growth and technological progress contributes directly to economic growth, the effective utilization of accumulated capital as a result of economic growth should be considered as the condition for adopting technological progress into industry. Japan's economy in the postwar period has followed a typical course of development beginning with an increase in scientific knowledge, then technological progress, then economic growth, then capital accumulation, then large-scale adoption of technology, finally culminating in high economic growth.

2. Leading Sectors

There are two patterns of innovation: one consists in the introduction of new production methods for existing products, and the formation of new production systems and the development of new markets. The other consists in invention of new products and acquisition of new resources. The high growth of Japan's economy was, in a word, enabled by the rapid development of the market; we cannot neglect, however, the invention of new products, formation of new industries and strong capability for market expansion, as factors contributing to rapid market development. These new industries and/or new products led the way to the creation of new demands and, with the reduction of costs after the introduction of mass production systems, contributed to market development.

In other words, a high economic growth rate in a period of technological innovation is brought about by vast new investment pararelled by the concentrated utilization of new technology and by the induced investment motivated by the expansion of demand, improvement of production efficiency and competition or limitation, which are caused by the first type of investment.

Generally speaking, it is natural to consider the heavy and chemical industries as the leading sector in technological innovation, since the major techniques in recent technological innovation belong to electronics and synthetic chemistry. As known well, income elasticity and the ratio of value added are much higher in the heavy and chemical industries than in others. For example, the elasticity of production against demand increase in secondary industry is 1.1 to 1.2, and that in the heavy and chemical industries is especially higher than the average in secondary industry, while that is about 0.5 in the primary industry and about 1.0 in the tertiary industry.[3] So we may say that, when technological innovation progresses with heavy and chemical industries as the leading sector, a more rapid production increase than demand increase is expected, and generally a high economic growth rate is achieved.

Table 2. Real Growth Rate of Demand

	1946–1955	1956–1965
Gross Demand	9.8	9.7
Personal Consumption	9.8	8.6
Private Installation Investment	10.7	12.6
Government Capital Expenditure	8.3	15.8
Government Consumption	10.7	6.4
Export	13.1	14.0

Source: Keizai kikaku-chō, *Keizai hakusho 1967.*

Net national demand of Japan's economy increased at the rate of 9.8% per year from 1945 to 1955, and 9.9% per year from 1956 to 1965. Table 2 shows the demand increase rate by items: the great expansion of the domestic market after the 1950's, except for the revival period, is largely due to the expansion of the market for capital goods caused by technological innovation and liberalization of trade. The trend in the 1960's shows an apparent increase in personal consumption and export. The increase in personal consumption means high consumer demand for new durable goods; and the increase in exports reflects the expanding export of products in heavy and chemical industries and by high technological standards.

J. A. Schumpeter called the process of how new products appear and old ones disappear along with technological progress "creative destruction"; the emergence of new products and new technology results in dynamic industrial and economic development. Table 3 shows the process of technological innovation in the postwar period in terms of the appear-

3 Yūjirō Hayashi, *Shihonshugi to gijutsu* (Technology and Capitalism), Tokyo, Chikuma-shobō, 1966.

Table 3. Changes in Growth Products

	1948–1953	1953–1957	1957–1961	1961–1964	1964–1968
Metal and Metal Products	Section steel, bar steel, plate, galvanized copper plate, tin plate, aluminum, aluminum ware	Ferro-nickel, broad hoop, special steel tube, nickel, cable, die cast, metal tableware	Sheet pile, electrical steel belt, special steel tube, PC steel wire, germanium, magnesium, aluminum ware, aluminum alloy ware, die cast, high pressure container	Silicone, aluminum alloy ware, light metal plate products for construction	Cold-rolled broad special steel, silicone, aluminum alloy ware, aluminum electric wire, aluminum sash, light metal plate products for construction
Chemical and Petroleum Products	Urea, carbon disulphide, titanium oxide, urea resin, vinyl acetate resin, vinyl chloride resin, soap, gasoline, light oil, heavy oil, paraphine	Urea, ammonium chloride, titanium oxide, urea resin, melamine resin, vinyl acetate resin, vinyl chloride resin	Double superphosphate of lime, silica gel, surfactants, LPG	Double superphosphate of lime, carbon black, polyethylene, polystyrene, synthetic rubber, naphtha, LPG	Oxygen gas, hydrogen gas, ethilene, propylene, acrylonitrile, polystyrene, polypropylene, synthetic rubber
Fiber and Textile Goods	Viscose rayon staple, nylon, blended textile, knitted texture, towel, crude wool textile	Nylon, vinylon, tire code	Vinylon, synthetic fishing-net	Vinylon, polyester, synthetic fishing-net, tire code	
Machinery	Portable sewing machine, electric washer, automobile, autobicycle, motor scooter	Air blower, walking tractor, power tiller, machine-tool for metal, electric fan, electric washer, refrigerator, TV set, car, track, forklift, microscope	Excavator, land readjustment machine, machine-tool for metal, press machine, forging machine, air-conditioner, refrigerator, TV set, transistor, car, track, autobicycle, forklift, microscope, electronic computer	Typewiter, tape-recorder, transistor, car, electronic computer	Rolling mill, calculating machine, air-conditioner, car, color TV set, electronic computer, automat, TV set for industrial use
Ceramics, Clay Products, Paper and Paper Products, Other	Polished plate glass, asbestos high pressure tube, dissolving pulp, kraft pulp	Fiber glass, asbestos slate, asbestos high pressure tube, fiber board, corrugated cardboard	Polished plate glass, tempered glass, fiber board, gypsum board, corrugated card board	Tempered glass, piano, organ	Fire-proof goods, tissue paper

Notes: (1) Products whose ratio of growth rate to income elasticity is more than 3 have been selected.
(2) Selection has been made on the basis of volume of production except for electronic computers where value was the basis.

Source: Keizai Kikaku-chō, *Keizai hakusho 1969*.

ance of products with a high growth rate, and their alteration with others: it shows that such products did not appear together at once, but that new products came gradually. Also the table shows how the production of such products as durable goods, which in a sense promoted high economic growth, developed from small-scale to large-scale production in tandem with technological improvement. On the one hand, these new products promoted the alteration of old materials and parts with new ones and, on the other, cultivated new demand for them to become themselves growth products by playing a new role as leading products.

Production of various new products and alteration of raw materials and production system at large enterprises began in the heavy and chemical industries. The leaders of technological innovation in the postwar period were large-scale enterprises, who began importing technology early in the 1950's. They were more capable of fully adopting this technology, of obtaining more information, of negotiating with foreign enterprises, of showing enough credit and of financing, than were small enterprises. Technological progress then expanded, by way of the manufacture of materials and the production of parts, to smaller enterprises which are connected with the large ones and to subcontractors.

The trend of capital-labor ratio in small enterprises shows the delay in the modernization of those enterprises. Though the growth rate of capital-labor ratio in small enterprises was slower than that in large companies before 1960, it has grown as rapidly as that in large enterprises (with a capital of more than ¥1 billion) since 1960. This trend means not only a severe shortage of labor in small enterprises but also the expansion of technological equipment, which strengthens and rationalizes the enterprise system, into small-scale enterprises. However, in 1966 the capital-labor ratio of a small enterprise (with less than 50 workers) was as small as 28, while that in a large manufacturing enterprise (with more than 1,000 workers) was put at 100.

In order to lessen the productivity gap between large and small enterprises, it is necessary to raise not only the capital equipment ratio but also quality and the standards which are dependent upon technological progress. Stimulation of technological progress has spread first to the metal, machine and fiber industries, and then to such industries as wholesale, furniture, rubber and leather, which had been dependent upon traditional methods of production. Thus, in the latter sector where small-scale enterprises are the majority, labor productivity has been improved by the transition from old materials to new, and modernization and rationalization of machine and equipment.

3. Diffusion of Technological Progress

The dissemination of technological progress to economy and society proceeds via (1) the discovery of scientific and technological knowledge; (2) inventions which apply the knowledge to new products and devices through consideration of profit and usefulness; (3) development of new products and new technology for industrial production; and (4) expansion of products into economy and society—i. e., application.

This process constitutes a relationship between the demand and supply of technological knowledge, and production and consumption. As mentioned above, three stages in postwar economic growth may be discerned: in the late 1950's technological progress stimulated industrial investment mainly for innovation; in the early 1960's it caused an increase in domestic consumption demand; and in the late 1960's it contributed to the development of export markets mainly for the products of heavy and chemical industries.

Investment should be made in order to attain technological progress, since this creates the chance to invest in the invention of new products and in improvements in production. And the type, scale, character and speed of that investment regulate the pattern of industrial and economic development.

Investment in equipment in postwar Japan may be classified into investment for (1) the invention of new products; (2) the diversification of enterprise; (3) corporate groups; (4) the modernization of smaller enterprises; and (5) the formation of new industrial districts. It is not incorrect to explain such investment by purely economic factors. However, we cannot neglect the high correlation between such investment and the nature and characteristics of technological progress in the postwar period.

Technological progress in the postwar period, compared with that before the War, has been excellent for its imaginativeness and variety, for its economy of scale in an economic sense, for its continuity and integrity; it has both innovative and quantitative aspects. Innovative aspect includes investment in the invention of new products, and in industries where change of products due to technological progress was great as in oil-refining, synthetic chemicals, synthetic fibers, electronic machines and automation machines. Also, investment for diversification has consisted mainly for that caused by varieties of technological progress, for specialization in the growth sector, and for the underdeveloped sector.

The major reason behind the investment in corporate groups has been the development of new techniques with which enterprises in several different industries can utilize one resource in the same production system for different products, as may be seen in the case in which the diversification of techniques in the chemical industry changed chemical "combination" into the grouping together of chemical, petroleum-electric power, iron-chemical and iron-machinery companies and later into even more complex groups. Also, the tendency toward integration of production techniques, the growing importance of the economy of scale and the expansion of regional development policies have made such investments larger and larger. Characteristic of the growth of "investment for further investment" in the latter 1950's was the interrelated development and expansion of investment in equipment and technological progress.

As technological progress spreads from larger enterprises to smaller ones, investment for modernization in smaller enterprises tends to aim at rationalization and production of new products rather than just the development of productive ability due to demand increases. Also, investment in mechanized equipment is increasing in agriculture, which has been technologically backward because of the smallness of the farming scale. Labor productivity in agriculture increased by 60.4% from 1960 to 1967; this increase was dependent upon the increase of the formation of agricultural fixed capital which in 1967 was 2.41 times that in 1960, rather than by the 22.2% decrease in labor power during that period. Labor-saving machines have been employed to a great extent because of the efflux of agricultural population: in 1960 only 8.5% of the farm families possessed power tractors and cultivators, while it increased to 56.8% in 1967.

Even during the late 1960's this investment in equipment has been increasing. However, the internationalization of Japan's economy, further technological progress, the labor shortage and change in consumption trends have changed the nature of investment slightly. Nuclear power plants, electronic computers, related equipment and parts, etc., are areas in which new techniques draw investment. To improve international competitive ability further investment for large-scale production, aiming at economy of scale, is being made in such industries as iron and steel, metals, automobiles, ethylene and ammonium.

One of the qualitative changes in Japan's economy in the 1960's was the transition to an economy with a labor shortage. This transition can be examined by calculating the contribution rate of capital stock increase and that of increase in labor input, respectively, to the increase in productivity. The rate to which increase in productivity depends upon increase in labor input was 20–30% before 1960 and 1–2% in 1968. An increasing labor shortage necessitated urgent and rapid automation of production; it stimulated investment in techniques which would do away with human labor force. Reflecting this situation, capital stock has increasingly contributed to the development of productivity.

Table 4 shows the trend in the production of automated machines; the recent sudden increase in their production has been due to the increasing demand for such machinery, and we can see that investment in automation is made not only in the manufacturing sector but also in the managerial, service and marketing sectors.

Table 4. Increasing Production of Labor-Saving Machines

Year	Conveyors (ton)	Computers for Business Use (number)	Forklift (number)	Automat (number)	Packing Machine (number)	Digital Electronic Computer (million yen)	TV Set for Industrial Use (number)	Giant Track (More than 10-ton carrying capacity) (number)
1952	8,497							
1953	14,729							
1954	16,275							
1955	15,305	19,247	567					
1956	22,653	17,278	1,166					
1957	32,119	23,449	2,259			39		
1958	28,996	20,685	1,656			240		
1959	33,136	25,339	2,317			475		
1960	53,972	37,968	4,464		5,615	1,010	85	
1961	71,605	46,030	7,894		6,696	1,997	187	
1962	68,791	54,709	8,491	16,406	11,432	4,772	359	
1963	57,426	58,384	9,414	17,068	13,637	9,701	1,526	
1964	64,806	98,015	11,877	10,702	16,622	14,565	1,878	
1965	77,271	257,305	11,880	38,426	17,699	31,536	3,250	987
1966	88,349	321,131	13,570	34,835	16,234	48,623	12,054	1,517
1967	107,843	462,708	22,940	42,773	18,253	86,803	13,191	3,836
1968	139,141	716,475	34,446	66,731	63,079	141,361	20,320	20,238

Source: A survey conducted by the Ministry of International Trade and Industry.

In any case, an epochal new technique produces a large diffusion effect; once correlated with high consumption propensity, it has a great influence on raising the standard of domestic consumption and standard of living. This process is seen in the rapid spread of durable consumption goods in postwar Japan (see Table 5). The permeation of durable goods owes greatly to the raising and standardization of the level of income, while the appearance of various new products caused by technological progress lies behind the trend.

As mentioned above, new techniques not only improve the productivity but also, when correlated with new consumer demands, cause structural change in industry and dynamic change in the economy and society as a whole. This process is symbolized in the development of electronics,

Table 5. Diffusion of Durable Consumer Goods (Except Farm Households)

Rate of Diffusion	1960	1965	1969
Higher than 70%	Radio	Radio, sewing machine, TV set, electric washer, electric *kotatsu*, electric fan	Sewing machine, TV set, radio, electric washer, refrigerator, electric fan, electric *kotatsu*, oil stove, vacuum cleaner
50–69%	Sewing machine, bicycle	Transistor radio, camera, bicycle, electric rice cooker, refrigerator	Camera, bicycle
40–49%	Camera, electric washer, TV set	Vacuum cleaner, oil stove	Stainless sink
30–39%	Electric rice cooker, electric fan	Gas range, telephone	Knitting machine, stereo, tape-recorder, gas water heater
20–29%		Stereo, tape recorder, gas stove, stainless sink	Electric fan, electric blanket, gas stove, organ
10–19%	Motor scooter, auto-bicycle, refrigerator, gas stove, transistor radio	Organ, motor scooter, autobicycle, car, electric stove	Color TV set, car auto-bicycle, motor scooter
Lower than 9%	Organ, motion picture camera, vacuum cleaner	Air-conditioner, electric fan	Air-conditioner

Note: Annual surveys are made in cities with more than 50,000 population at the end of February.

Source: Keizai Kikaku-chō, *op. cit.*

which is a technology representative of the postwar period. For example, a series of developments in semi-conductors, beginning with transistors, gave birth to a new area in the electronics industry which went beyond the boundary of the electrical machine and the communications industries. The techniques for controlling, measuring and electronic computer in the electronic industry have greatly contributed to the expansion of automation and have been utilized to raise productivity, efficiency and automation in all industries, particularly via improvements in transportation and especially the railroads, to which technological advances have been applied with marked success.

The development of industrial technology has generated a social atmosphere for further technological innovation in mechanization, efficiency, and central management. The spreading of automation, and the reduction of human labor in the comprehensive management of production, in inventory management, and various service jobs are actual examples. Also this atmosphere has given rise to the growth of creative, future-oriented values in forecasting the future of society, economy and technology; to the development of a systematic way of thinking; and an increase in scientific planning in management and the economy.

III. FACTORS IN TECHNOLOGICAL PROGRESS

Factors causing technological change may be generally classified into (1) self-supporting factors such as research and development in science and technology; (2) economic factors such as capital accumulation, supply-demand relation of production factors and market trends; (3) social factors such as social institutions and people's living; (4) resources such as man-power and natural resources; (5) international factors such as international incentives, trade and dependence on raw materials; and (6) practical factors like policies and mass behavior. The process of technological change appeares as the result of the close inter-relationship among these factors. *Kagaku gijutsu hakusho* (White Paper on Science and Technology) enumerates among the factors which supported postwar development of science and technology as the following:[4] (1) Japan already had fairly high standard of technology before World War II; (2) each company has endeavored to import technology and undertake research aiming at development; (3) the government has tried to promote industry, science and technology; and (4) there has been a sufficient supply of trained manpower in science and technology. While the *Paper* further points out that behind the scientific and technological development was the relatively favorable development of Japan's economy, which is owed to the national characteristic of diligence and to the international situation.

Here, I would like to concentrate my discussion on two problems—the importation of foreign techniques and the research activities which most directly influenced postwar technological progress. We may say that postwar technological innovation in Japan has been promoted through the importation of excellent industrial techniques from the developed countries. According to Schumpeter's interpretation, entrepreneurs in postwar Japan were "entrepreneurs" in the sense that they were astute in seizing opportunities for the development of their enterprises, but they were imitators rather than forerunners. This is the characteristic of science, technology and technological progress in Japan, of which we may see the evidence in the fact that the balance of Japan's technological trade shows a heavy

4 Kagaku gijutsu-chō (Science and Technology Agency), *Kagaku gijutsu hakusho* (*1968* White Paper on Science and Technology 1698).

inclination toward imports.

Japan has tended to lessen the technological gap with developed countries by the importation of foreign techniques rather than by improving the standards of industry, science and technology through research done by Japanese themselves. This tendency may have been inevitable, considering the historical backwardness of science and technology in Japan. For example, much of the importation of foreign technique in the heavy electrical machine industry in the postwar period could be considered as part of the historical process of technical cooperation with foreign enterprises since Meiji period. However, as is often mentioned about the nylon industry, most cases of importation involved receiving license to use patents in order to solve difficulties in production and in export during industrialization, because foreign techniques were often a step ahead of Japanese practices which might have been perfected only in their essentials. A third type of importation of foreign technique may be seen in the case of synthetic plastics, where Japanese technology lagged far behind because of the technological isolation during the War.

An overview of the importation of foreign technology from 1950, when the Foreign Investment Law was enacted, until 1967, shows that there were 4,773 cases of importation in which the period of payment was longer than one year. About 80% of these were in the machine (including electric machine) and chemical industries; it was in these sectors that most of the postwar technological importations were made. However, the importation of innovatory technology which caused great change in production and similar important techniques ceased by 1963. Recently, the importation of secondary technology has been increasing. Table 6 shows that recent technological importations are concerned with processing rather than man-

Table 6. Changes in Introduction of Techniques (Synthetic Resin Industry)

(Number of Cases)

Period	Manufacturing Know-how	Processing Machine	Processing Know-how	Total
1950–56	11	0	1	12
	(92)	(0)	(8)	(100)
1957–60	11	4	7	22
	(50)	(18)	(32)	(100)
1961–64	40	15	56	111
	(36)	(14)	(50)	(100)
1965–68	35	13	92	140
	(25)	(9)	(66)	(100)

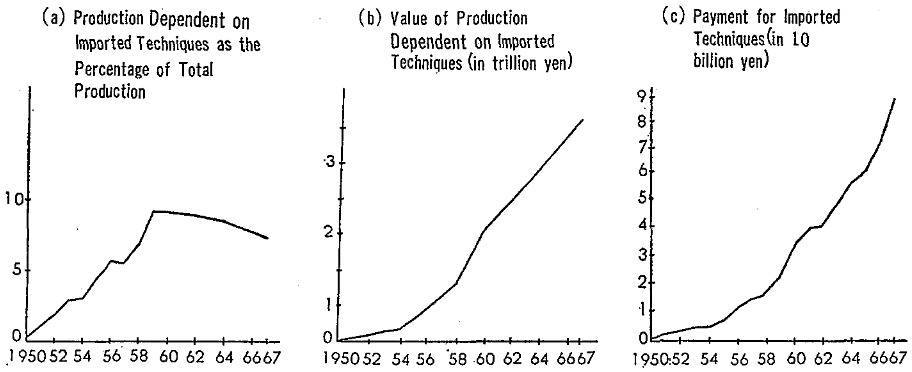
Source: Keizai kikaku-chō, *Keizai hakusho 1969.*

ufacturing method. Sixty per cent of the importations have come from the U.S.A.; 11% from West Germany, followed by Switzerland and Britain. The change from dependence upon European countries to the U.S.A. is apparent. The new and improved techniques imported in the postwar period are spread throughout almost all industries. Yet a large part was concentrated on the machine and chemical industries which were, as mentioned above, the leading industries supporting postwar technological innovation.

Those industries in which there was substantial technological importation and the percentage of goods produced thereby was large achieved relatively high value added. High value added, in turn, stimulated the desire for technological importation. Figure 1 shows that the trend in production utilizing imported techniques increased suddently after 1956. Importation of foreign techniques enables a rapid rise of technological standard, because the imported technique functions immediately; use of it diminishes the possible risk involved with research, and only excellent ones need be selected for import. Besides these advantages, existing technology in Japan has had the potential not only to imitate imported techniques but also to digest and improve them, and to achieve industrialization making possible further economic effects of technological importation.

On the other hand, the recent decreasing tendency in the percentage of production utilizing imported techniques to over-all production shown in Figure 1 means that research of our own is progressing. As shown in Table 7, the gross investment in research and development is ¥606 billion ($1.7 billion) in 1967, which is about six times as much as ten years ago. Recently, the government has been trying to formulate policies

Figure 1. Changes of Production due to Importation of Techniques



Note: Payment for Imported Techniques is for whole industry.
Source: For 1950–60, a survey conducted by the Enterprise Bureau, Ministry of International Trade and Industry and for 1964 and 1967, a survey conducted by the Promotion Bureau, Science and Technology Agency.

Table 7. Investment Trend in Research and National Income (or GNP)

Fiscal Year	Investment in Research (in 100 million yen) Total	Companies, etc.	Institutes	Universities, etc.	National Income (in 10 billion yen)	GNP (in 10 billion yen)	As a Percentage of National Income	As a Percentage of GNP
1959	1,489	956	257	276	1,075	1,338	1.38	1.11
1960	1,844	1,244	294	306	1,301	1,605	1.42	1.15
1961	2,452	1,638	399	415	1,541	1,981	1.59	1.27
1962	2,812	1,794	477	541	1,722	2,119	1.63	1.33
1963	3,211	2,073	512	626	1,998	2,473	1.61	1.30
1964	3,818	2,439	606	773	2,258	2,859	1.69	1.34
1965	4,255	2,524	681	1,050	2,501	3,135	1.70	1.36
1966	4,883	2,922	772	1,189	2,925	3,666	1.67	1.33
1967	6,060	3,790	885	1,385	3,459	4,312	1.75	1.41

Source: Sōrifu tōkei-kyoku (Bureau of Statistics, Office of the Prime Minister), *A Report on the Survey of R and D*, 1968.

which will promote this tendency, since the technological standard in Japan has almost reached international standards and also, on the other hand, pressures against importation of technology are increasing. For example, first limitation of the selling market due to technological importation occurred in 53% of the total cases of importation before 1960 and 71% in 1966. Second, the cases in which capital participation was requested by foreign capital in exchange for technological information increased from 3.5% of the total before 1960 to 7.9% after 1960; and third, recently the requests and actual contracts for cross licenses are increasing.[5]

In summary, we may say that the typical pattern of past industrial and technological development in Japan is a process beginning with the importation of goods, then the importation of technique, then the establishment of industry, then export of products and finally the exportation of Japanese technique. Recently, the improvement of technological standards through the development of our own research and the increase of integrated high-level exportation of Japanese technique are being planned.

IV. THE INFLUENCE OF TECHNOLOGICAL CHANGE

As technological changes function to urge dynamic economic development, their influence causes certain changes in industrial structure. Table 8 shows change in industrial structure as seen in the change in the number of workers employed. The ratio of production income by industry, in 1965, was 11.8 for primary industry, 35.6 for secondary industry and 52.6 for tertiary industry. Technological progress contributes to the growth of

5 *Ibid.*

Table 8. Change in Industrial Structure

	1955	1960	1965
Total Workers	39,261 (100.0)	43,691 (100.0)	47,629 (100.0)
Primary Industry	16,111 (41.0)	14,236 (32.6)	11,747 (24.7)
Secondary Industry	9,220 (23.5)	12,764 (29.2)	15,201 (31.9)
Tertiary Industry	13,928 (35.5)	16,691 (38.2)	20,681 (43.4)

Source: Keizai kikaku-chō, *Keizai hakusho 1969.*

industrial structure through investment which adopts changes and utilizes them, production, increase in productivity of value added, and/or labor mobility. The change in industrial structure during the period of technological innovation means not only structural change from industries with low productivity to those with high productivity, but also the alteration from old industries to new ones. And the alteration of industries is accelerated through changes in demand structure which have been caused by the rapid spread of new products.

Also, various changes are manifested in the nature of jobs, when new means and new subject of labor are introduced. Such changes include (1) taking-over of simple jobs by machinery; (2) change of skilled jobs into semi-skilled or unskilled labor; (3) changes from operational jobs to care-taking jobs and (4) the introduction of machinery such as computers into the sphere of intellectual jobs. Change in the nature of jobs promotes modern type of labor mobility through change in industrial structure: Japan's economy in the postwar period is a representative example showing change in industrial structure as caused by technological progress.

On the other hand, Japan has not only to raise her level of industrialization through technological progress, but she also has to try to increase the exportation of products with high value added, since she imports most of the raw materials for her industrial production. Rapid development of industrialization in the field of heavy industries in the late 1950's had a gradual effect on exports; and the percentage of exports by heavy industries to total exports was 43.7% in 1960, and increased to 67.9% in 1968. The sophisticated machinery and tools occupy a large percentage of total manufactured exports. Also, standards have risen to a high level; in 1967, the percentage of sophisticated products to total exported goods was 64%, while ten years ago, the percentage of crude products was 62%. The increase in competitive ability of these exports is considered to be dependent upon the development of competitive price power brought by the relative increase of productivity.

Though it is easy to describe the influence of technological progress on the economy and society qualitatively, it is not so simple to demonstrate this influence quantitatively. Generally speaking, there are three types of qualitative indices to measure technology and its influence: simple scaling, complex scaling and econometric modelling.

Simple and/or complex analysis uses or combines such technical and economic indices as equipment, quality, cost creativity, input-output ratio, productivity, capital-labor ratio and technical activity; these scalings are used in the micro and idiosyncratic analysis of each industry and/or of each product. However, for macro analysis such as the influence of technological progress on the economy, an econometric model is usually utilized. It was after the 1950's, when technological innovation was under way and some explanation for it was needed, that measurement of technological progress using this method began.[6]

Here, the realtionship between economic growth and technological progress will be seen using an approximation, regardless of theoretical strictness. Table 9 explains the increase in labor productivity by the capital-labor ratio and rate of technological progress based on the produc-

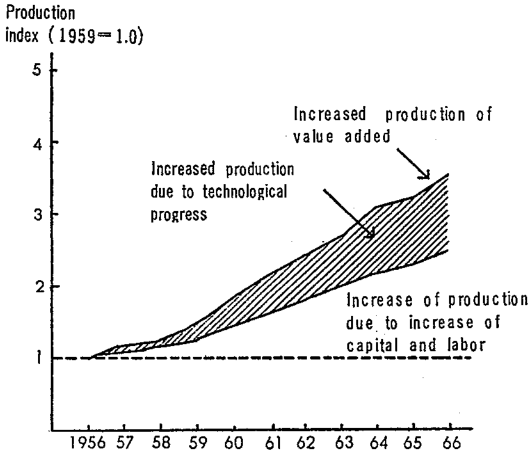
Table 9. Contribution to Economic Growth

	Growth Rate of Labor Productivity	Capital Equipment Ratio	Rate of Technological Progress
Japan	9.4	5.2	4.1
(1955–66)	(100.0)	(55.8)	(44.2)
U.S.A.	3.5	1.6	2.0
(1955–64)	(100.0)	(44.1)	(55.9)
England	2.9	1.3	1.6
(1955–64)	(100.0)	(45.2)	(54.8)
West Germany	5.9	3.5	2.2
(1955–64)	(100.0)	(61.9)	(38.1)

Source: Keizai kikaku-chō, *Keizai hakusho 1967.*

6 R. M. Solow undertook the pioneering work in this field, and this type of positivist economic analysis is done by economic growth theorists of the Neo-Classical School. One of the major subjects of such studies is the endogeny of technological progress by production function (concerning disembodied and embodied technological progress); the other major subject is the pattern of technological progress (concerning such well-known forms as Hicks neutrality, Harrod neutrality and Solow neutral technological progress; or concerning the combining, decreasing and/or additive types of capital and labor.

Figure 2. Contribution of Technological Progress to Increase of Production



Source: Kagaku Gijutsu-chō, *Kagaku gijutsu hakusho, 1968.*

tion function model of Neo-Classical School. Figure 2 shows similarly how technological progress contributed to the development of production.

The estimations which have been made up to now cannot be considered as absolutely valid; many theoretical and practical problems such as assumptions about the production function, types of technological progress, elasticity of the production factor and consistency among the data remain to be solved. Nevertheless, an observation of the many estimations about Japan's economy reveals that the rate of technological progress in postwar Japan was 4–5% while that in Europe and the U.S.A. was about 1–2%, and that technological progress in Japan was quite rapid compared with Europe and the U.S.A. At the same time, a comparison of the situations prevailing before and after the War and the trend of the rate of technological progress shows that postwar technological progress in Japan had a rapid and concentrated influence on economic growth.

Generally, technological progress which will save on human labor is chosen in an economy with a labor shortage, and technological progress which will utilize human labor is chosen in an economy with surplus labor. Postwar Japan chose to aim for technological progress of a unique form —a combination of both types. We should also notice that the type of technological progress differs by the period treated and/or by the method of analysis, and a simple categorization is not possible.

Most of the techniques imported from developed countries, on which postwar technological progress was dependent, were to save on human labor and utilize capital. The reason why the economic growth rate in

Japan is characteristically high compared with other countries is because labor-saving techniques were introduced into an economy with a labor surplus. This will be proved by the facts that entrepreneurs with relatively high competence and surplus labor increased production efficiency through the clever utilization of technological progress for labor saving, and that accordingly the market was developed rapidly. Recently, surplus labor has been absorbed by the production increases accompanying high economic growth, and Japan's economy seems to have transferred into the labor shortage type.

Due to its rapidity and scale, the high economic growth of Japan's economy based upon rapid technological progress has raised problems of economic imbalance such as unequal development among different industries, and social problems like public hazards and lack of social capital. Also, mass production and mass consumption brought by technological progress caused some change in the national image of labor and life; they are the cause of material discontent and alienation. Japanese society today is characterized by the conflict between the traditional social system and a highly industrialized social system; by a close, mutual relationship between technological change and social, economic change.