1

Main Features of the Industrial Structure and Industrial Technology in China

Basic Conditions Sustaining Technology

A country's scientific and technological standing is usually measured in terms of a variety of general indices, such as the total amount of value added of its manufacturing sector, the amount of its trade in technology, the amount of technology-intensive products it exports, the number of patents granted, its expenditures for research and development (R&D), and the number of its researchers. In assessing the country's technological potential, however, these static indices alone do not suffice; it is also necessary to examine whether its social system and institutional organization are well adapted to nurturing human resources and facilitating technological progress.

Looking at the question of how technologically competent men and women are trained in China, the country's sample survey of the population census conducted in June 1987 put its illiteracy rate at 26.77 per cent. According to official government statistics for 1987, 97.2 per cent of children of primary school age and 69.1 per cent of those of junior-middle-school age were actually enrolled in school. These percentages are far better than those for most low-income countries. Indeed, it is commonly acknowledged that at present China stands far above the level of other low-income countries,[1] not simply in terms of performance in elementary education but also in terms of fulfilling the basic needs of its population as shown in such indicators as infant mortality, average life expectancy, and the average caloric intake per day per person. On the other hand, government outlays for education as a percentage of total government budget stood at only 6 per cent during the 1970s. This increased to an average of 10.8 per cent for the four years from 1980 to 1984. UNESCO statistics show that the 6 per cent average for the 1970s was close to the lowest level in Asia and similar to the figures for the poorest countries in Africa. Although the percentage since the early 1980s has become more or less comparable to those of most of the ASEAN countries (i.e., Singapore, Thailand, Malaysia, and Indonesia), China still remains one of the poorest countries in the world in terms of per capita government expenditures for education.[2]

The contrast of scanty government investment in education with the extensive spread of elementary education and low ratio of illiteracy may strike one as very unusual. This imbalance is because the people's communes in the countryside and large state-owned enterprises in the cities was bearing much of the cost necessary for meeting the basic needs of the population such as elementary education and medical care. Despite the spread of elementary education, it was not until 1985 that nine years of education became compulsory. The improvement of the basic standards of the population is a phenomenon commonly observed in many socialist countries, because their governments are usually committed to the ideal of social equality as a basic goal in social reconstruction. China fits into this category, but it should be kept in mind that the way China has tried to accomplish this reconstruction has produced significant regional imbalances in the quality of education and medical care (imbalances which faithfully mirror the economic gaps among the different regions), and has ended up equalizing the overall living standard at a low level.

The insufficient government investment in education is reflected in the realities of college education, which is a key to nurturing technologically talented people. For every 100,000 Chinese there were only 116 college students in 1980, and 178 in 1986. UNESCO statistics provide comparable figures for other low-income countries in Asia: 776 for India in 1982, 479 for Burma in 1982, 443 for Bangladesh in 1984, and 121 for Afghanistan in 1982.

Looking at indicators showing China's technological capabilities (Table 1-1), the number of scientists and engineers engaged in R&D activities on a full-time basis in China is larger than the average for Asian countries, and is comparable to the figures for upper middle-income countries.

The ratio of China's spendings for R&D to its GNP is disproportionately high for a country of its economic size. This shows that China has been putting much effort into upgrading its R&D activities. At the same time this might also be taken as a logical consequence of the policy of self-reliance that China has been pursued thus far. What matters here is the imbalance between the relatively huge expenditures for R&D and the insufficient efforts made in the education of scientists and engineers who are supposed to undertake these activities.

Briefly described above are some of the indicators of China's technological potential, a potentiality that is supposed to sustain the country's advancement of R&D and in turn the progress of its industrial technology. We need to now look at the institutional infrastructure of China which is a far more important determinant of the country's technological competence.

TABLE 1-1
ESTIMATED NUMBER OF SCIENTISTS AND ENGINEERS ENGAGED IN R&D AND EXPENDITURES FOR R&D, 1980

	Estimated Number per Million Population	Percentage of R&D Expenditures to GNP
China (1985 and 1986 average)	300 – 500	1 – 1.5
Developed countries	2,986	2.23
Developing countries	127	0.45
Africa (excluding Arab states)	49	0.36
Asia (excluding Arab states)	273	1.18
Arab states	206	0.27
Northern America	2,679	2.33
Latin America and the Caribbean	251	0.49
USSR	5,172	4.67
World total	848	1.78

Sources: For China, the author's estimation based on State Statistical Bureau, *Zhongguo tongji nianjian* [Statistical yearbook of China] (Beijing: Zhongguo-tongji-chubanshe), 1985 and 1986 editions, and figures frequently mentioned in Chinese literature. For other countries, UNESCO, *Statistical Year Book, 1986* (Paris: UNESCO, 1986), Table 5-1.
Notes: "Scientists and engineers" refer to those people who, after having completed college or higher level education in the natural sciences or engineering, are actually engaged in R&D-related activities or are supervising such activities. For China's definition, see the section for "manpower" of Chapter 2.

During the ten-year period from 1966 to 1976 when the Cultural Revolution swept over China, the country's institutional framework for promoting technology was driven into a state of complete disorder. This period coincided with a time of high economic growth on a global scale which was made possible by rapid technological innovation. Caught up in the confusion of its cultural revolution, China lost opportunities to participate in this global technological progress, a loss of far greater significance than a mere decade would suggest. The backward state of higher education mentioned earlier can also be attributed to the confusion caused by the Cultural Revolution.

The reconstruction of the country's institutional framework for technology began to move forward during the late 1970s. Pursued side by side with a comprehensive effort to overhaul the country's strategy for economic development, this reconstruction effort became something of a "fresh start" for Chinese science and technology.

In public education this reconstruction brought about the introduction of a system of nine-year compulsory education (in accordance with the Party Central Committee's decision of May 27, 1985 on educational reform). The propagation of public education is considered an important prerequisite for modernization, and the new nine-year system was put into effect in 1985 in big cities like Shanghai; but full implementation of the system in financially poor rural districts remains a goal for the distant future.[3]

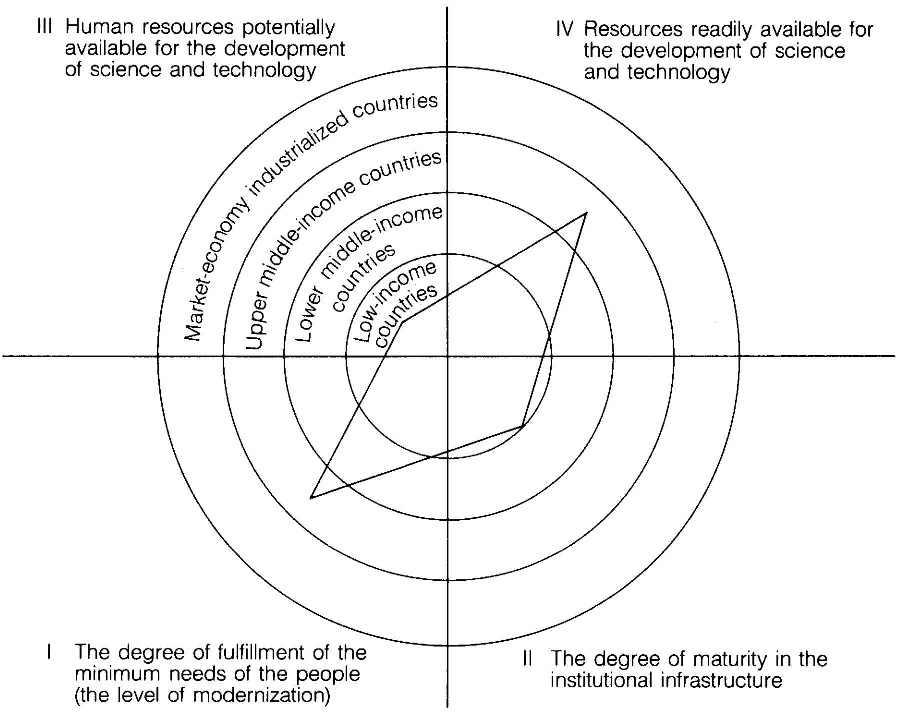
A system of postgraduate education for the training of professional talent was established not long ago, and a regulation on academic degrees (*Xuewei tiaoling*) was promulgated in February 1980 to facilitate the functioning of this system.

Starting in the late 1970s steps were taken to rectify the strong social bias that had taken root during the Cultural Revolution belittled professionals and their contributions to the progress of science and technology. The abolished titles for professional jobs were restored, and salaries for professionals were raised. A regulation for encouraging innovations (*Faming jiangli tiaoling*) was promulgated in December 1978 and a regulation for encouraging the progress of science and technology (*Kexuejishu jiangli tiaoling*) in 1984. These provided incentives for individual researchers and engineers to make significant contributions to R&D. Even a patent law (*Zhuangli fa*) was enacted in March 1984 ensuring private ownership of patents. This law is substantially the same as those prevailing in the West, in that it recognizes an individual's right to patent, grants foreign enterprises the right to apply for patents in China, and issues patents not only for pieces of production technology but also for materials used in manufactured goods. Furthermore, in March 1985, in the hopes of accelerating technology transfer from abroad, China officially joined the International Convention for the Protection of Industrial Property.

To facilitate technological institutions that were directly involved with innovation in industrial technology, China faced the urgent task of putting back into working order its system of industrial standards which had been in a state of chaos since the Cultural Revolution. With the promulgation in July 1979 of a regulation on standardization (*Biaojunhua guanli tiaoling*), China began to prepare a new system of industrial standards, and to accelerate its effort to adopt international standards. In September 1985 it adopted a new measurement law (*Jiliang fa*), and with this China fully adopted the metric-based International System of Units for the first time since 1949. That these institutional reforms have been underway in China since the late 1970s means that the country is switching from its previous pattern of inward-looking or self-reliant scientific and technological development to an outward-looking one that emphasizes international collaboration and coexistence.

The basic factors that are sustaining China's scientific and technological capabilities today can be schematically assessed through an international comparison. This is shown in Figure 1-1. Quadrant I schematically illustrates the level of modernization of a certain country as evaluated in terms of such measurements as the illiteracy ratio, the primary school enrollment ratio, the per capita caloric intake per day, the number of copies of newspapers and books published, and the number of hospital beds per certain number of people. Quadrant II assesses the degree of maturity of a country's institutional infrastructure for the development of science and technology. This is evaluated in terms of

Fig. 1-1. Basic Factors Sustaining China's Science and Technology



Source: Prepared by the author.

whether or not the country has institutions that highly regard and can effectively facilitate the development of science and technology, and whether or not its social system is well adapted to allowing people of talent to give full play to their capabilities. Quadrant III measures a country's endowment in potential human resources for the development of science and technology and is evaluated in terms of size of educational expenditure as well as in the number of students in college, in graduate school, and studying abroad. Quadrant IV presents the index of a country's present capacity to develop science and technology as measured in terms of the number of scientists, the number of research institutions, and the amount expended on R&D.

The lopsided quadrangle exhibited in the Figure 1-1 shows schematically how

China compares internationally regarding the four basic determinants of any country's technological competence. As will be pointed out later, this lopsidedness reflects the purpose as well as the trajectory of the Chinese strategy for technological development that has been pursued thus far. The relative prominence of R&D resources already available in China means that the country's system of science and technology as a whole is built on an unstable, unbalanced base.

The Peculiarities of the Chinese Industrial Structure

Figure 1-2 compares the industrial structure of China with those of various other countries by estimating China's GDP in accordance with the methods for calculating GDP used in the West. Although agriculture remains the largest sector as in many other low-income countries, the share of the Chinese manufacturing sector in the national economy is disproportionately large for a low-income country. China is on a par with upper middle-income countries or with the newly industrializing economies (NIEs) of Asia when it comes to the manufacturing sector's share of the total value added of the economy.

Looking closer at the makeup of China's manufacturing sector, Table 1-2 shows the 1986 sectoral breakdown of the value added of the Chinese manufacturing industries, while Figure 1-3 makes an international comparison of the shares for investment-goods industries, intermediate-goods industries, and consumer-goods industries. These figures reveal that China's investment-goods sector, i.e., the machinery and metal industries, accounts for a very high percentage of manufacturing industries and is comparable to the percentages in the advanced industrialized countries. It is also clear that China's industrial structure as a whole is rather similar to that of India, which has been pursuing the import-substitution type of industrialization policy.

In a commonly observed pattern of economic development, the makeup of a country's manufacturing sector begins to change from one centered on consumer goods to one centering on capital goods as its per capita income reaches a certain level, the so-called process of heavy and chemical industrialization. In China's case, however, the process of heavy and chemical industrialization was set in motion not as a result of an increase in per capita income, but because of the government's intentionally determined policy of resource allocation. China's developmental pattern has numerous characteristics of that commonly observed in countries like India, which have emphasized import substitution as the strategy for economic development, and thus have concentrated much of their investment into the capital-goods sectors.

Logically speaking, an industrial structure like China's with its peculiarly exaggerated industrial nature would have to be sustained by a matching degree of progress in industrial technology. The degree of this progress can be measured by the share of technology-intensive products that make up imports and exports.

TABLE 1-2
COMPOSITION OF VALUE ADDED OF THE MANUFACTURING INDUSTRIES, 1986

Ranking	Industry	Share in Value Added of Manufacturing Industries (%)	Ranking	Industry	Share in Value Added of Manufacturing Industries (%)
1	Machinery	28.8	8	Paper & printing	3.2
2	Textile & clothing	14.3	9	Rubber products	2.0
3	Metal	12.9	10	Plastic products	1.7
4	Food, beverage & tobacco	11.5	11	Medical & pharmaceutical	1.6
5	Chemical	7.3	12	Wooden products	1.4
6	Building material	7.1	13	Leather products	0.9
7	Petroleum refining & processing	4.7	14	Other manufactured products	2.6

Source: Calculated by the author based on State Statistical Bureau, *Zhongguo tongji nianjian,* 1987 edition.

TABLE 1-3
INTERNATIONAL COMPARISON OF STRUCTURE OF MERCHANDISE EXPORTS, 1985 (%)

	Percentage Share of Merchandise Exports				
	Fuels, Minerals, and Metal[a]	Other Primary Commodities[b]	Machinery and Transport Equipment[c]	Other Manufactures[d]	Textiles and Clothing[e]
China	28.4	22.8	2.8	46.5	19.5
Lower-income economies	25	31	4	41	20
Lower middle-income economies	51	29	3	17	7
Upper middle-income economies	37	16	18	30	9
Industrial market economies	11	13	40	37	4
India	25	26	4	45	18
Republic of Korea	4	5	36	55	23
Indonesia	75	14	1	10	2
Thailand	5	60	7	28	13
Malaysia	34	39	19	8	3

Sources: The World Bank, *World Development Report, 1987* (New York: Oxford University Press, 1987). Figures for China are from *China's Customs Statistics* (Hong Kong), No. 1 (April 1986).

[a] Mineral raw materials and fuels in SITC (Standard International Trade Classification) Section 3, Divisions 27, 28, and 68.

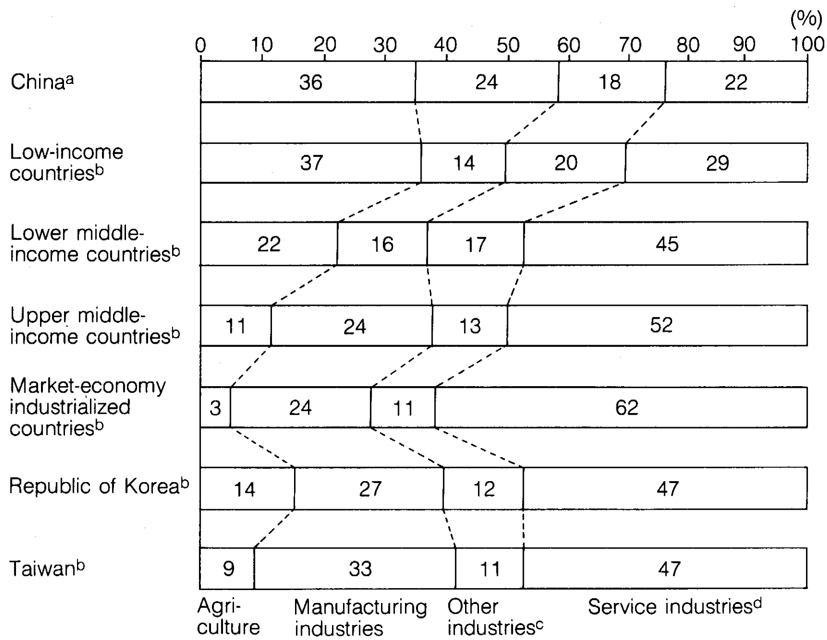
[b] Corresponding to commodities in SITC Sections 0, 1, 2, and 4 less Divisions 27 and 28; these consist mainly of animal and botanic raw materials.

[c] SITC Section 7.

[d] SITC Sections 5 through 9 less Section 7 and Division 68.

[e] SITC Divisions 65 and 84, which are included in "other manufactures."

Fig. 1-2. International Comparison of GDP by Industry



Sources: The data for China are from "China, Economic Structure in International Perspective" (Annex 5 to China, Long-term Development Issues and Options), A World Bank Country Study, mimeographed (Washington D.C.: The World Bank, 1985), p.22. The data for the other countries are from Koichi Ohno, "Chūshinkoku no kōgyoka to sangyō" [Industrialization and industrial policy in middle-income countries], *Ajiken nyūsu* (Tokyo), No.85 (November 1987).

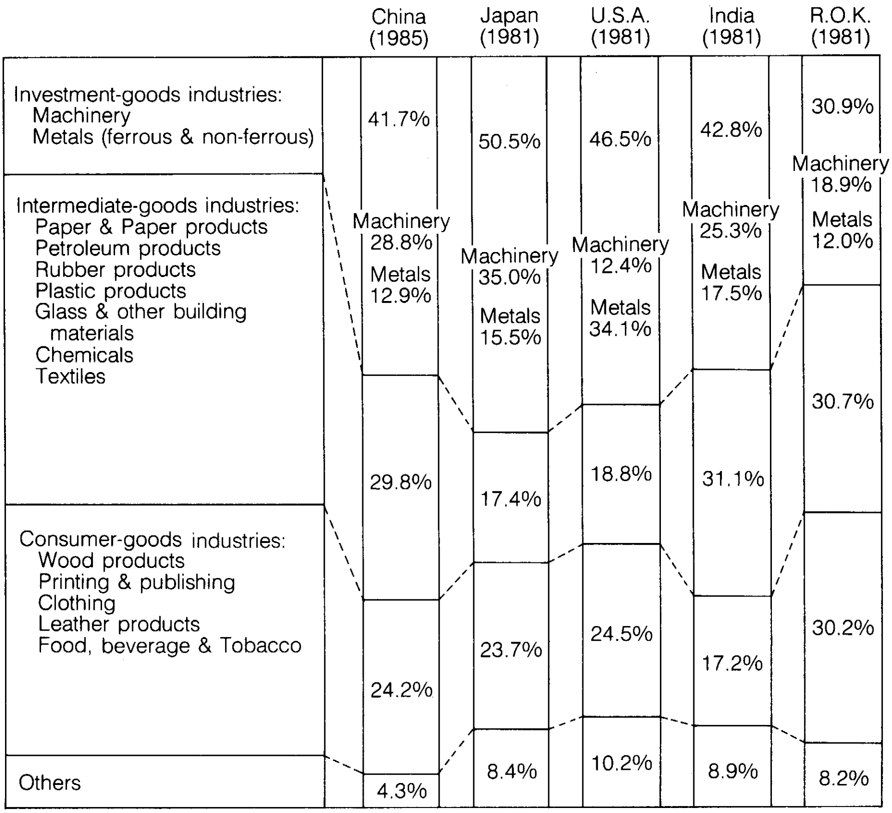
[a] 1981

[b] 1983

[c] "Other industries" consist of mining, construction, and utilities (electricity, gas, and water).

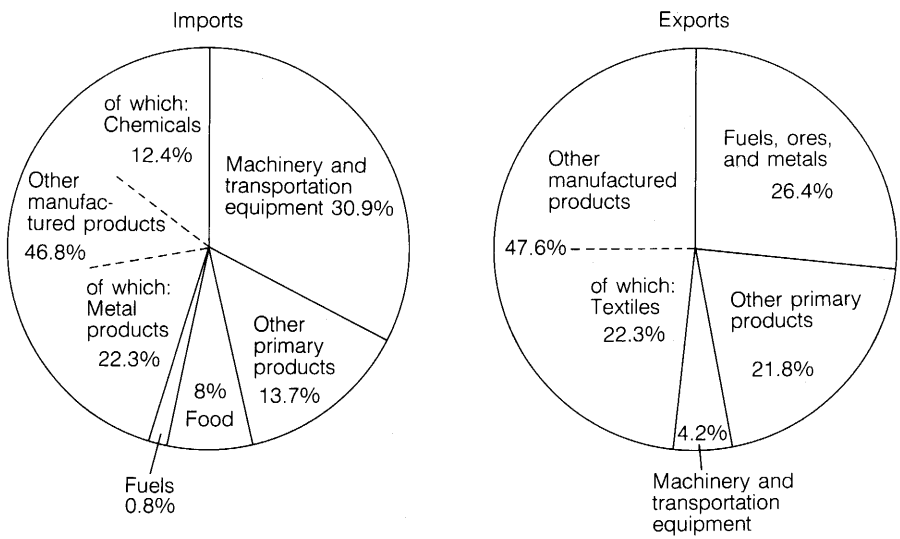
[d] All the sectors not classified under "agriculture," "manufacturing industries," or "other industries" are included in the "service industries."

Fig. 1-3. International Comparison of the Composition of Value Added of Manufacturing Industries



Sources: Figures for China are from Table 1-2, while those for the other countries are from State Statistical Bureau, *Zhongguo tongji nianjian*, 1987 edition.

Fig. 1-4 China's Imports and Exports by Product, Average for 1983–86



Source: State Statistical Bureau, *Zhongguo tongji nianjian*, 1984–87 editions.
Note: For the classification of products, see the notes to Table 1-3.

Figure 1-4 shows that "machinery and transportation equipment" (the section 7 of the SITC) make up only 4.2 per cent of China's total exports, but nearly 31 per cent of the country's total imports; and from Table 1-3 it can be seen that although a rather large percentage of China's exports are manufactured goods, reflecting a large part of the GNP produced by the manufacturing sector, these manufactured exports consist mainly of textiles and miscellaneous products. The share of machinery and transportation equipment in China's manufactured export is still no higher than the level common to low-income or lower middle-income countries. This tendency has remained unchanged since the 1950s. The experiences of the NIEs in Asia and Latin America have shown that a country pursuing an inward-looking type of development strategy usually falls behind countries adopting an export-oriented strategy when transforming the commodity composition of its exports from one centered on primary goods to one centered on manufactured goods, and then to one centering on technology-intensive goods.

The industrialization strategy that China adopted following liberation was one of "socialist industrialization," which gave the utmost priority to the development of the capital-goods sector. Ever since, the term "industrialization" in China has connoted the continuous raising of the share of the "gross value of industrial output" in the "gross value of industrial and agricultural output," with the target share usually understood to be 70 per cent. When measured by

TABLE 1-4
TECHNOLOGICAL GAP BETWEEN CHINA AND ADVANCED COUNTRIES

Program	Year					
	U.S.A.	USSR	Britain	France	Japan	China
Nuclear						
First reactor	1942	1946	1947	1948		1956
First A-bomb	1945	1949	1952	1960		1964
First H-bomb	1952	1953	1957	1968		1967
Space						
First satellite	1958	1957		1965	1970	1970
Aeronautics						
First jetplane	1942	1945	1941	1946		1958
First Mach 2 jet	1957	1957	1958	1959		1965
First 8,000 kg engine	1958	1957	1957	1966		1970
Computers						
First prototype computer	1946	1953	1949		1957	1958
First commercial use of computer	1951	1958	1952		1959	1966
First transistor	1952	1956	1953		1954	1960
First integrated circuits	1958	1968	1957		1960	1969

Source: M. Macioti, "Scientists go barefoot," *Successo,* January 1971, cited in Jon Sigurdson, *Technology and Science in the People's Republic of China* (Oxford: Pergamon Press, 1980).

this yardstick, China attained its "industrialization" target twice, going over the 70 per cent mark during the period of the Great Leap Forward (1958–60) and again during the period from 1977 to 1979. Likewise, the yardstick that has been used in China for measuring the quality of its industrialization is the share of the "gross value of output by heavy industries" in the "gross value of industrial output."

Socialist countries have traditionally emphasized heavy and chemical industrialization not simply because of their belief that this would be the fastest possible way to attain industrialization; this choice has also been necessitated by defense requirements. The volume of resources that China has allocated for defense build-up during the last forty years is highly significant in assessing the trajectory of Chinese industrialization efforts. The advanced weaponry in the country's armed forces, including nuclear bombs, ICBM (intercontinental ballistic missiles), satellites, jet fighters, and nuclear submarines, are all manufactured domestically, the only exceptions being long-range bombers and aircraft carriers. Table 1-4 reveals that China began developing advanced weapons rough fifteen years on average after the other military powers; nevertheless it succeeded in developing in a very short time such advanced weapons as nuclear warheads, jet planes mounting engine of 8,000 kg capacity, and super-computers for military use. Even if allowance is made for the benefits enjoyed by a late-comer, this superb performance would have been impossible had it not been for the China's competence in R&D.

TABLE 1-5
MILITARY INDUSTRY SHARE OF CHINA'S INDUSTRIAL SECTOR

Military Industry	Value (Billion Yuan)	Share in Machinery Industry (%)	Share in Total State-owed Mining and Manufacturing Sector (%)
Total production	14.057	8	2
Fixed assets (at book value)	28.86	25	6

Sources: *Zhongguo guofang jingjixue yanjiuhui choubeizu* [Preparatory research group on Chinese national defense economics], *Guofang jingjixue lunwenji* [Collected papers on national defense economics] (Beijing: Jiefangjin-chubanshe, 1986), p. 304.

Priority projects that constitute an important part of the science and technology development plans of the state of China are called *gongguan* ("tackling key problems"). Since the mid-1950s, projects for developing nuclear power, jet engines, and computers have continually been *gongguan* and given top priority. A number of the industrial ministries within the State Council—such as that for the nuclear power industry, the astronautics industry, the aviation industry, the ordnance industry,[4] and the electronics industry—are equipped with their own R&D facilities and plants and have played a leading role in military production. They have always received preferential treatment in the allocation of R&D budgets, human resources, and production facilities which have put these ministries at the forefront in developing the nation's industrial technology.

China has spent enormous sums on the development of advanced weaponry. After peaking at 22.4 per cent in 1970, the ratio of defense expenditures to total government expenditures gradually declined, decreasing to 16 per cent in 1980 (19.4 billion yuan) and 8.6 per cent in 1987 (21 billion yuan). As a portion of GNP, as calculated by the Chinese authorities, these expenditures stood at 4.6 per cent in 1980 and 1.9 per cent in 1987. But it should be kept in mind that the Chinese statistics on "defense expenditures," like those for the Soviet Union, cover only a portion of total defense-related expenditures, because a large amount of the expenses for military industries are included in the investment that goes into the industrial sector in general.

Table 1-5 provides some fragmentary information on the size of the military industry as a portion of the industrial sector as a whole. It is highly probable that the data in the table fail take into account the amount of military production undertaken by ordinary industry which is under a different jurisdiction from the military industry. Still more important is the fact that many of the Chinese arsenals are reported to be operating in the red because the government procurement prices are set artificially low. This makes for a substantial underestimation of their output.[5]

Since the early 1980s, the government, out of the necessity to spur production for civilian uses, has begun to cut back on defense expenditures. The ratio of military expenditures to the total government expenditures has declined to as low as 8.6 per cent, as mentioned above. With much of their idle capacities, the military industries have been forced to search for ways of survival. One of the ways has been to utilize their idle facilities for the production of civilian goods, and since 1980 these goods have made up an increasingly large share of the total output for military industries, reportedly increasing from 10 per cent in 1979 to some 49 per cent by 1987.[6]

The heavy concentration of resources into military industries is not necessarily a total waste, so long as these industries take the lead in developing technology for use in the civilian industrial sectors. The Chinese military industries, however, have built up ''forces of production'' confined to themselves, isolated from the civilian sectors, or in what the Chinese call a ''self-closing'' system, and have thus seldom transferred their technology to the civilian sectors. This has been partly because of the need to preserve military secrecy, but also, and more importantly, because of the vertically divided administrative system.

In an effort to maintain production in its military industries since the government began cutting back on military expenditures, China has started to promote exports of jet fighters and other advanced weapons. Weapons manufacturing is one of the few areas where China enjoys export competitiveness. As a result, its military industries are becoming the country's new export industries.

The Level of Industrial Technology Achieved

China's industrial policy has emphasized domestic production and import substitution of capital goods which has equipped the country, unlike most other developing countries, with a full spectrum of basic industries. This has allowed China to become considerably self-sufficient in its supply of capital goods; approximately 85 per cent of the machines and equipment needed by basic industries are manufactured domestically. The percentages of domestically manufactured capital goods used by various industries are as follows:[7]

(1) 80 per cent of the thermal electrical power generating equipment (China's total thermal electrical power capacity is 6.9 million kilowatts.);

(2) 95 per cent of the equipment used in the production of synthetic ammonia (China's total annual production of synthetic ammonia is 1.48 million tons.);

(3) 80 per cent of the transport vehicles used throughout the country; and

(4) 95 per cent of the three million machine tools used throughout the country.

In addition to these, China has two automobile plants (Hubei No.2 Automobile Plant and Changchun No.1 Automobile Plant) with annual production capacities of 100,000 vehicles each. The country has constructed on its own an integrated iron and steel mills (Panjihua Iron and Steel Mill) with a capacity to produce 1.5 million tons of crude steel annually.

China has actively upgraded its steel-producing facilities, building a 2,500 cubic meter blast furnace (at Anshan Iron and Steel Mill), a 1,700 millimeter hot-strip mill (at Benxi Iron and Steel Mill), and other facilities without external assistance. Even though much of the equipment in these advanced facilities has been constructed by way of reverse engineering or through adoption of foreign technology, these could not have been built had China not had a high level of competence in machine working.

All the accomplishments mentioned above are the outcome of various *gongguan* projects, implemented and given top priority by the state. Under the Seventh Five-Year Plan (1986–90), China is making further efforts toward domestic production of capital goods and trying to build a range of its own sophisticated production equipment and products requiring state-of-the-art technology. Included in these projects are nuclear power plants, passenger jet planes, a 300,000 ton-a-year ethylene plant, a high-energy accelerator, thermal power plants of 600,000 kw capacity, and super high-voltage transmission and transformer equipment, as well as the main facilities (coke ovens and a 4,063 cubic-meter-capacity blast furnace) to be built as the second phase of the project for the Shanghai Baogang Iron and Steel Complex.

The efforts to attain self-sufficiency in capital goods have naturally begun with the promotion of domestic production in the machine-tool industry, which supplies capital goods. Although this has enabled China's machinery industry to acquire a considerably high degree of technological competence, the industry still has to make far greater effort in the areas of product diversification, quality improvement, and mass production. To cite one instance, China ranks second in the world after the Soviet Union in the number of machine tools in use (more than three million), and is an exporter as well as importer of those tools. But as is evident from the export-import statistics of machine tools shown in Table 1-6, the country's imports in value terms have continually far exceeded its exports. This is because China's machine-tool exports consist primarily of conventional, inexpensive lathes, while its imports are mostly machines for high-precision metal working such as numerical control (NC) machines and machining centers.

An important prerequisite for a country trying to become self-sufficient in capital goods would be to secure supplies of metal products. To meet this prerequisite, China has continually given high priority to its iron and steel industry as a leading sector, but the industry has not yet acquired the capability to ensure stable supplies of iron and steel products. As is shown in Table 1-7, more than 20 per cent of apparent steel consumption in China is supplied by imported steel.

Steel is not the only product that is in short supply. Import-dependency ratio still range between 20 per cent and 50 per cent for approximately twenty other major industrial products such as ethylene, chemical fertilizer, raw materials for synthetic fiber, and construction materials. The products with high import-dependency ratios are concentrated in those sectors supplying intermediate goods. This means that as China tries harder to strengthen its processing industry as a means of becoming more self-sufficient in capital goods, the more

TABLE 1-6
IMPORT AND EXPORT OF MACHINE TOOLS, 1983–87

	Imports		Exports	
	No. of Units	Value (Million Yuan)	No. of Units	Value (Million Yuan)
1983	3,762	102.48	26,309	37.63
1984	9,423	124.75	16,635	39.73
1985	13,005	425.43	17,268	50.00
1986	10,079	1,282.54	48,935	124.00
1987	25,817	1,709.00	183,866	294.85

Source: *China's Customs Statistics,* various issues.

TABLE 1-7
CHINA'S STEEL TRADE AND IMPORT-DEPENDENCY RATIO

	Output (1,000 tons) (a)	Imports (1,000 tons) (b)	Exports (1,000 tons) (c)	Import-dependency Ratio (%) (d)[a]
1980	27,160	5,006.4	397.7	15.8
1982	29,020	3,937.8	1,101.1	12.4
1984	33,720	13,314.5	203.3	28.4
1985	36,930	19,634.9	181.2	34.8
1987	43,860	11,749.4	277.3	21.2
1949–87	540,830	148,645.1	11,039.3	21.9

Source: Ministry of Metallurgy, *Zhongguo gangtie gongye nienjian* [Almanac of the Chinese iron and steel industry] (Beijing: Yejingongye-chubanshe), 1986 and 1987 editions.
[a] (d) = (b) / [(a) + (b) − (c)] × 100.

serious grows the bottleneck posed by shortages of intermediate goods. This causal relationship has been a perpetual annoyance to China's industrial strategy.

In order to accomplish industrialization across all the sectors (or to establish what Chinese call a self-contained industrial system), it was imperative for China to first try to become self-sufficient in capital goods. It was believed that an efficient way of attaining this would be to separate the capital- goods sectors from the consumer-goods sectors, and to make the reproduction processes in the former complete within themselves. The underdevelopment of the consumer-goods sector, a direct result of the industrialization strategy based on this line of reasoning, has made China's export structure highly dependent upon primary commodities and low value-added labor-intensive products, and has made the country's balance-of-payments structure extremely unstable. At the same time, the shortages of intermediate goods needed by the capital-goods producing sectors have had to be made up for by imports, adding a further strain on the country's balance of payments position. The outcome has been that China's development strategy based on capital goods has been seriously restrained by its unstable balance-of-payments position.

The Condition of Industrial Equipment

The experience of industrialization in developing countries suggests that an import-substitution strategy entails the misallocation of resources in the long run, and delays the transformation of a country's industrial structure. When the strategy has been implemented under a centralized economic system where the market mechanism is excluded, it has caused serious difficulties and the deterioration of equipment at industrial facilities.

It was not until the early 1980s that the Chinese leaders began to pay attention to the replacement of the wornout industrial equipment which had been seriously delayed. Table 1-8 summarizes the findings of a survey showing vintage composition of industrial equipment being used in a total of 8,285 to large and medium-size enterprises. In interpreting this table, one point should be borne in mind. It has been pointed out that the fixed assets built during the inflationary years of 1970–85 are overestimated, and that equipment of pre-1970 vintage in actual service is far more than the table suggests.[8]

As of 1986 the legal rate of depreciation for all industries was set at 4.9 per cent, while it was 5.1 per cent for the mining and manufacturing industries. Table 1-8 shows, therefore, that production equipment of which the cost is totally paid off after twenty years of service constitute more than 20 per cent of the total fixed assets belonging to the 8,285 enterprises. A considerable number of machines and equipment which no longer carry any book value are still in use. There has been a rapid introduction of foreign technology-based equipment since the beginning of the 1980s, but leaving these aside the state of old machines and equipment still in use can be summed up as follows:

(1) Of the 2.8 million machine tools that were in existence in China as of 1980, approximately 900,000 are being put to largely normal use, and as many as 100,000 machine tools of pre-revolution vintage are still in use. A serious problem exists with the approximately 1.3 million machine tools built during the periods of the Great Leap Forward and the Cultural Revolution. Either of defective quality due to careless manufacturing, or built to varied and confused standards, these machine tools often cause problems while in use.

(2) In the iron and steel industry, including small iron mills, old equipment dating back to the 1950s and 1940s, and even to the 1930s, account for two-thirds of all equipment in use, a surprisingly high average. Even at the Anshan Iron and Steel Mill, the largest of its kind and a main pillar in China's modernized sector, as much as 67 per cent of its major equipment date back to these decades. Eight of its twenty-four open-hearth furnaces, and eight of its seventeen coke ovens have become so seriously deteriorated as to render their maintenance extremely difficult.

(3) The situation in the light-industry sectors, which have not enjoyed heavy government patronage, is much worse. In the cotton spinning and weaving industry, for instance, it is reported that as much as 20.4 per cent of the 17.8

TABLE 1-8
VINTAGES OF INDUSTRIAL EQUIPMENT (%)

	Vintage				
	1980s	1970s	1960s	1950s	Pre-revolution
Total for the 8,285 enterprises surveyed	33	44	13.4	8.6	1.0
Large enterprises	32	45	12.5	9.6	0.9
Medium-size enterprises	35	42.2	15.2	6.7	0.9
State-owned enterprises	33	44.2	13.5	8.7	0.6
Collective enterprises	70[a]	26	3.5	0.2	0.3
Light industrial enterprises	50[b]	36	7.8	5.0	1.2
Heavy industrial enterprises	30	45.6	14.5	9.3	0.6
Mining and extraction	43.5	43.6	7.8	4.3	0.8
Raw-materials industries	28	45.5	15	10.6	0.9
Processing industries	26	47	17.3	9.5	0.2

Source: Leading Group of National Industrial Census under the State Council, *Zhonghuarenminggongheguo 1985 nian gongye pucha zuliao* [Industrial census of the People's Republic of China, 1985], Vol. 1 (Beijing: Zhongguo-tongji-chubanshe, 1987).
Notes: The dates are based on the government's 1983 census of industries which surveyed the age of production equipment in actual use at a total of 8,285 large and medium-size enterprises out of the national total of 360,000 industrial enterprises. The percentages given are in terms of the original installation costs (at book value) for the equipment.
[a] That equipment of 1980s vintage should account for as much as 70 per cent of all equipment at collective enterprises directly contradicts all that we know about China's technology. Therefore there must be some flaws in the statistics.
[b] This percentage seems to be too high and perhaps reflects the significant increase in imported production lines for manufacturing household electric appliances that took place in the 1980s.

million spindles in use are of pre-revolution vintage, and that weaving machines of the Toyoda model, manufactured in Japan during the Meiji era, are still in use.

(4) In the paper and pulp industry, an astonishingly high 85 per cent of the major equipment dates back to the 1930s–1950s period. If we look at the production facilities under the Ministry of Light Industry as a whole, over half of the equipment in use is of 1940s–1950s vintage.[9]

The deterioration of industrial equipment gives rise to a variety of problems, including those that need to be rectified urgently, such as environmental pollution, the poorly inefficient use of raw materials and energy, low product quality, and the antiquation of product designs due to a common Chinese practice of continuing to manufacture a product of a particular design for at least ten years.

One important root cause for the deterioration of production equipment is the system of depreciation practiced in China. It is a common practice in socialist countries to set the rate of depreciation at low levels in line with Marx's assertion that machines and equipment are free from "non-physical abrasion." In China, the composite depreciation rate for machines and equipment in the mining and manufacturing industries is still set at a very low level, even though it was gradually raised from 3.7 per cent during the 1950s to 5.1 per cent in 1986.[10] Since 1985, China has begun to take the "non-physical abrasion" factor into account in setting the depreciation rate for machines and equipment which undergo rapid technological innovation,[11] even though the country has not yet gone to the extent of adopting a measure similar to the accelerated depreciation procedure which Japan adopted in the early post–World War II era.

Table 1-9 partially reproduces the table of durable years for fixed assets in various industries which came into use in China in April 1985 replacing the old table; the comparable schedules used in Japan and the Republic of Korea are also shown. The rate of depreciation for each machine or item of equipment seems to be calculated based on the durable years specified for it in the table, and by taking into account the amount of time it has actually been put to use; but there is no explicit provision as to exactly what rate is applied to each type of machine. The government has set out guidelines defining the depreciation rates on a sector-by-sector basis, e.g., 5.1 per cent for industry, 3.6 per cent for railways, 4.4 per cent for transportation, and 4.9 per cent for commerce. In practice, however, there is good reason to suppose that a decision as to what rate should be actually applied to a particular machine or facility in a particular industry in a particular province is arbitrarily made by the organizations supervising the enterprise concerned. This practice is making the system of depreciation very complex.

It would be worthwhile at this point to look briefly at the depreciation system in China. The system has changed with each major change in economic policy. During the First Five-Year Plan (1953–57) and during the period of economic adjustment (1962–65) a system was followed whereby all the sums of money officially recognized to constitute depreciation funds were paid to the national treasury, and were then reallocated by the government as *sixiang feiyong* ("expenditures on four items"),[12] which included funding for technological innovation. During the period of the Great Leap Forward (1958–60) the system required that the basic depreciation funds be submitted in their entirety to the government treasury, and the expenditures on four items were paid not out of the government budget but were financed from retained profit of the individual enterprises. Under yet another system that was enforced during the Cultural Revolution (1966–76), enterprises and their supervising organizations were allowed to retain the basic depreciation funds without submitting these to the national treasury, while the government subsidies for the expenditures on four items were abolished. Under the current system, the basic depreciation fund of an enterprise is divided into three portions: 50 per cent of the

TABLE 1-9
DURABLE YEARS OF FIXED ASSETS

Fixed Assets	China (Years)	Japan (Years)	Republic of Korea	
			Years	%
Average for machines and equipment[a]	19	11	10	20.6
Trucks	12	4	4	43.8
Large airplanes	15	10	6	31.9
Steel ships (2,000 DWT or more)	24	15	12	17.5
Computers	8	6	6	31.9
Iron- and steel-making plants	17	14	14	15.2
Hydroelectric power stations	32	22	20	10.9
Plants manufacturing metal-working machine tools	12	10	10	20.6
Automobile plants	15	10	9	22.6
Polyethylene plants	13	8	9	22.6
Chemical fertilizer plants	18	10	9	22.6
Cement plants	15	13	12	17.5
Synthetic textile plants	14	7	8	25.0
Concrete buildings for office use	55	65	60	3.8
Wooden buildings for office use	40	26	25	8.8

Sources: The legally specified durable years of machines and equipment in China are from *Guowuyuan gongbao* [State Council bulletin], May 30, 1985. Those in Japan are the years officially specified by the Ministry of Finance as of 1986. The durable years in the Republic of Korea are as specified by the corporate law promulgated in December 1982 (Kankoku-sangyō-keizai-kenkyūjo, *Kankoku kin'yū keizai kankei hōreishū* [A collection of Korean banking and economic laws and regulations]).
[a] An unweighted average for major items.

fund is paid to the national treasury, 20 per cent to the supervising organizations, and the balance is retained by the enterprise; along with the above change, that portion of the expenditures on four items which is related to technological innovation is no longer paid out of the national treasury, but instead is financed by that portion of the basic depreciation fund which is retained by the individual enterprise.

For a country upholding socialist principles and valuing planned allocation of resources rather than allocation through the market mechanism, it is not at all erroneous to try to use the depreciation funds of individual enterprises effectively by placing these under direct control of the state instead of allowing the enterprises to retain them. What is problematic about the Chinese practice is the way in which these funds have been used. The five-year plans and the annual plans in the past contained no provisions for replacement of obsolete equipment even when they contained programs for basic capital construction investment. It was not until 1981 that programs for *genxin gaizao touzi* ("investment for renovation and reconstruction") began to be incorporated into state planning. Of the cumulative investment in fixed assets made by the state for the twenty-seven years from 1953 to 1979, only approximately 19 per cent was used for renovating equipment used by the state-owned enterprises.[13] After 1981 investment for renovation and reconstruction began to increase rapidly, from 19.5 billion yuan in 1981 to 76 billion yuan in 1987, or more than 30 per cent of total investment in fixed assets. Nevertheless, a problem still persisting is the considerably large portion of depreciation funds used for financing the new expansion of fixed assets (such as basic capital construction) instead of being used for the renovation of facilities and the replacement of obsolete equipment.

However, to simply emphasize that the rate of depreciation for industrial equipment in China is lower than that in Japan or Korea is to neglect the fact that the three countries are at different stages of development. For a country like China at a low stage of development and without much capital accumulation, a high rate of depreciation would mean excessive financial burden on enterprises and the national treasury. But added to this has been China's economic policy pursued for more than thirty years. This has consistently emphasized the quantitative expansion of capital stock rather than maintaining the value of the existing capital stock. This in turn has contributed to the prevailing uncritical attitude toward the existing low rates of depreciation and induced a lack of enthusiasm among individual enterprises for renovating their facilities. The end result is that China's industrial technology has been seriously inhibited.

A Tiered Pattern of Technology

One important reason why machines and equipment in China often continue to be used even after they have been totally depreciated is that the country has a variety of technological systems existing side by side. For instance, machine tools are seldom, if ever, scrapped when they are written off. There is a built-in mechanism at work whereby machines which have been totally depreciated and retaining only their use-value are transferred from large enterprises to small enterprises, from state-owned enterprises to collective enterprises, and from enterprises in cities to those in rural districts.

This situation can be better seen from a brief overview how enterprises are classified in China. Enterprises are classified by size, and the principle used is fairly complicated. They are classified as large, medium, and small, and the benchmark used to determine which category is an enterprise's productive capacity. When classifying enterprises belonging to a sector whose products are considerably uniform (such as the energy, iron and steel, automobile, glass, and paper and pulp industries), this benchmark can be applied straightforwardly; enterprises in a certain sector of this kind are classified into large, medium, and small categories in accordance with productive capacity. When dealing with sectors whose products are diversified, and therefore whose constituent enterprises cannot be readily classified in terms of productive capacity, the classification is in terms of the book value of an enterprise's fixed assets.

TABLE 1-10

Classification of Enterprises by Size, 1985

	No. of Enterprises		Value of Output		No. of Workers		Fixed Assets (Book Value)	
	No.	%	Billion Yuan	%	No. in Thousand	%	Billion Yuan	%
Total	463,210	100	829.5	100	57,810	100	530.7	100
Large enterprises	2,494	0.55	232.7	28.1	11,960	20.7	308.2	58.1
Medium-size enterprises	5,791	1.25	153.6	18.5	9,470	16.4	146.3	27.6
Small enterprises	454,925	98.2	443.2	53.4	36,380	62.9	76.1	14.3

Source: State Statistical Bureau, *Zhongguo tongji nianjian,* 1987 edition.

TABLE 1-11

Classification of Enterprizes by Number of Workers, 1984

No. of Workers	No. of Enterprises		Heavy Industry		Light Industry	
	No.	%	No.	%	No.	%
Large and medium-size enterprises						
Over 100,000	6	—	6	—	0	0
50,000 – 100,000	27	—	27	—	0	0
30,000 – 50,000	36	—	35	—	1	—
10,000 – 30,000	207	0.05	195	0.01	12	—
10,000 or less	5,731	1.3	3,978	2.3	1,753	0.07
Small enterprises	431,193	98.6	165,559	97.5	265,634	99.92
Total	437,200	100	169,800	100	267,400	100

Source: State Statistical Bureau, *Zhongguo tongji nianjian,* 1986 edition.

Note: 1. The distribution of workers between large and medium-size enterprises and small enterprises is not specified. The numbers of enterprises in the heavy and the light industries have been calculated by the author.

2. "—": negligible.

The classification of enterprises in China in 1985 based on the foregoing method, which is considerably different from that used in the West, is as shown in Table 1-10.

Table 1-11 shows the classification of enterprises by number of workers as of 1984, calculated on the basis of the statistics presented in the 1986 issue of *Zhongguo tongji nianjian* [Statistical yearbook of China]. Since the yearbook presents statistics only for large and medium-size enterprises, those for small enterprises are calculated by subtracting the numbers of large and medium-size enterprises from the total figures.

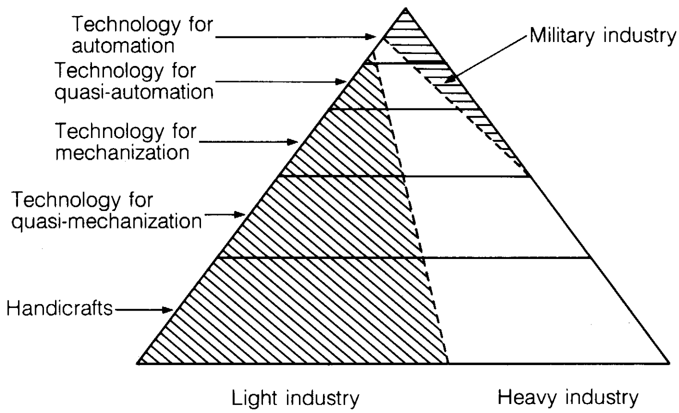
According to Tables 1-10 and 1-11, more than half of China's industrial production in terms of value is undertaken by small enterprises, which account for more than 98 per cent of the country's industrial enterprises. These small enterprises are poorly equipped; their combined share of fixed assets total a small 14.3 per cent, or 167,500 yuan per enterprise.

The structure of the Chinese industrial enterprises described above is schematically illustrated in Figure 1-5. Sun Shanqing points out in his study[14] that the structure of Chinese industrial technology is characterized by its pyramidal hierarchy. Technologies at different stages of development, such as those for automation, quasi-automation, mechanization, quasi-mechanization, and handicrafts coexist side by side and form each layer of the pyramid, with technology for mechanization (a medium-level technology) being the most prevalent. At the top of the pyramid and always enjoying preferential allocation of the best resources available are the military industries and some segments of the heavy machinery and the materials industries. Forming the vast bottom layer are the collective industrial enterprise which made up a dominant percentage of the total number of enterprises. More than half of the collective enterprises are village and town enterprises which have been increasing rapidly recently, numbering as many as 217,200 in 1984, 217,100 in 1985, and 237,000 in 1987. If we take into account smaller enterprises at the hamlet level, which are collectively or privately owned, the number of enterprises in the countryside is enormously larger. These enterprises in the countryside are where machines and equipment written off and transferred down along the pyramidal hierarchy finally end up. But only a small percentage of these enterprises are fortunate enough to get hold of the obsolete machines, and a majority of enterprises in the countryside seem to be still at the handicraft stage.

There seem to be four reasons why these multifarious systems of technology continue to exist side by side in China today and keep old, even pre-modern, technology from being weeded out in the process of rapid industrialization. First, the extensive growth strategy of economic development that China has been pursuing, particularly its strategy of ''walking-on-two-legs'' industrialization (which emphasizes the coexistence of large industries with small and medium-size enterprises, as well as advanced technology with indigenous techniques) has allowed the number of industrial enterprises to grow virtually uninhibited. Second, the limited amount of resources at the disposal of the state has been allocated preferentially to state-owned large enterprises in urban sectors, leaving the enormous number of enterprises in the rural areas with no choice but to rely on their own efforts at accumulation. Third, the absence of a competitive market mechanism along with bureaucratic sectionalism that separates industrial sectors from one another and each district from the other have prevented the smooth diffusion of information and technology. And fourth, Chinese society, with its poorly developed systems of transportation and communication, is characterized by a high degree of self-sufficiency at the community level.

Given the underdevelopment of the social division of labor, each of the technological systems sustaining China's industrial production tends to pursue local self-sufficiency. This is expressed in the organizational makeup of Chinese

Fig. 1-5. The Pyramidal Structure of Technologies in China



Source: Based on Sun Shanqing et al., eds., *Lun jingji jiegou duice* [On the policy of economic structure] (Beijing: Zhongguo-shehui-kexue-chubanshe, 1984).
Note: The above figure is a schematical illustration of the technological structure as looked at in terms of the numbers of staff and workers.

enterprises which emphasize being equipped fully and comprehensively. Large enterprises try to be *daerquan* ("big and having everything necessary") and small ones try to be *xiaoerquan* ("small but having everything necessary"). Even the military industrial enterprises at the top of the pyramid are no exception. They have attained a considerably high degree of self-sufficiency, undertaking casting and forging operations, and manufacturing machine tools for themselves.

The fact that the forces of industrial production have been divided up not simply along regional and sectoral lines, but even along corporate lines, has presented a serious obstacle to the diffusion of technology. It has also made the standardization of industrial products extremely difficult. Rectifying this confused state of industrial standards, and making products better patterned and adapted to multiple uses have been important tasks that China has been trying to deal with since the early 1980s.

There are three different types of industrial standards now in use in China: state standards, ministerial standards (applied to industries on a sector-by-sector basis), and enterprise standards (set by each first-level regional administrative district[15] and applicable to enterprises under their individual jurisdiction). According to the 1983 statistics, there were 5,496 state standards, some 13,000

TABLE 1-12
NATIONAL INDUSTRIAL STANDARDS OF VARIOUS COUNTRIES

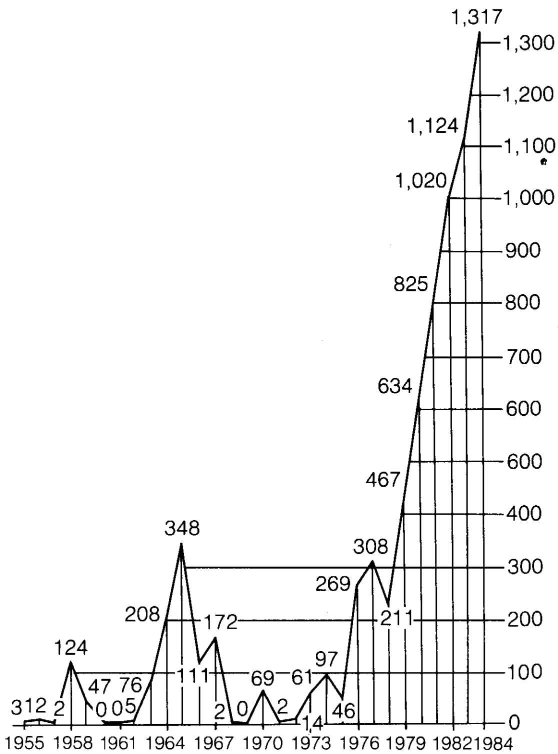
Country	Year When the Law Concerning National Standards Was Fisrt Enacted	No. of National Standards and the Year of Survey
China	1958	5,324 (1978)
		18,763 (1984)
Japan	1921	7,220 (1978)
U.S.A.	1918	9,092 (1978)
U.K.	1901	7,800 (1978)
West Germany	1917	18,000 (1978)
France	1918	10,465 (1978)
USSR	1923	22,120 (1978)
India	1952	11,202 (1982)
Philippines	1964	485 (1984)
Republic of Korea	1961	7,413 (1984)
Taiwan	1946	11,132 (1985)
Singapore	1973	307 (1982)
Thailand	1968	654 (1984)
Indonesia	1964	1,376 (1984)
Malaysia	1975	734 (1981)

Sources: For the advanced countries, Yukihiko Kiyokawa and Shigeru Ishikawa, *The Significance of Standardization in the Development of Machine-tool Industry: The Case of Japan and China,* Hitotsubashi University Economic Institute Discussion Paper Series, No. 123 (Tokyo: Hitotsubashi University, 1985), p. 27. For the Asian countries, Reeitsu Kojima and Futaba Ōiwakawa, *Hakari to kurashi: Dai-san sekai no doryōkō* [Scales and livelihood: The weights and measures of the Third World], Ajia-o-miru-me, No. 70 (Tokyo: Institute of Developing Economies, 1986), pp. 222–23.

sectorally applied ministerial standards, and as many as 89,000 regionally specified enterprise standards.[16]

The state system of standards came into effect in 1958, but was suspended until 1979 when it was reintroduced. According to Table 1-12, which compares the number of national industrial standards in various countries as of 1984, China has a larger number of standards than do most other countries in Asia, although it is far smaller than those in advanced countries. But of greater importance than the mere number is the quality of these standards. As of the end of the 1970s, approximately 20 per cent of all the industrial products produced in the country were being manufactured with no regard at all to industrial standards. Many of the national standards used today were copied directly from the Soviet industrial standards that were established during the 1950s and 1960s, and as such are not well suited for the current state of technology. More specifically, approximately 20 per cent of the national standards still in use are totally obsolete from a technological standpoint, and the percentage of the industrial products to which the existing standards cannot be applied is approximately another 20 per cent. Of the 18,763 state standards in existence as of 1984, only 28 per cent conformed to international standards.[17]

Fig. 1-6. Number of New National Industrial Standards Set in Each Year, 1955–84



Source: *Dangdai Zhongguo de biaojunhua* [Contemporary standardization in China] (Beijing: Zhongguo-shehuikexue-chubanshe, 1986), p.638.

The number of officially set standards is one important measure for assessing how well developed the industrial standards of a country are. But as Yukihiko Kiyokawa has pointed out, an even more important measure is whether or not the country has a system and attitude supportive of these standards.[18] Quite revealing in this regard is Figure 1-6, which shows the year-to-year change in China for the number of newly established state standards. These dropped sharply during the periods of the Great Leap Forward (1958–60) and the Cultural Revolution (1966–76), when industrial standards were denounced as a means for suppressing the productive incentive of the masses. At such times the authorities in charge of setting standards were dismantled, and state standards were replaced by *tu biaojun* ("indigenous standards") established autonomously by various ministries and localities.

The confused state in the standards of industrial products has inhibited the development of industries to produce standardized parts. This in turn has retarded the development of mass production system in China. What has developed instead is a large number of localized enterprises which manufacture a wide variety of similar products in small quantities. The mechanization of agriculture is a case in point. China has poured much effort into this area. Unfortunately agricultural machines have been developed in so many localities and with such ill-coordination that there are 53 different types of small and medium-size diesel engines being manufactured in a total of 250 different models; tractors are manufactured in 34 different models. There is virtually no interchangeability of parts among machines of different models, and once a machine breaks down, it cannot be repaired quickly. The automobile industry is another example. Domestic production of motor vehicles begun with the Jiefan ("liberation")-model four-ton truck launched in 1957, less than ten years after the liberation. By 1987 the industry had grown to nearly 100 factories throughout the country, but in that year these produced a combined total of only 471,800 vehicles of all types. Having always suffered from a shortage of practically every kind of manufactured product, China's industrial policy planners failed seriously in allowing such a state of affairs to develop. Instead the country should have concentrated its efforts first on mass producing a limited variety of standardized goods.

The Mechanism of Introduction and Absorption of Technologies

The ability to acquire foreign technology and the willingness of other countries to provide technology have greatly affected the progress of technological development in China's industries. There have been two significant external restraints that have obstructed China's efforts at introducing technology from abroad, and these have to be taken into consideration in any discussion that intends to be fair in its evaluation of China's technological development. One obstruction came from the Soviet Union when it suspended its aid to China in 1960. The other was the long-term embargo on the exportation of advanced technology that the West carried out against China and the other socialist countries. Had it not run into these two obstacles, China might have avoided some of the difficulties that befell it and which will be described below.

Assessing the introduction of technology on a quantitative basis poses considerable difficulty because China has not compiled statistics on what are usually considered important components of technological imports, such as royalties for patents and designs and payments for technological know-how. This is partly due to the fact that, for a country at an early stage of industrialization, importing technology almost always means purchasing hardware such as production equipment and machinery, but is seldom perceived as including purchases of software as well.

This used to be the same with Chinese importation of industrial plants. In the past concluding contracts for imports frequently did not go smoothly because the Chinese insisted that the software necessary for operating the plants should come with the hardware, something not acceptable to Western suppliers who were accustomed to concluding contracts for the provision of software separately from those for the supply of hardware. It was not until the mid-1970s that China began to accept the Western practice of differentiating between contracts for software and hardware, and it was only in the early 1980s that China clearly shifted its policy on technological imports from a hardware-oriented to a software-oriented one.

A lack of statistics on imports of software is only a part of the problem. In fact little is known about China's entire past performance at introducing foreign technology, almost all of which has been hardware. A rough estimate puts the share of plants imported in the past at 80 per cent of total technological imports, that of machinery at 17 per cent, and that paid for fees at imported software at 3 per cent.[19] In other words, plants and machines accounted for a large 97 per cent of China's technological imports. The problem however, was that the importation of all this technology was handled by so many different authorities in so uncoordinated a manner that it was virtually impossible to compile statistics on these imports in any consistent way.

In principle, the China National Machinery Import and Export Corporation, a subsidiary organization of the Ministry of Foreign Trade (now the Ministry of Foreign Economic Relations and Trade) was supposed to be primarily responsible for handling the importation of machines, and the China National Technical Import Corporation, another subsidiary organization of the same ministry, was to handle the importation of technology. However, the demarcation of jobs between the two organizations was not clearly drawn. Moreover, other corporations and ministries also took it upon themselves to conclude contracts for importation of machinery and plants. And now with the recent decentralization of foreign trade, the importation of technology and technological knowhow is becoming ever more diversified.

With this brief look at the general situation, let us look at some data on China's introduction of foreign technology. Table 1-13 shows the changes in the amount of technological imports handled by the China National Technical Import Corporation, broken down into several periods when these imports surged. Figure 1-7 shows the changes in the percentage of machinery and plants in China's total imports. Table 1-14 shows changes over the years in the value of imported machinery and plants as a percentage of basic capital construction investment into domestic industries.

The percentage of imported machinery and plants in total investment varied widely at different periods. At the inception of China's industrialization during the First Five-Year Plan, many new industrial facilities were built, and a large amount of machinery and plants were imported from the Soviet Union.

TABLE 1-13
TECHNOLOGY IMPORTED BY CHINA

	Period 1 1950–59	Period 2 1963–66	Period 3 1973–77	Period 4 1978–79	Total for Periods 1–4	Period 5 1980–85
Total amount of technology imported (U.S.$100 million)	27	3.02	35	79.9	144.9	69.2
Of which: turn-key plants imported (U.S.$100 million)	24	2.8	31.5	76.1	134.4	
	(89%)	(91%)	(90%)	(95%)	(93%)	(65.6%)[a]
Number of projects	233	over 80	over 220	145		
Percentage for each industry						
Energy	36.8	10.8	18.8	24.7	25.2	29.2
Petroleum	2.9	5.8	2.0	1.7	2.1	4.9
Coal	4.5	—	3.0	11.5	8.0	4.7
Electricity	29.4	5.0	13.8	11.5	15.1	19.6
Iron and steel (inclusive of nonferrous)	22.9	31.7	20.1	26.1	24.1	25.5
Chemicals	5.6	28.1	26.2	29.1	24.0	2.5
Light industry	4.3	16.7	24.5	9.2	12.1	9.3
Textiles	1.6	11.7	23.4	7.5	10.3	4.8
Machinery industry	11.3	10.9	3.1	1.1	3.7	21.4
Military industry	11.8	—	5.6	6.3	7.0	n.a.
Construction-materials industry	2.6	—	0.9	0.5	0.6	n.a.
Transportation	0.5	—	0.9	0.5	0.6	n.a.
Agriculture, forestry, and irrigation	0.7	—	—	0.1	0.2	n.a.
Others	3.5	1.8	0.6	1.3	1.6	9.9
Total	100	100	100	100	100	100

Sources: (1) Data for periods 1–4 is from Chinese sources taken from Chen Huiqin, "Woguo sansi nianlai jishu yinjin gonzuo jingji xiaoguo chubu fenxi" [Preliminary analysis of economic results after thirty years of Chinese technological importation, Part 2], *Gongye jingji* (Zhongguo renmin daxue, fuyin baokan zuliao [People's University of China, materials copied from newspapers and magazines]), Nos. 16–31 (1981). (2) Data for period 5 is estimated on the basis of information about plant exportation to China. These are not consistent with the Chinese data for periods 1–4, primarily because of the difference in the coverage of the two sets of data. The data for period 5 are from "Nitchū keizai kyōryoku, 1985" [Economic cooperation between Japan and China, 1985], in Japan-China Association on Economy and Trade, *Chūgoku keizai kankei chōsa hōkokusho* [Research report on the Chinese economic affairs], 1986, p. 215. The "percentage for each industry" has been derived by breaking down the grand totals for 1980–85 in accordance with the industrial classification adopted for periods 1–4. (3) The figure for the "total amount of technology imported" of period 5 is the one announced by the Chinese Ministry of Foreign Economic Relations and Trade [*Beijing Review* (Japanese edition), March 11, 1986].

Note: Technological imports in the table are in terms of the amounts of contracts concluded by the China National Technology Import and Export Corporation of the Ministry of Foreign Economic Relations and Trade for the imports of plants and machines, and for the use of patents and know-how.

[a] The *Beijing Review* (Japanese edition), March 11, 1986, put the ratio of imports of "software technology" to the total technological imports at 34.4 per cent, which means that the balance of 65.6 per cent should be the share of plants and machines imported. It must be noted, however, that this figure is wider than that for the data of periods 1–4.

TABLE 1-14
THE PERCENTAGE OF IMPORTED PLANTS AND MACHINERY IN BASIC CAPITAL CONSTRUCTION INVESTMENT

Period	Value of Plants and Machinery Imports/ Value of Investment in Basic Capital Construction × 100 (%)	Average Import Exchange Rate with the U.S. Dollar
First Five-Year Plan period (1953–57)	57.1	3.42
Second Five-Year Plan period (1958–65)	15.5	3.18
Economic readjustment period (1963–65)	8.6	2.73
Third Five-Year Plan period (1966–70)	8.6	2.58
Fourth Five-Year Plan period (1971–75)	12.2	2.12
Fifth Five-Year Plan period (1976–80)	19.5	1.72
Sixth Five-Year Plan period (1981–84)	30.5	1.97 (2.26: year 1984)

Note: Using the average import exchange rate, the value of imported plants and machinery in dollar terms was converted to yuan, from which was derived the percentage of imported plants and machinery in the total investments for basic capital construction.
Sources: State Statistical Bureau, *Zhongguo tongji nianjian,* 1987 edition; and the Editorial Board of the Almanac of China's Foreign Economic Relations and Trade. *1985 Almanac of China's Foreign Economic Relations and Trade* (Beijing: Water Resources and Electric Power Press, 1985).

The percentage plummeted during the 1960s, but picked up again during the 1970s. In the early 1980s China began to encourage manufactured exports for the sake of earning foreign exchange. This caused the government to readjust its exchange rate, which by 1986 declined to an average of 3.5 yuan to the dollar. Until that time China had for over thirty years maintained the exchange rate between its currency (the renminbi) and the U.S. dollar at a level higher than its actual purchasing power would justify. The government had done this as part of its effort to procure capital goods.

The share of imported machinery and plants in total basic capital construction investment dropped during the 1960s primarily because China was suffering from a serious shortage of industrial raw materials and intermediate goods for industrial production and had to allocate much of its foreign exchange to the importation of steel, nonferrous metals, and raw materials for its chemical industry. This shift is evident in Figure 1-7 which shows the changes in commodity imports. The reason for the shortages was because machinery industries, which were given priority during the 1950s, grew significantly during the boom in local industrialization that took place from the mid-1960s onward, while the industrial sectors producing industrial materials and intermediate goods, which required large amounts of investment and long gestation periods, not only failed to grow fast enough but also, due to technological difficulties, did not transform themselves into sectors capable of mass production.

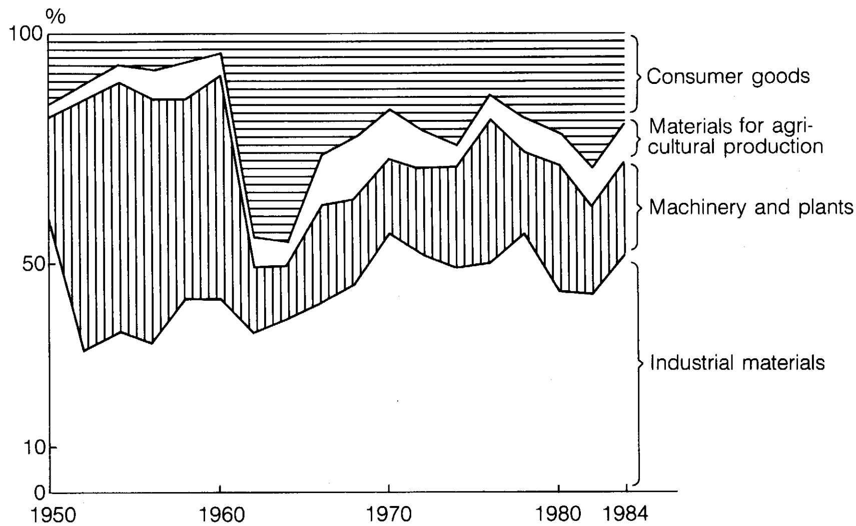
By the late 1960s, the relative overgrowth of processing industries had become a serious problem, and this brought about a shift of emphasis away from the import-substitution strategy and toward the sectors producing industrial materials and intermediate goods. Consequently, as is evident from Table 1-13, priority on imported technology was shifted toward the importation of large-scale plants that would enable the steel, petrochemical, and electric power sectors to build up their capabilities for mass production and to carry out technological innovation in as short a time as possible.

As can be seen in Table 1-15, the machinery industry has continued to enjoy the second largest share, after the steel industry, of total basic capital construction investment, which averaged 15.6 per cent from 1953 to 1980. Nevertheless, as shown in Table 1-13, the industry's share in imported technology has remained small, averaging only 3.7 per cent from 1950 to 1979. It can be concluded from this that China's machinery industry has been basically denied the benefits of large-scale technology from abroad which would produce significant technological trickle-down effects and promote mass production. Instead the industry has had to pursue development based primarily on indigenous technology with the importation of indispensable machinery and equipment playing a very limited role.

Machinery industries producing durable consumer goods and electrical and electronics appliances for civilian use have traditionally been regarded as non-priority sectors, and thus have not been treated preferentially in the importation of foreign technology. The plant for manufacturing for color-TV picture tubes purchased from Hitachi, Ltd. of Japan and built in Xianyang, Shanxi Province, in the mid-1970s was perhaps the first large foreign-made plant ever to be introduced into this field.

The order of priority that China adopted for the introduction of foreign technology into its industrial sectors has differed significantly from that taken by the Asian NIEs in their pursuit of export-oriented industrialization. Table 1-16 shows that in Korea and Taiwan, two of the Asian NIEs, the electrical and electronics, machinery, and chemical industries occupy the top three places in the amount of technological imports. The consequence of this difference has been spectacular. In the years since 1980, when the exports of home electric appliances from the Asian NIEs began to grow phenomenally, China began to import these products in ever increasing quantities. In the face of the explosive increase in demands for durable consumer products, the Chinese government had no choice but to relax its time-honored bans on the importation of consumer goods.

Fig. 1-7. Changes in the Composition of Imports



Source: The Editorial Board of the Almanac of China's Foreign Economic Relations and Trade, *1985 Almanac of China's Foreign Economic Relations and Trade* (Beijing: Water Resources and Electric Power Press, 1985).

TABLE 1-15
BASIC CAPITAL CONSTRUCTION INVESTMENT BY INDUSTRY (%)

	First Five-Year Plan Period 1953–57	Second Five-Year Plan Period 1958–62	Economic Readjustment Period 1963–65	Third Five-Year Plan Period 1966–70	Fourth Five-Year Plan Period 1971–75	Fifth Five-Year Plan Period 1976–80	Sixth Five-Year Plan Period 1981–85
Metallurgical industry	19.00	23.58	16.82	22.39	14.45	17.70	9.08
Power industry	12.28	11.98	8.29	13.99	14.56	16.25	22.96
Coal industry	12.13	11.83	12.92	8.19	8.83	9.51	13.04
Petroleum industry	4.10	3.25	6.79	7.69	9.73	9.95	9.72
Chemical industry	4.36	6.44	12.44	9.40	8.07	15.14	9.74
Machine-building industry	15.08	16.99	11.58	15.76	25.42	15.67	12.31
Forest industry	2.84	2.54	6.46	3.68	3.27	1.94	2.62
Building-materials industry	2.70	3.46	3.57	2.93	3.34	3.36	4.95
Textile industry	6.88	2.84	4.49	2.95	1.72	5.32	6.82
Food industry	4.41	3.74	1.78	2.14	1.90	2.32	4.83
Paper-making industry	1.51	1.29	0.48	1.73	1.04	0.79	0.76
Other industries	14.73	12.08	14.37	9.16	7.66	2.05	3.16

Source: State Statistical Bureau, *Zhongguo tongji nianjian,* 1987 edition.

TABLE 1-16
INDUSTRIES EMPHASIZED WHEN IMPORTING TECHNOLOGY: A COMPARISON OF KOREA, TAIWAN, THAILAND, AND MALAYSIA

Republic of Korea (1962–86)	Taiwan (1952–85)	Thailand (1982)	Malaysia (1982)
1. Electronics & electric machinery (19.9)	1. Electronics & electric products (26.4)	1. Transportation equipment	1. Electric machinery
2. Oil refining & chemical (19.5)	2. Chemical products (19.8)	2. Chemicals	2. Iron & steel
3. Machinery (19.2)	3. Machinery & measuring instruments (17.3)	3. Electric machinery	3. Transportation equipment
4. Electricity (11.9)	4. Metal products (8.1)	5. Machinery	4. Chemical
5. Shipbuilding (6.4)	5. Services (7.6)	5. Textile	5. Machinery
6. Metals (5.7)	6. Mining & quarrying (3.6)	6. Iron & steel	

Note: For the Republic of Korea and Taiwan, the industries are ranked in the order of their percentage of total technological imports. For Thailand and Malaysia, the industries are listed by the amount of their technological imports from Japan. Because 60–70 per cent of the latter two countries' technological imports are from Japan, these percentages seem to be applicable to the order of their percentage of total technological imports.
Sources: The Federation of Korean Industries, *Hankuk kyonje yongwan* [Korean economic yearbook], 1987 edition; Taiwan-kenkyūjo, *Taiwan* sōran [General outlook for Taiwan] (Tokyo: Taiwan-kenkyūjo), 1986 edition; and "Nihon to hatten tojōkoku tono aida no gijutsu masatsu bōeki masatsu mondai to kongo no kokusai bungyō no arikata ni tsuite no chōsa" [A survey of technological and trade friction problems between Japan and developing countries, and the nature of future international division of labor] (Tokyo: Institute of Developing Economies, 1985).

However, the imports of color TVs, refrigerators, laundry machines, passenger cars, and other consumer durables increased so swiftly that by the mid-1980s the Chinese government found it imperative to restrict the importation of these goods once again out of concern for the country's balance-of-payments position and also because of the need to protect the country's infant industries in these sectors from the competitive pressure of imported goods. The ban on the import of these goods, however, triggered a rush to import manufacturing and assembling lines for these products, with the result that the stepped-up production of consumer durables at home caused serious shortages of parts and industrial materials, forcing many of these lines to halt production.

The recent increase in the percentage of imported machinery and plants shown in Table 1-14 seems to indicate a new change is in the making. Among the sectors producing industrial materials and intermediate goods, the petrochemical industry has undergone a rapid change as a result of the introduction of a large number of plants since the mid-1970s. As of 1986 the industry had a production capacity of 1.5 million tons of synthetic fiber per annum, making it one of the largest in the world. In marked contrast to petrochemicals, the machinery industry was long encouraged to pursue import substitution which did not bring about technological innovation. Since the early 1980s the deficiencies in this industry have become increasingly acute, and the government can no longer ignore the long overdue need for large-scale renovation of its production equipment and the substantial introduction of foreign technology.

At the beginning of the 1980s, the Chinese government reexamined its practice of technological introduction and identified several problems. It pointed out that too much emphasis had been placed on purchasing productive forces rather than technology, as could be seen from the large portion of technological imports that took the form of plant purchases. The government noted too that following the introduction of foreign technology, the links of this technology with domestic R&D efforts and the machinery industry were too weak to be absorbed fully. As a result domestic reproduction of the imported plants and machines could not proceed satisfactorily, making it impossible for China to move beyond the stage of imitation. Another problem was the lack of a well-defined, long-term perspective in the government's policy for importing technology. This often led to careless, haphazard introduction of technology, a typical example being the importation of the same type of technology in quantities greater than needed. Moreover much of the imported technology was left unused for lack of engineering skills.

When introducing technology from abroad, a country has to choose from several alternatives: it can emphasize the signing of contracts for the use of patents and other types of technological know-how, or it can purchase mainly hardware, such as plants; if it takes the latter course, then it must decide whether to purchase them in the form of turn-key packages, in the form of non-packages, or to purchase only component machinery in piecemeal fashion. As part of the first step in deciding which alternative to pursue, the country must give careful consideration to such important factors as its own R&D and engineering capabilities, the state's own technological policy, and the condition of its foreign exchange reserves.

China opted for introducing foreign technology mainly in the form of purchasing plants, in the belief that this would be the shortest way to bridge the wide gap that had opened between the domestic level of technological expertise and the world's state-of-art technologies. When technological imports were resumed in 1963, following the economic setback caused by the rift with the Soviet Union and the failure of the Great Leap Forward, emphasis was placed on importing technology for use by the petrochemical industry in producing chemical fertilizers and synthetic fibers, and on importing LD converters for use by the steel industry. In the next period of active technological importing that began in 1973, following the economic confusion of the Cultural Revolution, emphasis was put on importing rolling mills for use by the steel industry and on large plants for use by the petrochemical industry to process products from intermediate goods. When technological imports began to surge again in 1978 following the fall of the Gang of Four, the main item brought in were large integrated iron and steel mills, technology for prospecting and extracting of petroleum deposits, and petrochemical plants for producing light manufactured goods. Each time technological imports expanded, China sought out plants embodying the world's state-of-art technologies, most likely in the hope that these would help China make up for its huge technological lag.

Having been compelled to pursue self-reliant development in the wake of the termination of Soviet aid in 1960, and not wanting to be left behind in the world of advancing technological innovation which was proceeding at a far faster tempo than China's own R&D efforts, it is not difficult to understand that China had no real alternative other than to import technology embodied in hardware (plants and machinery) and to try to produce its own copies through reverse engineering. Nor is it difficult to see that having lived for years in a hostile international environment characterized by the West's policy of containment, and having suffered from recurrent political upheavals domestically, China should have leaned toward purchasing whatever pieces of hardware were available when one of the few favorable but short-lived chances availed itself, rather than introduce software technology which could be absorbed only after long effort.

Such a pattern of technological importation, however, always runs into conflict with a country's ability to pay, and it is often argued that to avoid this problem and save foreign exchange, it is imperative that foreign technology be acquired primarily through importing non-packaged plants and through licensing contracts, as well as by increasing the components of plants to be procured domestically, and by stepping up the pace of import substitution through encouraging domestic production. Whether such efforts can be successfully implemented depends on whether or not a country is equipped domestically with mechanisms for absorbing and assimilating the imported technology. In the West where importation of technology is undertaken by an individual enterprise at its own risk, the enterprise will give up the idea of importing certain technology if it finds itself lacking the ability to absorb and assimilate it. In China, however, the authorities which make decisions about importation of technology, those in charge of negotiating with foreign suppliers, and the end users of the imported technology are all different. Decisions about importation of technology are made by ministries in charge of various industrial sectors, and their primary concerns are to import the most advanced large plants which are expected to strengthen the technological competence and productivity of the industrial sectors concerned. Negotiations are undertaken by the China National Technical Import Corporation and the China National Machinery Import and

Export Corporation, whose primary preoccupations are to drive a hard bargain with the foreign suppliers. The end users are of course the individual enterprises.

This division of labor often results in the purchase of foreign technology with little or no regard given to the interests or technological competence of the end-user enterprises concerned. This irrational division of labor has been blamed for many episodes where glittering machines imported from abroad now lie idle in warehouses because enterprises are unable to use them properly. If the three parties concerned (the enterprises which are the final users of the imported technology, the authorities outside the enterprises in charge of R&D, and manufacturers of machines) collaborate with each other more closely, the less than sufficient capabilities of the enterprises expected to use the imported technology may be improved. Ever since its inception, however, the present system for the introduction of foreign technology has suffered from absence of proper communications and exchange of information between the authorities in charge of R&D and individual enterprises. At the same time sectionalism continues to prevent enterprises in different lines of business from collaborating directly with each other.

In order to overcome these various deficiencies, the government has designated important machines and equipment as *gongguan* items and has organized systems under which all the parties concerned are supposed to collaborate with each other across sectors and provinces in order to promote domestic production of these items. The various products referred to in the previous section, which China has succeeded in producing domestically, are the result of these collaborative efforts. However, if the domestic production process is not supported by permanent relationships of mutual dependence that link production, R&D, and the supply of machines and equipment, it can never be properly improved, renovated, or maintained on a day-to-day basis. The adage in China that as soon as a piece of technology is imported or developed, the process of its ossification begins, attests to this situation.

The lack of communication among the organizations concerned not only has inhibited China's ability to assimilate imported technology, but also has prevented its industrial technology from moving beyond the stage of copying and imitation. Moreover it has given rise to the importation of technology in excess of what is actually needed, and has caused recurring rushes for importation. The vicious circle of a rush for technological imports followed by a phase of stagnation, only to be followed by a renewed rush to import, and then by another phase of stagnation has remained unabated.

Let us now turn to the mechanism by which new technology is absorbed, assimilated, and disseminated within China, beginning first with an outlining of the relevant institutional framework.

In principle, various research laboratories and design institutes (*shejiyuan*) under the jurisdiction of each ministry of the State Council are charged with undertaking the development of new products and R&D for improvements of production processes involving significant technological changes. Another source for furthering R&D is the importation of technology embodied in machines and equipment made abroad.

Large state-owned enterprises are usually the ones receiving the results of R&D efforts. One important task these enterprises are expected to accomplish is the standardizing of new products based on the designs forwarded from the authorities in charge of R&D and the mass production of these products. Another important task of these enterprises is to train skilled workers and engineers. They are also expected to provide other enterprises with the various technologies they have perfected. Typically, large state-owned enterprises collaborate with *gongguang* projects by dispatching their own skilled workers and engineers to work on these projects and providing them with machinery, equipment, and model plants.

In the development of the Daqing Oil Field, for instance, which began in the late 1950s, a large number of skilled workers and engineers transferred from an old oil field in Yumen, Gansu Province, played a very important role along with engineer corps of the Liberation Army that were also mobilized. In the mid-1960s, when production at the Daqing Oil Field was well underway, it began dispatching engineers, skilled workers, and supervisors, reportedly totaling more than 50,000 people, to work on the new projects developing the Shengli Oil Field in Shandong Province and the Dangang Oil Field on the coast of the Bo Hai.

Likewise, the construction of the Panjihua Iron and Steel Mill in Dukou, Sichuan Province, that began in the mid-1960s was assisted by the Anshan Iron and Steel Mill and other large steel mills which supplied needed manpower and equipment. The construction of the Hubei No.2 Automobile Plant received assistance from the Changchun No.1 Automobile Plant and several other large plants. Large state-owned enterprises in cities have also been active in supporting the construction of small plants in the countryside by building such things as small synthetic ammonia plants and turbines for small hydroelectric power stations.

There exists an institutional or tacit division of labor among enterprises in China. Large state-owned enterprises enjoy preferential treatment in the allocation of manpower, technology, financial resources, and equipment; they also have their own R&D and design staffs. For these reasons these enterprises are charged with mass producing a limited variety of products which require relatively high technological sophistication or which are specially demanded by the state. These enterprises are usually in the mining industry and the industries producing industrial materials.

State-owned enterprises of small to medium size and collective enterprises are supposed to operate with minimum possible investment funds. In allocating various productive resources, the state makes it a rule to allocate to these enterprises only those resources that are left after the needs of the large enterprises have been met; or it encourages them to make the best possible use of the resources that are left unused at local levels. Naturally, these enterprises do not have the basis for working on technological innovation. Their production activities are supposed to be oriented toward utilization of resources, meeting a diversity of local needs, and undertaking tasks not covered by large state-owned enterprises (sometimes by acting as subcontractors to the larger enterprises). These enterprises are mainly in the light industries and low-tech machinery manufacturing industries.

From the foregoing observations, the pattern of technology transfer that has been at work within China can be summed up as follows. When a new product is developed by a state-run institution for R&D, a state-run design institute prepares design drawings and the industrial standards for the product; the product is then mass-produced by large state-owned enterprises. When the technology necessary for producing the product matures and becomes well established, the pertinent know-how and skills are handed down to small and medium-size enterprises. This pattern of technology transfer, while seemingly good in theory, has been caught up in a contradiction: on the one hand, the large state-owned enterprises capable of undertaking R&D have not been particularly eager to promote technological innovation because of institutional restraints and the lack of sufficient capacity to assist smaller enterprises. (This will be discussed in detail in Chapter 2.) On the other hand, the small and medium-size enterprises, while eager to promote technological innovations, are deficient in R&D capabilities.

During the periods of the Great Leap Forward and the Cultural Revolution, China's industrial policy gave utmost priority to promoting industrialization in the countryside and to attaining technological breakthroughs which would enable China to catch up quickly with the advanced countries of the West. During these periods, the institutional framework for technology transfer was neglected, and large enterprises were encouraged to undertake the development of new products for and by themselves, while small and medium-size enterprises, were likewise encouraged to become self-reliant in carrying out technological innovations. The consequences were disastrous, bringing about the destruction of the institutional framework vital for the promotion of technological innovations (e.g., the system of industrial standards and the system of quality checks). With the base for R&D seriously weakened, there was no way for China to develop many of the new products that it really needed.

For more than thirty years, China has been without the types of large monopolistic enterprises that Schumpeter called important agents of technological innovation. Nor have venture businesses that could take the lead in developing new products emerged from among the small and medium-size enterprises. These latter enterprises have always suffered from serious shortages of investment funds, equipment, and human resources, and they have always had to depend upon their own resources to satisfy local demand. In this respect, these enterprises, while unable to serve as agents of technological innovation, have nurtured many skilled and capable workers who have been very good at resolving technical problems of the production processes and have effectively utilized the locally available technology. These skilled and experienced workers form the technological base of China's small and medium-size enterprises, and these enterprises in turn make up the overwhelming majority of industrial enterprises in the country.

The institutional framework for technology transfer does not consist solely of the channel described above. Government authorities have also been making efforts to explore advanced model cases and to disseminate the experiences of such models by organizing seminars and workshops for the exchange of information and know-how.[20] But the transfer of technologies organized by government authorities from above can never fully satisfy the real needs felt daily by individual enterprises and customers. This points out another significant shortcoming in China's setup for technology transfer, which is that it provides no reliable system or method for transferring technology to points where it is really needed.

In the past in China a piece of technology was not regarded as a commodity to be bought and sold for a price. There was no institutional setup for the transaction of technology, nor was there any active dissemination of information on technology (as will be discussed further in Chapter 2). This situation made it extremely difficult for technologies to be transferred across jurisdictional boundaries between ministries, districts, and supervisory authorities, even though from time to time these would be made freely available within a specific area of jurisdiction. This was due in part to the fact that each jurisdiction tended to form a self-containing world, equipped with its own institutional framework ranging from its own industrial standards to its system for qualifying professionals. The difficulty was also due to the strong sectionalist atmosphere that is peculiar to the centralized system of economic administration. The problems hindering the transfer of military technology to be used for civilian purposes, mentioned earlier, is a typical instance of this.

The technological confines of each industrial sector or jurisdiction helps keep intact China's multi-layered hierarchical system of technology, and maintains or even expands the technological gaps separating the various sectors and jurisdictions. Looked at from the standpoint of R&D, this gives rise to a situation where research is carried out on the same theme by a number of entities in parallel with each other; or even worse, it leads to a situation where a number of entities repeat research on certain technology already fully developed by another. This is happening in the high-tech areas where more than one hundred R&D institutions have been attracted to the development of technologies for laser and optical fiber communications, which the state has designated as *gongguang* fields. However, this whole research effort has been so dispersed that the majority of these institutions are still at the stage of imitating the accomplishments already made abroad.[21] The duplication of R&D efforts is also prevalent in the West, but this takes place primarily as a result of competition. In contrast, the duplication of R&D efforts in China is ascribable primarily to the lack of shared information among the R&D institutions and also to China's bureaucratic sectionalism.