2

Research and Development Systems

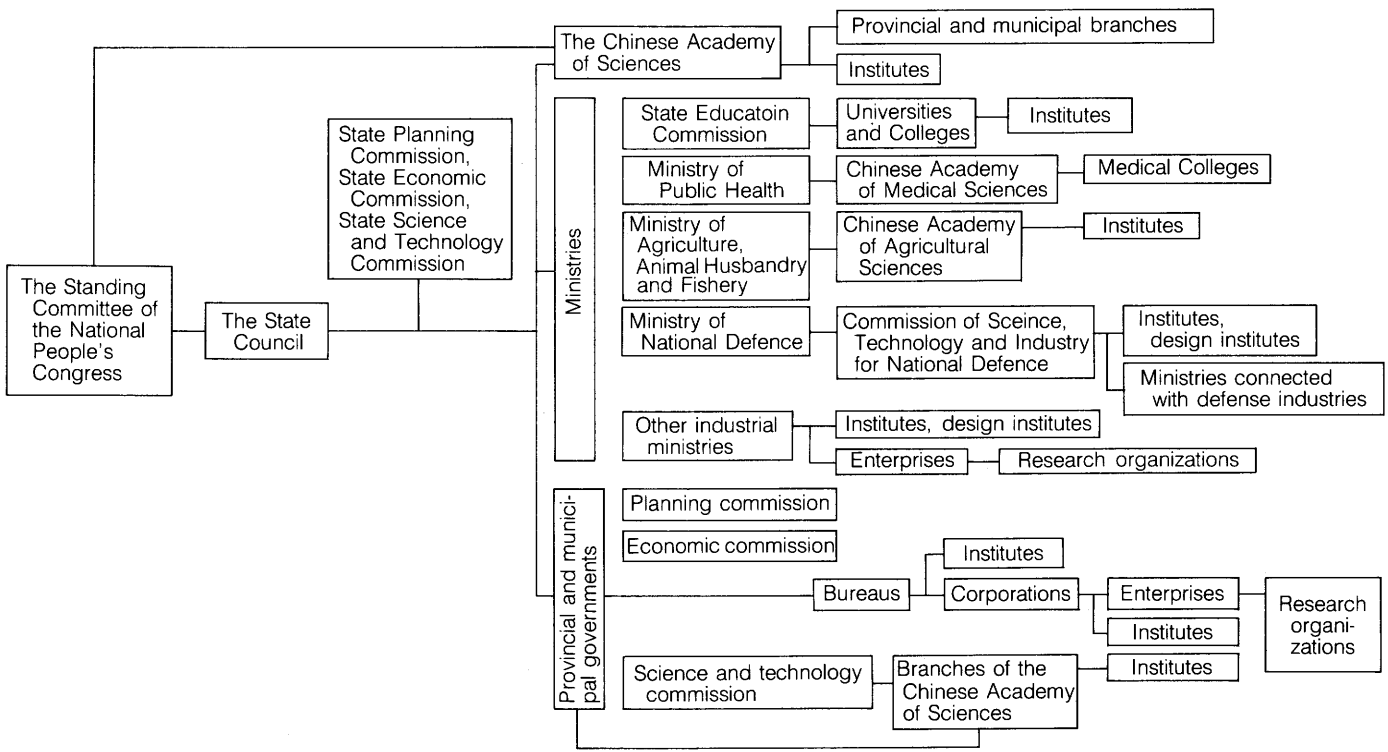
Institutional Framework for R&D

Reflecting the state sector's dominance in the national economy, scientific and technological R&D in China is for the most part carried out by the state itself (see Figure 2-1 for R&D organization chart). R&D policies as well as major R&D projects are incorporated into the state's long-term economic planning or into its five-year economic plans. R&D plans are made and implemented by the State Science and Technology Commission (SSTC) under the supervision of the State Planning Commission. In recent years the SSTC's role in the planning, guidance, and adjustment of R&D has been strengthened.

The SSTC was established at the end of 1958 through the merging the Science Planning Commission and the State Technology Commission, both R&D bodies set up for the First Five-Year Plan period. The two commissions were unified to facilitate overall coordination of R&D activities and to rectify the chaotic situation in the planning and implementation of R&D programs that had characterized the Great Leap Forward period.

The SSTC has eight functions: it (1) implements the state's R&D policies; (2) plans, implements, and supervises R&D plans (annual and long-term); (3) coordinates activities of the agencies carrying out major R&D projects; (4) evaluates major R&D achievements, inventions, and creative innovations and promotes their application; (5) educates, trains, and manages personnel engaged in R&D; (6) allocates R&D budgets and provides R&D equipment; (7) drafts and proposes R&D-related legislation, rules, and other instruments to the National People's Congress; and (8) organizes scientific and technological exchanges with other countries.

Fig. 2-1. R & D Organization Chart



Source: An organization chart on p.141 of Wu Mingyu ed., *Keyan guanri gongzou shouce* [The handbook of scientific research management] (Beijing: Kexue-jishu-wenjien-chubanshe, 1986) provides the basis of this charter. The author has modified the chart to include recent changes in organization.

[a] The Seventh National People's Congress held in April 1988 decided to merge the State Economic Commission and the State Planning Commission.

The SSTC thus is responsible for implementing major state R&D projects as well as for coordinating the various R&D organizations and activities nationwide. Looking back over the commission's history since 1958, it can be seen that its role has grown in periods of economic centralization and has weakened, even become nominal, in periods of decentralization. During the Cultural Revolution the SSTC was temporarily abolished, its duties divided between the science and technology group of the Party Central Committee's Cultural Revolution team and the National Defense Commission of Science and Technology. It was not until September 1977 that the SSTC was reestablished.

Though the state's primary office for coordinating China's R&D activities, the SSTC has found it extremely difficult to coordinate all the activities of the numerous administrative bodies and other organizations involved in R&D, each often plagued by sectionalism and bureaucratic self-interests. To break through this tangle, the government organized in January 1983 the Leading Group of Science and Technology under the State Council headed by then Premier Zhao Ziyang. This reorganization was to strengthen the central government's R&D coordinating functions.

Chinese R&D activities are conducted primarily by the following five bodies which have been dubbed the "five R&D armies" (For the total number of R&D institutes, see Table 2-1): (1) the Chinese Academy of Sciences, (2) R&D institutes belonging to the industrial ministries under the State Council, (3) research institutes belonging to universities and specialized colleges, (4) R&D institutes for national defense, and (5) R&D institutes belonging to local governments.

Chinese Academy of Sciences

The Chinese Academy of Sciences (CAS) was set up toward the end of 1949 by unifying the major research institutes that had existed in the pre-liberation period. With its large number of top-notch researchers from all over the country, the CAS has lived up to its role as the very center of China's scientific research.

The CAS has five disciplinary divisions: the Division of Mathematics and Physics, the Division of Chemistry, the Division of Biological Sciences, the Division of Earth Science, and the Division of Technological Science.[1] Its headquarters are in Beijing, and it has branches in twelve other cities (including Shenyang, Changchun, Shanghai, Wuhan, Guangzhou, Nanjing, and Xi'an). As of 1985, it had 122 institutes under its supervision. The CAS not only controls its own research institutes but also runs nine manufacturing plants and manages four science and technology universities (University of Science & Technology of China in Hefei City, Zhejiang University in Hangzhou City, Chengdu University of Science and Technology in Chengdu City, and Harbin University of Science and Technology in Harbin City). The number of research institutes managed by the CAS has fluctuated over time as Table 2-2 indicates. During

TABLE 2-1
STATE-OWNED R&D INSTITUTES

	No. of Institutes		No. of Researchers and Staff		No. of Scientists and Engineers	
	1985	1986	1985	1986	1985	1986
Institutes above county-level	4,690	5,271	770,416	1,020,500	231,050 (30)	324,800 (32)
Belonging to ministries under the State Council	622	922	266,412	515,290	93,026 (36)	175,070 (34)
Belonging to Chinese Academy of Sciences	122	122	69,650	70,510	32,174 (46)	34,989 (50)
First-level regional administrative districts	3,946	4,227	434,354	434,700	105,850 (24)	114,700 (26)
County-level institutes	3,267	3,369	77,435	78,500	4,960 (6.4)[a]	6,200 (8)[a]
Institutions of higher learning[b]	1,254	1,490			23,081	27,925

Sources: For 1985, State Science and Technology Commission ed., *Zhongguo kexue jishu zhinan* [The guidance of China science and technology] (Beijing: Kexue-jishu-chubanshe, 1986), p.231 and State Statistical Bureau, *Zhongguo tongji nianjian* [Statistical yearbook of China] (Beijing: Zhongguo-tongji-chubanshe), 1986 edition; for 1986, *Zhongguo tongji nianjian*, 1987 edition.

Note: Figures in parentheses represent the percentage of scientists and engineers within the total of researchers and staff.

[a] Represents all personnel with college or higher diplomas and so includes non-scientists and non-engineers also.

[b] Science, engineering, agricultural, and medical education units out of the 910 daytime "general institutions of higher learning" throughout China.

the Cultural Revolution period basic research was neglected, and many CAS institutes were dissolved or reorganized into institutes studying applied technology for local industries under the administrative control of local governments.

Institutes Belonging to Industrial Ministries under the State Council

The research and design institutes directly controlled by the ministries under the State Council are mainly engaged in studies on applied technology. Their main function is to set industrial standards for products that their respective ministries are responsible for. These institutes thus develop designs and new products and test them against the standards they formulate. The designs and product models developed and standardized by the ministerial research and design institutes are made available free to enterprises under the supervision of the ministries concerned. Table 2-3 shows that development personnel and R&D functions are heavily concentrated in the heavy chemical industrial sectors, primarily machinery, chemical, and steel industries.

Large state-owned enterprises usually have their own R&D institute capable

TABLE 2-2
DEVELOPMENT OF THE CHINESE ACADEMY OF SCIENCES

Year	No. of Research Institutes	No. of Senior Researchers	Year	No. of Research Institutes	No. of Senior Researchers
1949	16	122	1973		414
1952	31	351	1975	36	
1957	68	753	1978	over 70	1,261
1960	110	n.a.	1980		2,565
1962	113	623	1982		2,764
1965	over 120	688	1986	122	

Sources: The number of research institutes for 1949–62 from, Chu-yuan Cheng, *Scientific and Engineering Manpower in Communist China 1949–1963* (Washington, D.C.: National Science Foundation, 1965), p.21; those for 1965 and 1975–76 from, Richard P. Suttmeier, *Science, Technology and China's Drive for Modernization* (Stanford, Calif.: Hoover Institution Press, 1980), p.24. For the number of senior researchers, see State Statistical Bureau, *Zhongguo tongji nianjian* 1987 edition and *Zhongguo shehui tongji ziliao* (Beijing: Zhongguo-tongji-chubanshe, 1985), p.24.

of developing new products independently (e.g., Anshan Iron and Steel Mill and Changchun No.1 Automobile Plant). But generally state-owned enterprises have simpler R&D structures capable only of solving their own technological problems such as improving in their products and processes, workplace safety, and environment issues.

The R&D systems described above were originally patterned on the Soviet model which was transplanted to China in the 1950s. China had to follow the Soviet model for several reasons: the need to centralize control over the country's poorly endowed R&D resources for effective utilization; the need to raise the overall technological level through administrative control rather than through inter-enterprise competition—an inevitable choice when there existed too many technological backward enterprises; and the need to control all enterprises from a single center so as to keep enterprise behavior in line with state economic planning.

Key Universities and Their Research Institutes

The Chinese system of higher education is arranged into three groups of universities and colleges. The first group is composed of those key universities (seventeen by early 1980) and colleges (about twenty) which are supervised by the State Education Commission and bureaus of education in the provincial governments. The second group consists of the technical colleges (over fifty) and secondary professional schools which are mainly supervised by the corresponding industrial ministries. The third group is made up of the four previously mentioned universities managed by the Chinese Academy of Sciences. The research institutes of the key universities continue to engage mainly in basic research as well as educate and train advanced research personnel although they

TABLE 2-3
R&D INSTITUTES OF THE MINISTRIES UNDER THE STATE COUNCIL

Ministry	No. of Scientists and Engineers	Other Technical Personnel	No. of R&D Institutes
Chinese Academy of Science	34,989	9,540	122
Machine-building Industry	16,480	7,146	61
Chemical Industry	7,378	3,805	27
Agriculture, Animal Husbandry and Fishery	6,863	2,656	84
Metallurgical Industry	6,686	3,053	19
Geology and Mineral Resources	5,823	2,587	56
Public Health	5,680	6,753	37
China National Nonferrous Metals Industry Corporation	5,672	2,704	23
Water Resources and Electric Power	5,382	2,637	32
Coal Industry	3,939	1,945	22
State Administration of Building Materials Industry	3,553	1,867	21
Railways	3,368	1,050	25
Posts and Telecommunications	3,361	3,641	39
Light Industry	2,246	1,040	25
Petroleum Industry	2,176	1,617	10
Total of 34 ministries	19,660	2,663	193
Others	74,722	42,500	239

Note: *Zhonggua tongji nianjian*, 1987 edition contains data about forty-nine ministries and commissions (out of the eighty ministries and commissions belonging to the State Council) which have R&D institutes in the fields of natural science and technology. This table shows the top fifteen ministries and commissions in terms of the number of scientists and engineers. The remaining thirty-four ministries and commissions are shown as a group. ''Others'' indicate scientists and engineers not belonging to the said forty-nine units. ''Others'' are believed to cover most of the defense-related R&D personnel as the said forty-nine units do not include the Ministry of Defense; the Commission of Science, Technology and National Defence; the ministries of Nuclear Industry, Electronics Industry, Aviation Industry, Astronautics Industry, and Ordnance Industry; and the China State Shipbuilding Corporation, which are all engaged in defense-related R&D. All data are for the pre-reform period (before April 1988).

have acquired rather strong application and development capabilities through projects contracted from the government.

Defense-related R&D Institutes

Since the 1950s, the development of military technology has fallen into the top-priority *gongguan* category. This means that like other *gongguan* projects, technological development projects for military purposes encompass the whole spectrum of industry and go beyond the jurisdiction of any one ministry. The R&D institutes of the industrial ministries connected with defense industries are the main groups developing military-related technology. The primary ministries involved are: the Ministry of Electronics Industry, the Ministry of Aviation Industry, the Ministry of Astronautics Industry, and the Ministry of Ordnance Industry. Table 2-3 does not give the number of defense-related R&D institutes, but it is known that they are better staffed than the R&D institutes belonging to the ministries under the State Council control. The Chinese Academy of Sciences and research institutes of the key universities also participate in *gongguan* projects. The development of nuclear weapons, rockets, and computer projects in particular have been undertaken jointly by all these above-mentioned institutes.

Defense-related R&D used to be under the control of the National Defense Commission of Science and Technology which belongs to the Party Central Military Commission. Weapons production was under the management of the State Council defense industry office. In 1982, these two bodies were unified to form the Commission of Science, Technology and Industry for National Defence. This reorganization brought together the development and production of weapons under the central control of the State Council and the Party Central Military Commission.

R&D Institutes under Local Governments

This group has a far larger number of research institutes than the other four "armies." The institutes in this group are managed and financed by first-level regional administrative districts and county governments. Their technological capacities, however, are significantly inferior to the other four "armies." The county-level institutes suffer from an extreme shortage of personnel, as Table 2-1 indicates.

Because they are vertically controlled, the "five armies" lack horizontal integration. To overcome this weakness, academic societies at the national level and operating in specialized areas promote exchanges of knowledge and expertise among personnel from the five R&D groups.

The national organization for promoting scientific and technological knowledge among the general public is the China Association for Science and Technology. During the Cultural Revolution when the atmosphere was overwhelmingly hostile toward academia, this association along with other academic societies had to virtually cease functioning. They were able to renew their activities only toward the end of the 1970s.

In the past China has official emphasized the spread of scientific knowledge among the farmers, especially in the so-called four "ations" of agriculture (*nongye sihua*): mechanization, electrification, irrigation, and chemical fertilization. For this purpose, networks of science and technology teams and agricultural experimental stations were organized at the different administrative levels (formerly these were at the levels of the counties, people's communes, production brigades, and production teams). During the Cultural Revolution in particular, a great deal of propaganda was made about these networks, and their activities were encouraged to demonstrate that the farmers themselves and not "urban specialists" were the true promoters of science and technology in the countryside. But it is apparent that even where science and technology teams and experimental stations were set up, most remained inept and failed to produce any positive results. The reason for this is clear. There was an acute shortage of specialists in rural areas. Even recent data show that there are only about 12 agricultural specialists per 10,000 people in the countryside. Another reason for the failure was insufficient funding and other support for agricultural technology promotion programs.

R&D Expenditures

To get an idea of the size of R&D activities in China, one needs a clear picture of China's system for financing R&D. In Japan and other major countries of the West, total R&D costs, generally known as R&D expenditures, are the sum totals expended on R&D by government research institutes, private research institutes, private business enterprises, and universities. In China's case, R&D expenditures are overwhelmingly met by the government. (A slight change was made in this system after 1985, as will be mentioned later, but discussed here is the Chinese system valid until 1985). R&D is, of course, also being conducted by collective enterprises and agricultural experimental stations in the non-state-owned sector, but their R&D costs are negligible.

The composition of Chinese R&D expenditures is extremely complex, and many details remain unclear. Figure 2-2 shows their breakdown insofar as this author could clarify them. State fiscal expenditures for R&D is called "science and research expenditures" in Chinese budget and it is subdivided into "science and research working expenses" which are covered in the budget for "social, cultural, and education expenditures," as well as into "science and research basic capital construction expenses" and "science and technology expenditures on three items" which are covered by the budget for "economic construction expenditures." From 1956 until 1967 the expenditures needed for technological innovation and product development by enterprises were called "expenditures on four items" (*sixiang feiyong*). These were basically met by the state budget. During the Great Leap Forward period and for a while during the Cultural Revolution, enterprise depreciation funds were used to meet the expenditures on four items. In 1967 a fiscal reform was carried out which resulted in three of the four items being integrated with the "investment for fixed assets replacement" as shown in Figure 2-3. The consolidated fund was to cover "fixed asset replacement and technological innovation." Since that time the expenditures for the fixed asset replacement and technological innovation have been paid from the depreciation fund. "Expenditures for trial manufacture of new products" of the "four items" had been financed by government expenditures.

Since 1972 this trial manufacturing expenditures has been classified under "science and technology expenditures on three items."

The "science and research working expenses" included in "science and research expenditures" are general managerial expenditures and general research expenses incurred by the Chinese Academy of Sciences, Chinese Academy of Social Sciences, State Science and Technology Commission, Association of Science and Technology, and organizations dispersing scientific and technological information. These expenses are now under the sole control of the State Science and Technology Commission. Funds budgeted for "science and technology expenditures on three items" are managed by the State Planning Commission and the State Science and Technology Commission and allocated to the industrial ministries of the State Council.

In 1984 funds for science and research expenditures amounted to 8,250 million yuan. Of this sum, the State Planning Commission controlled only 1,970 million yuan, or 23.88 per cent; the rest was allocated to the above-mentioned commissions and ministries. It would appear that funds are spread too thinly over the various bodies.[2]

The funds at the disposal of the State Planning Commission are used for the state's R&D activities, education and training of personnel, and international technological exchanges. High-priority *gongguan* projects, which are set out at the national planning level and undertaken by more than one industrial ministry, receive their research funds channeled through the State Planning Commission to the contractual units (research institutes, enterprises, and universities). Key R&D projects undertaken by individual industrial ministries are funded by the ministries concerned which allot money to the research institutes and enterprises under their respective jurisdictions.

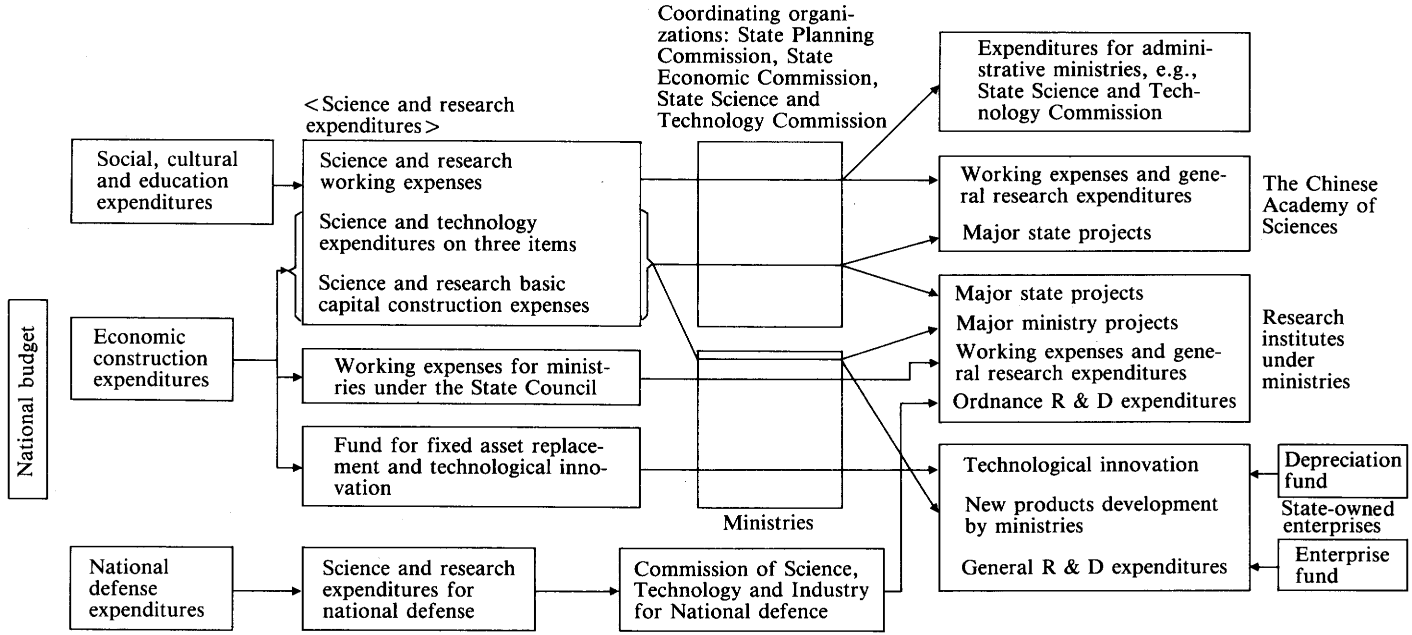
The personnel, managerial, and routine research expenses of the institutes belonging to industrial ministries of the State Council are met by business budgets of the ministries concerned. The operational expenses of university institutes are met by the business budgets of the universities concerned, but when such institutes conduct *gongguan* projects, the State Education Commission pays for the costs out of the budget for "science and technology expenditures on three items." The institutes belonging to local governments of first-level regional administrative districts are financed basically in the same manner as the state-supported institutes.

R&D is financed at state-owned enterprises in the following manner:

(1) Funds for technical innovation (for improvements in production processes and equipment and in the designs and quality of products; for energy and for environment conservation): The sources of funding are the enterprise's "fund for fixed asset replacement and technological innovation" as well as depreciation funds, retained profits, and bank loans.

(2) Funds for new product development: When *gongguan* projects are undertaken, the ministry(ies) concerned provide(s) funds from their own ministerial

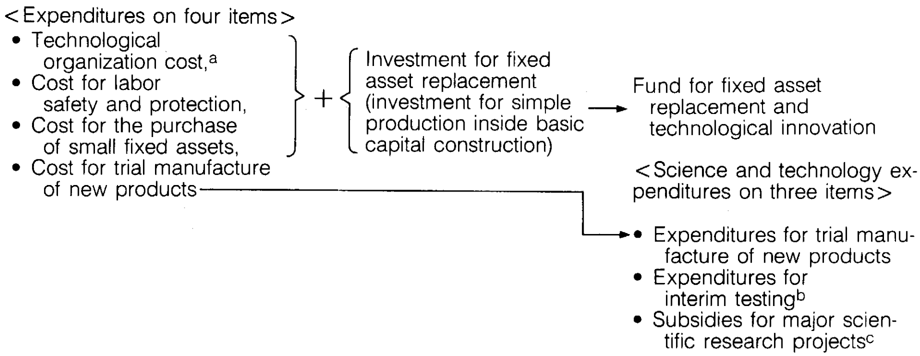
Fig. 2-2. Sources and Flow of R & D Funds



Note: The chart does not show the expenditures incurred by local R & D units, but the basics are the same for them: major project costs are met by the state through "science and technology expenditures on three items" budget, and other projects are financed by local governments.

Source: Prepared by the author.

Fig. 2-3. Expenditures on Four Items and Science and Technology Expenditures on Three Items



[a] Costs for product quality improvement, production process improvement, mechanization, automation, energy-saving, etc.

[b] The cost of testing trial products before they are put into full production.

[c] For supporting research by universities and enterprises in connection with *gongguan* projects covered by state planning.

budgets for "science and technology expenditures on three items." If an enterprise develops its own new product, the R&D cost is met through its own managerial budget and retained profits.

The flow of funds allotted for defense R&D is unclear, but there seem to be two funding channels. One source is the national defense budget from which funds can be channeled through the Commission of Science, Technology and Industry for National Defence to defense industries. The second source is the budget for "science and technology expenditures on three items" which can provide R&D funds for developing of "dual-use technology," meaning technology used for both military and civilian purposes.

It is reported that defense-related R&D accounts for about 10 per cent of the defense budget which would mean that China's defense R&D outlays for the 1980s would be 1,600–1,900 million yuan. But other reports claim that half of the state's R&D spending is for defense purposes. If this is true, then total defense-related R&D expenditures would come to 3,000–4,200 million yuan.[3] At present no reliable data are available on this matter.

What has been set forth so far in this chapter has been an outline of China's R&D costs. At present there is no data indicating the total size of the country's R&D investments. The government's science and technology expenditures are known, but there are no statistics on R&D spending by state-owned enterprises. As enterprise-level R&D investments are generally very low, the government

TABLE 2-4
R&D Expenditures in Some ESCAP Countries or Areas (As percentage of GNP)

Country or Area	Year	R&D/GNP (%)
Australia	1978	1.0
Bangladesh	1979	0.2
Burma	1973	0.1
China	1978	1.0
Hong Kong	1973	n.a.
India	1979	0.6
Indonesia	1979	0.4
Iran	1972	0.3
Japan	1979	2.1
Maldives	1979	0.4
Mongolia	1980	0.13
Nepal	1979	n.a.
New Zealand	1979	1.0
Pakistan	1974	0.14
Philippines	1979	0.17
Republic of Korea	1979	0.6
Samoa	1978	1.9
Sri Lanka	1979	0.2
Singapore	1979	0.25
Thailand	1979	0.26
USSR	1979	4.6

Source: United Nations, Economic and Social Commission for Asia and the Pacific, *Technology for Development*: *Study by the ESCAP Secretariat for the Fortieth Session of the Commission* (1984), p.124.

R&D certainly carries a dominant weight in the total of R&D activities of the country.

The Chinese recently announced the cost of their R&D as 1 per cent of GNP. In 1985 China began to calculate its GNP (using a slightly different method from that used in the West as noted in Chapter 1). Using the 1985 figure as the basis, Chinese have retroactively estimated past GNP figures. We can calculate the ratio of R&D costs to GNP using these figures. The R&D costs taken as the basis here are the annual science and technology expenditures. The R&D cost / GNP ratios that result are only rough figures; nevertheless, according to this formula, the ratio for 1984 was 1.46 per cent. Table 2-4 provides an international comparison of the relative sizes of R&D expenditures. China of course lags far behind the advanced industrial countries but ranks higher than other developing countries in its R&D / GNP ratio.

Comparing China's science and research expenditures relative to total fiscal expenditures with corresponding ratios for other countries, it can be seen from Table 2-5 and Figure 2-4 that the figures for China began to rise rapidly from 1979 and have stayed higher than those for Japan, the United States, and the Soviet Union throughout the 1980s.

TABLE 2-5
CHANGES IN SCIENCE AND RESEARCH EXPENDITURES, 1953–84

	Science and Research Expenditures (1) (100 Million Yuan)	(1) / Total Fiscal Expenditures (%)	(1) / National Income (%)
1953	0.56	0.3	0.008
1955	2.13	0.7	0.003
1957	5.23	1.7	0.006
1959	19.15	3.5	1.50
1961	19.49	5.5	1.92
1963	18.61	5.5	1.78
1965	27.17	5.8	2.02
1967	15.35	3.5	1.07
1969	24.15	4.6	1.57
1971	37.68	5.2	1.87
1973	34.59	4.3	1.54
1975	40.31	4.9	1.64
1977	41.48	4.9	1.61
1979	62.29	4.9	1.85
1981	61.58	5.5	1.58
1983	79.03	6.1	1.65
1984	95.01	6.1	1.68

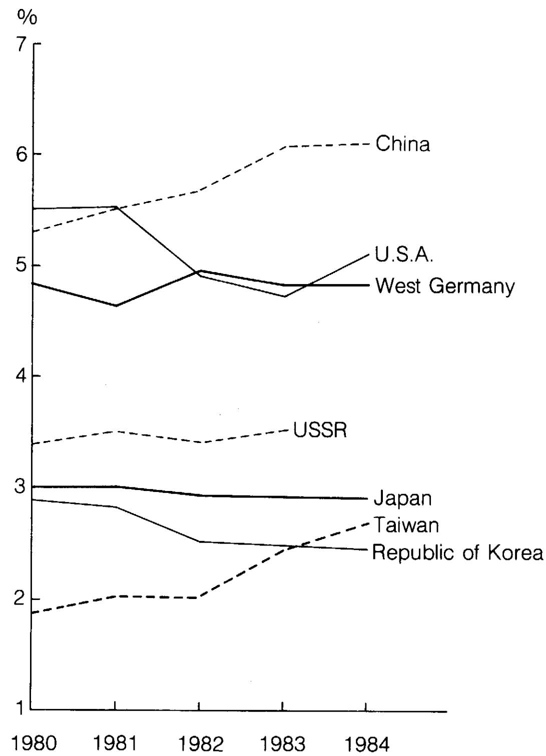
Sources: State Statistical Bureau, *Zhongguo tongji nianjian*, 1987 edition; *Keji ribao*, June 20, 1987, for 1984 figures.

As these figures indicate, China's R&D expenditures are not small in relation to the government budget. There are however problems with enterprise-level R&D expenditures. The ratio of R&D cost to sales is the usual yardstick used to measure the size of enterprise-level R&D investment. Though China lacks statistics giving this ratio, the Chinese government, as will be discussed later in this chapter, allows 1 per cent of sales to be retained for R&D purposes. This indicates that Chinese enterprises are actually appropriating less than 1 per cent of their sales for R&D purposes and that the government is encouraging them to raise it to 1 per cent.

Instead of the usual R&D cost / sales ratio, China gives R&D costs as a percentage of total output. A survey taken in 1984 of 400 enterprises, 100 each in the metallurgical, chemical, machinery, and electronics industries, provided the following figures: metallurgy, 0.5 per cent; chemical, 1.1 per cent; machinery, 1.0 per cent; and electronics, 5.5 per cent.[4] According to this survey, 72 per cent of the presidents of the enterprises surveyed complained about the shortage of R&D funds. R&D cost / sales ratios for Japanese and U.S. enterprises in similar industries in 1984 are shown in Table 2-6.

R&D institutes belonging to industrial ministries generally receive poor funding allocations for routine R&D activities. For this reason they see state *gongguan* projects as their major source of funds and tend to disregard the

Fig. 2-4. Percentage Share for Science and Technology Expenditures in Total National Budgets



Source: Japan, Science and Technology Agency, *Kagaku-gijutsu hakusho* [White paper on science and technology], 1985 edition (Tokyo: Kagaku-gijutsusha, 1985); The Federation of Korean Industries, *Hankuk kyonje yongwan* [Korean economic yearbook], 1987 edition; Republic of China, Council for Economic Planning and Development, *Taiwan Statistical Data Book, 1987* (1987).

development of industrial products and their quality improvement which require constant and cumulative efforts. At state-owned enterprises, too, R&D is not given high priority, and as often pointed out, their R&D budgets are frequently misappropriated for basic capital construction investment.

In the allocation of the R&D funds for basic, applied, and product development research, the share for the three areas has changed greatly over time. Basic research has always been in conflict with applied and product development research over fund allocation, and during the Great Leap Forward and Cultural Revolution periods, the former was very hard pressed. Table 2-7 gives a breakdown of estimated R&D expenditures. As can be seen, basic research was completely stagnant in 1973, a year during the Cultural Revolution period, while the figures for 1979 indicate a shift of emphasis toward basic research in the subsequent period when all efforts were made to reconstruct research institutes including the Chinese Academy of Sciences.

Figure 2-5 gives the breakdown of funds released for 73,000 research projects conducted in 1985 by county and higher echelon research institutes. The expenditures totaled 1,810 million yuan (not including personnel, administrative, basic capital construction, and fixed asset costs). The chart shows clearly where R&D emphasis lay for that year. According to the figures, basic research accounted for approximately 4 per cent of funding, applied research 10 per cent, product development 30 per cent, engineering-designing 27 per cent, public relations-services 23 per cent, and productive activities 6 per cent. In most countries product development takes the largest share of all R&D (Table 2-8); it is likewise in China. But the share of basic research is strikingly small in China compared with other countries.

Figure 2-6 provides a breakdown of R&D expenditures by research subject undertaken in the aforementioned 73,000 projects. Given that research institutes under the county and higher-echelon administrative units spend most of the R&D expenditures, this breakdown can be safely regarded as mirroring the general R&D priorities in China. In Japan as well as the United States and West European countries, R&D in industrial technological fields is conducted mainly by private enterprises, their R&D expenditures usually accounting for 70 per cent of the national total spent on R&D. By comparison China's R&D expenditures for "promotion of industrial development" is obviously too small.

According to Figure 2-6, China's defense R&D share is a meager 3 per cent. Even considering national defense budget cuts during the 1980s and the emphasis on civilian purpose-R&D, this figure appears too small when compared with the corresponding figures for 1973, shown in Table 2-7. This is probably because major portions of defense R&D costs are spread over other industrial branches in the form of R&D for "dual-use technology."

Manpower

The people engaging in R&D in China are called "natural scientific and technical personnel." This term however denotes a wide range of personnel from researchers and medical doctors to engineers assigned to production lines, college teaching staff in natural sciences and to managerial staff of R&D institutes.

The term "scientists and engineers" used in Table 2-9 refers to scientific and technical personnel with university or other higher education diplomas, or with senior and middle-level position titles. "Other technical personnel" are those people doing scientific or technological work with secondary specialized school or university careers or with junior position titles.[5]

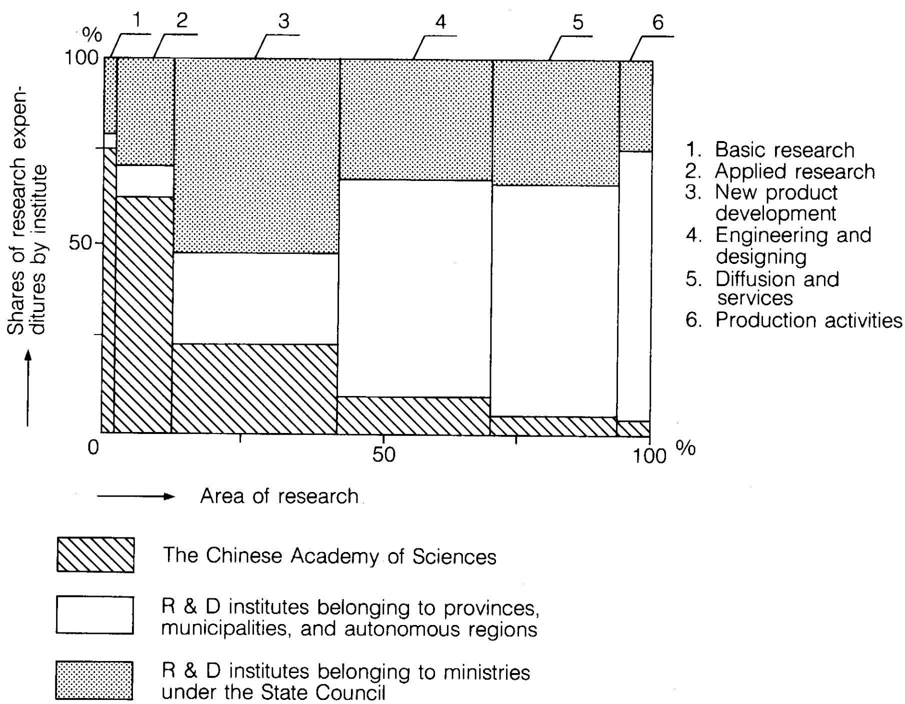
TABLE 2-6
R&D Cost/Net Sales Ratio for Japan and the United States, 1984

(%)

Industry	Japan	U.S.A.
Iron & steel[a]	1.54	11.45
Chemical	3.46	4.5
General machinery	2.59	6.0
Electrical machinery	4.55	7.2

Source: Japan, Science and Technology Agency, ed., *Kagaku gijutsu yōran*, 1986 [Indicators of science and technology] (Tokyo: Science and Technology Agency, 1987).
[a] Includes nonferrous- and metal-product industries following the Chinese categorization; the figures are the average of the three branches.

Fig. 2-5. R & D Expenditures by Area and Organization, 1985



Source: State Science and Technology Commission, ed., *Zhongguo kexue jishu zhinan*, p.236.

TABLE 2-7
BREAKDOWN OF R&D EXPENDITURES BY MAJOR CATEGORIES
(1973 and 1979 estimates)

(%)

	1973 (1)	1973 (2)	1979 (3)
Basic research	2.4	4.0	10.0
Applied research			20.0
Developmental research			70.0
Agriculture and natural resources excluding energy	18.0	14.0	
Medicine and public health	11.0	14.0	
Defense	22.0	24.0	
Manufacturing, energy, and transportation	47.0	44.0	

Sources: For column (1), from Boel Billgren and Jon Sigurdson, *An Estimate of Research and Development Expenditure in the People's Republic of China in 1973*, OECD Occasional Paper No. 16 (Paris: OECD Development Centre, 1977); for column (2), from Jon Sigurdson, *Technology and Science in the People's Republic of China: An Introduction* (Oxford: Pergamon Press, 1980, p.66; for column (3), ibid., p.72.

TABLE 2-8
COMPOSITION OF R&D EXPENDITURES, 1985

(%)

	Total	Industry	Government Institutes	Universities	Private Institutes
Japan					
Basic Research	12.9	5.9	13.0	54.2	10.6
Applied research	25.0	21.9	28.5	37.4	33.5
Developmental research	62.2	72.1	58.4	8.4	55.9
U.S.A.					
Basic research	12.2	3.6	14.8	57.8	33.1
Applied research	22.0	20.4	23.6	27.9	29.2
Developmental research	65.8	76.0	61.6	14.3	37.7
Taiwan					
Basic research	10.1				
Applied research	31.5				
Developmental research	58.4				
Republic of Korea					
Basic research	16.8				
Applied research	29.2				
Developmental research	54.3				

Source: For Japan and the United States, from Science and Technology Agency, *Kagaku gijutsu yōran*; for the Republic of Korea and Taiwan, same as Figure 2-4.

TABLE 2-9

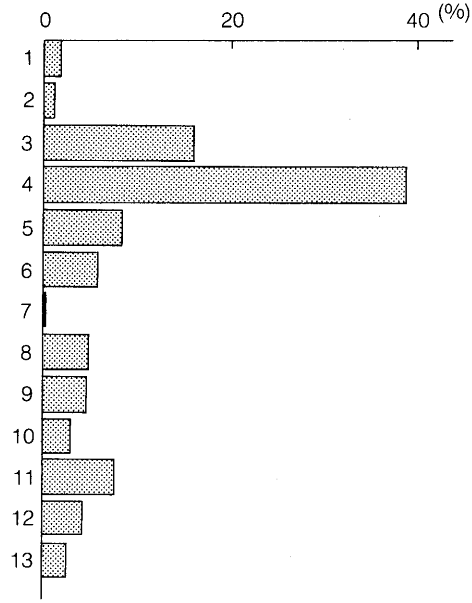
OCCUPATIONAL TITLES OF THE NATURAL SCIENTIFIC AND TECHNICAL PERSONNEL

	Scientists and Engineers			Other Technical Personnel		
	High-level		Middle-level	Junior-level		
Scientific research personnel	Research fellow	Deputy research fellow	Assistant research fellow	Research trainee		Management personnel and auxiliary personnel
Engineering professionals	Senior engineer		Engineer	Assistant engineer	Technician	Management personnel auxiliary and personnel
Agricultural professionals	Senior agronomist		Agronomist	Assistant agronomist	Technician	Management personnel and auxiliary personnel
Teaching personnel						
Universities, colleges	Professor	Associate professor	Lecturer	Teaching assistant		Management personnel and auxiliary personnel
Secondary specialized schools		Associate professor	Lecturer	Teacher	Teaching trainee	
Public health professionals	Director doctor	Deputy director doctor	Doctor in charge	Doctor	Assistant doctor	Management personnel and auxiliary personnel
	Director senior pharmasist	Deputy director senior pharmacist	Senior Pharmacist in charge	Senior pharmacist	Pharmacist	
	Director nurse	Deputy director nurse	Nurse in charge	Nurse	Assistant nurse	
	Director medical engineer	Deputy director medical engineer	Medical engineer in charge	Medical engineer	Assistant medical engineer	

Sources: Based on Que Weiming and Zong Jinzhi, ed., *Xiandai keji guanli cidian* [Dictionary of modern science and technology management] (Guandong: Guandong-gaodenjiaoyu-chubanshe, 1986), p. 609, and State Statistical Bureau, *Statistical Yearbook of China, 1986* (Oxford: Oxford University Press, 1986), p.759.

Fig. 2-6. R & D Expenditures by Research Subject

1. Land, marine, and atmospheric development and evaluation
2. Space development for civilian purposes
3. Development of agriculture, forestry, and fishery industry
4. Promotion of industrial development
5. Production, energy saving, and energy distribution
6. Development of transportation and communications
7. Development of Educational work
8. Development of public hygiene
9. Social development and social and economic services
10. Environment conservation
11. Development of public knowledge
12. Other civilian purposes
13. National defense

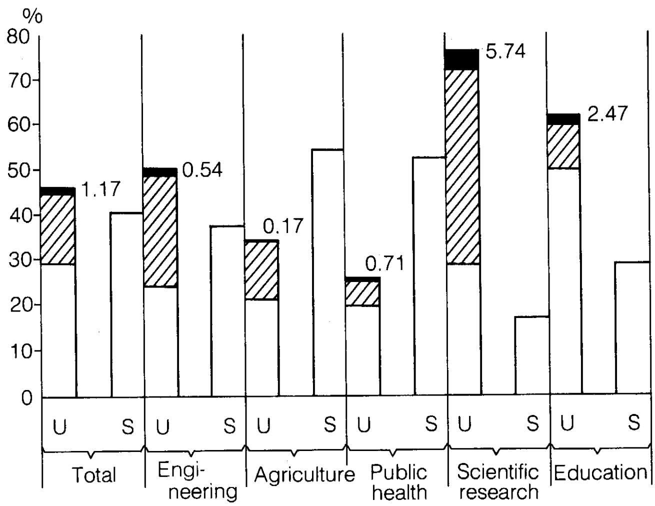


Source: State Science and Technology Commission, ed., *Zhongguo kexue jishu zhinan*, p.239.

OECD classification of scientific and technical statistics defines "researchers" as those who have a university diploma or scholastic knowledge of the same level as university graduates in their respective fields or have had a research careers of two years or more, and who are currently engaged in research with a specific goal. The Japanese Science and Technology Agency follows the same definition. The Chinese "research fellows" (*yanjiuyuan*), "deputy research fellows," and "assistant research fellows" who are all included under "scientific research personnel" generally correspond to Western and Japanese "researchers." "Engineers" as defined by the OECD generally correspond to China's definition of "engineering professionals" which includes "senior engineers," "engineers" (*gongchengshi*), and "assistant engineers."

Table 2-10 shows the breakdown of the natural scientific and technical personnel (NSTP). Figure 2-7 indicates NSTP in the state sector by position title and school career. Of a total of 8,250,000 persons classified as NSTP, 46.5 per cent are college graduates (including graduates from technical colleges), 40 per cent are secondary specialized school graduates, and 13.5 per cent are those having lower school careers. Only 0.43 per cent are those who have completed

Fig. 2-7 Composition of Natural Scientific and Technical Personnel in State-owned Units, 1986



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

Notes: 1. ■ : Share of senior natural scientific and technical personnel.
▨ : Share of secondary natural scientific and technical personnel.
2. U : Graduates of universities and other institutions of higher learning.
S : Graduates of secondary specialized schools.

post graduate courses. High- and middle-level title holders account for only 17 per cent of the total NSTP. This requires some explanation.

Before the Cultural Revolution people holding NSTP positions had carried various titles. But with the Cultural Revolution, those titles were abolished as part of a discriminatory status system. In this process many experienced scientists and researchers had their scholarly achievements and careers obliterated and were often assigned jobs having nothing to do with research.

From 1979 on NSTP began to be called back from the countryside where they had been sent for "rustication" and other purposes. They were called on to reconstruct the countries's R&D system. Technical titles were revived, but after a vacuum of ten years, it was extremely difficult to properly determine what titles and treatment people should be given. Often due to improper evaluations, many experienced researchers ended up ranked as junior title holders. To rectify this, a new adjustment measure was taken in 1985 mainly by promoting underrated personnel. Out of this readjustment China came to have 96,800 senior title holders, or 1.7 per cent of the total of NSTP in 1986. However most

TABLE 2-10
THE BREAKDOWN OF NATURAL SCIENTIFIC AND TECHNICAL PERSONNEL, 1986

	State-owned Units	Collectively owned Units	Total	As % of Total
Total	8,253,081	421,156	8,674,237	100
Engineering	3,581,226	146,909	3,728,135	43
Agricultural	465,201	22,749	487,950	5.6
Public health	2,225,633	251,498	2,477,131	28.6
Scientific research	365,754	—	365,754	4.2
Teaching	1,615,267	—	1,615,267	18.6

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

of these people are now well advanced in age having received university education in the 1950s or even before the liberation. According to the 1985 statistics, 88.35 per cent of the 78,200 senior title holders that year were above fifty years of age (55.5 per cent were more than fifty-six years old). Those under the age of forty-five accounted for only 0.93 per cent.[6]

An International comparison will better clarify the standing of China's R&D manpower. As already noted, "researchers" as defined by the OECD and the Japanese government generally corresponds to China's high-level "scientific research personnel" ("research fellows" and "deputy research fellows") and middle-level personnel ("assistant research fellows"). High- and middle-level research personnel numbered 158,200 in 1985 and 167,400 in 1986. (These figures cover only the state sector; but since there are few research personnel in the non-state sector, they can be regarded as virtually the national total). This meant that China had 0.153 researchers per 1,000 people in 1985 and 0.158 in 1986. The comparable figures for Japan in 1985 were 381,300 researchers or 3.1 per 1,000; for the United States, 790,000 or 3.3. The Soviet Union in 1984 had 1,460,000 researchers or 5.3 per 1,000; and Korea in 1985 had 41,473 or 1.01 per 1,000. It is quite apparent from these comparisons that China has an extreme shortage of researchers.

Added to this shortage is the irrational distribution of researchers, engineers, and other technical staff. In Japan and Western countries the majority of researchers are in industry. In Japan, for instance, 62.1 per cent of the researchers in 1986 were working at private companies, 8.0 per cent at research institutes, and 29.9 per cent at universities.[7] In China scientific and research personnel are heavily concentrated in research institutes and very few are working for enterprises, as Table 2-11 shows. Sixty to eighty per cent of the professors, senior researchers, and senior engineers belong to R&D institutes (including the Chinese Academy of Sciences) affiliated with various ministries of the central government.[8] Assuming that 17.5 per cent of China's scientific and research personnel, who totaled 336,400 in 1985, worked for enterprises, this would have meant

TABLE 2-11
WHERE SCIENTIFIC AND TECHNOLOGICAL PERSONNEL ARE ASSIGNED (%)

	Mining or Manufacturing Enterprises	Research Institutes	Universities
U.S.A. (1980)	68.5	11.3	15.4
Japan (1978)	56.3	10.2	33.5
USSR (1969)	7.7	55.7	37.0
China (1980)	17.5	81.6	0.9

Source: Li Xingquan and Mu Suping, ed., *Qiye yanjiu kaifa de zuzhi yu guanli* [Organization and management for research and development in enterprises] (Beijing: Kexue-jishu-chubanshe, 1986), p.11.

only 59,000 researchers for the nation's industries or only one researcher per 7.85 enterprises as China had 463,200 mining and manufacturing enterprises in 1985. This indicates an incredibly poor research capability in China's industry. Jilin Province is a case in point; 73.3 per cent of the local professional engineers are working for government agencies and projects and only 25 per cent for state-owned enterprises. The percentage of technical staff to total employees in the province is as follows: metallurgical enterprises, 4 per cent; machinery enterprises, 6.3 per cent; chemical enterprises, 3 per cent; light industrial enterprises, 3 per cent; and electronics enterprises, 8.4 per cent.[9]

The irrationality in the distribution of technical staff also causes mismatches between their specialties and their job assignments. According to a survey of 10,000 engineers in Shanghai, 20 per cent complained of such mismatches. Another 20 per cent said they were not assigned to any jobs or assigned to jobs below their capacities. Altogether, 90 per cent wished to transfer to proper jobs, but none had been able to.[10]

The degree of shortage in engineers and technical staff differs with enterprise size and region. The lower the echelon the more serious the shortage, and small and medium-size enterprises in the state sector suffer more seriously than the major state-owned enterprises. The situation is worse for collective enterprises, and village and town enterprises are in the worst situation.

Looking at how R&D personnel are educated and trained, China has two institutional systems of higher learning, namely general institutions of higher learning and institutions of higher learning for adults. The former comprise daytime universities, colleges, professional schools, and short-term professional universities; the latter includes TV universities, workers' high schools, peasants' high schools, cadres management colleges, educational colleges, and correspondence courses. Here we deal only with the general institutions.

As was explained in the first section of Chapter 1, the ratio of university students to the total population is very low in China.

In recent years the government has been endeavoring to strengthen higher education, but the number of annual university graduates in the 1980s has stayed at about the 500,000 level. In 1987 532,000 graduated from universities, 244,000 of them from natural science and engineering departments. In 1985 Japan produced 560,000 university graduates, including 142,000 from natural science departments (aggregate of university, two-year college, and professional college graduates).

Chinese higher education emphasizes the production of specialists at short-term professional colleges, rather than producing generalists. Priority is given to engineering because China wants to obtain personnel immediately useful for industrial construction. Figure 2-8 gives the composition of graduates from institutions of higher learning by discipline. As can be seen in the note, 35 per cent, or the largest group of the graduates from 1949 through 1985, were from engineering departments. The United States and Western European students in natural sciences tend to concentrate on the physical sciences and basic studies while Japanese students favor engineering. China shows a pattern similar to Japan.

In China more than half of the students are in natural sciences while in Japan it is only a quarter. Japan has more engineering students than the United States and Western Europe, but they represent only 16 per cent of the total number of students (1985) against 30 per cent or more for China. However, the ratio of physical science to engineering students are 1 to 6.8 in Japan and 1 to 5.3 in China making the share of physical science students slightly larger in China.

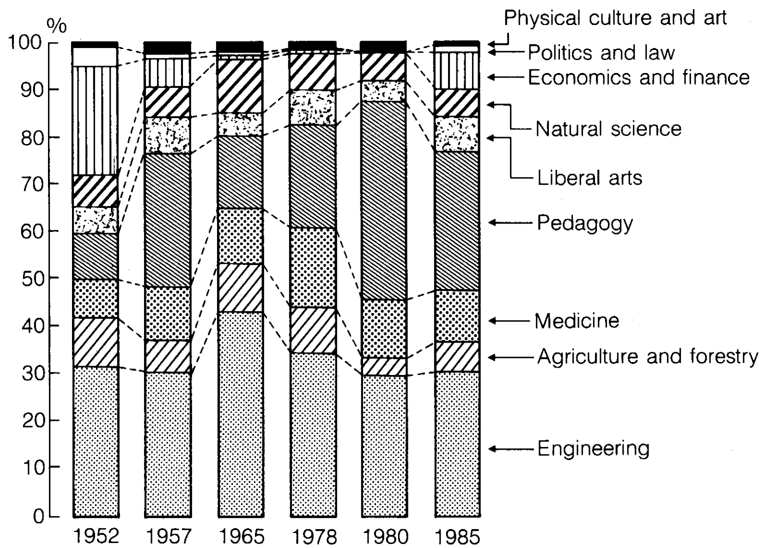
According to the *Statistical Yearbook of China, 1986*, the number of institutions of higher learning in China in 1985 and their breakdown were as follows:

Total number	1,016	Medical colleges	116
Comprehensive universities	43	Teachers colleges	253
Colleges of sciences and engineering	262	Colleges of economics and finance	62
Agricultural colleges	61	Others	219

In the past thirty years the number of comprehensive universities has remained about the same, but colleges of sciences and engineering have increased markedly.

The graduates of engineering schools constitute the single largest group of all graduates. Their fields of study are concentrated overwhelmingly in heavy industry, as seen from Table 2-12, primarily in the machinery industry sector. These graduates have traditionally been allocated in the order of priority to: (1) the defense industry, (2) heavy industry, and (3) light industry. This pattern of allocation directly reflects the sizes of technical staff retained by the three industrial branches. Light industry has suffered a chronic lack of engineers and

Fig. 2-8. Composition of Graduates of Institutions of Higher Learning by Field of Study



Source: State Statistical Bureau, *Zhongguo tongji nianjian*, 1986 edition.
Note: The cumulative number of graduates and their percentile by department from 1949 through 1985 are as follows: grand total 4,713,500 persons (100%); engineering dept. 1,630,200 (34.6%); pedagogy dept. 1,224,800 (26.0%); agriculture and forestry dept. 395,100 (8.4%); medicine dept. 557,700 (11.8%); liberal arts dept. 282,600 (6.0%); natural science dept. 337,500 (7.2%); economics and finance dept. 169,800 (3.6%); politics and law, physical culture, and arts depts. total 115,800 (2.4%).

other technical staff while the defense industry, given top-priority in staff allocation, complains of a plethora of technical personnel. Thus the coexistence of chronic shortfall and oversupply that characterizes many aspects of the Chinese economy is evident in the realm of R&D as well.

Reforms in the R&D System

The centralized R&D system transplanted from the Soviet Union in the 1950s served China's purpose of catching up with the more advanced countries. By concentrating R&D resources on the development of advanced weapons and

TABLE 2-12
NUMBER OF GRADUATES FROM ENGINEERING SCHOOLS AND THEIR FIELDS OF STUDY: THE TOTAL OF 1953–81

Total number	1,127,279		
	(%)		(%)
Geological	5.4	Foods	0.009
Mining	6.4	Light industry	2.1
Power	5.8	Land measurement, irrigation	1.0
Metallurgy	4.8	Construction	12.5
Machinery	26.7	Transportation	2.3
Electric machines and appliances	3.2	Communication	1.9
Radio technology and electronics	6.9	Others	11.1
Chemical industry	8.7	Not classifiable	1.2

Source: *Zhongguo jiaoyu nianjian, 1949–1981* [Chinese education yearbook, 1949–81] (Beijing: Zhongguo-dabaike-quanshu-chubanshe, 1984).

the introduction of domestic production for capital goods, China was able to make considerable progress in these areas. On the other hand, it almost completely ignored advancement in general industrial technology. This lack of interest was grounded in the system of "ownership by industrial ministries," a system which controlled R&D efforts vertically and bureaucratically. This system obstructed diffusion of technology and technological information, and the enterprise, which ought to be the main body to promote technological development, had little motivation to do so. Thus, despite all efforts, China's R&D investment efficiency at the macroeconomic level has stayed extremely low.

The big change in China's economic policy since 1978 has made it imperative to drastically modify the philosophy of R&D. It has become necessary to lessen dependence upon *gongguan* projects and to pay more attention to technological innovation, new product development, and quality improvement at the enterprise level.

Reforms in R&D were introduced as part of the urban economic management reform program launched at the end of 1984. This reform program is modeled after those of the Soviet Union and the East European countries. It is said that China learned from the Soviet experience about the formation of "science and production complex" and from Rumania concerning the commercial technology transfer.

The R&D system reform program was set forth in the Party Central Committee's decisions on the reform of the scientific and technological system published on March 13, 1985.[11] Laws, decrees, rules, and measures have since been introduced to implement the decisions. These are summarized and explained below.

Reform in R&D budgeting

To promote science and technology, state expenditures for this purpose will be increased proportionally with the growth of the Chinese economy. However, as a means of invigorating R&D activities, each recipient institutes should also develop new funding sources so as to maximize its own revenues for R&D. R&D cost management should follow the formulae shown below in accordance with the research tasks.

(1) Institutes for technological development

For those R&D institutes devoted mainly to application studies and technological development, state subsidies will be gradually phased out and finally eliminated in three to five years. These institutes are expected to depend for R&D funds on contractual incomes such as contract research, technology transfer, and technical information services.

(2) Institutes for basic research

The state will continue to provide institutes for basic research with a set amount of funds for management while research costs will be met by the science foundation. The science foundation is a funding body which obtains funds from the state budgetary savings resulting from the subsidy cuts mentioned under (1) as well as from the "science and technology expenditures on three items." In February 1986 the State Natural Science Foundation Committee was established as the body to receive and screen research fund applications.

(3) Public service-oriented institutes

The state will continue to provide funds to research institutes engaging in medical, hygienic, worker protection, family planning, disaster-prevention, and environmental sciences as well as to services involving information, standardization, measurement, and observation. These institutes however should operate within the limits of the budgets provided. Should there be deficits, the state will not bother compensation.

Since January 1987 the State Science and Technology Commission has assumed the sole responsibility for management of the science and research working expenses for the ministries. Likewise, the science and technology commissions of local governments take care of the science and research working expenses for local governments. These steps were taken to enhance the efficient use of expenses.

Technology as a commodity

To encourage technology transfer, technology has been recognized as a commodity and the Patent Law enacted to protect intellectual property rights.[12] To facilitate technological transfers a technology market has been set up, and such transfers should involve payment for the technology. Income earned through technology transfer will be tax-exempt if it is 100,000 yuan or less.

It has become legal for individual researchers to offer technological services including consultant service outside of their regular working time unless such services run counter to the interest of the institutes they belong to. The income thus earned belongs to the individual researcher.

The technology market was opened at the end of 1984, and in April the following year, the National Coordination Group of Planning Legislation for Technology Market was established as part of the State Council to facilitate technology trade. Then in June 1987 the Technological Contract Law was promulgated. Technological information centers were set up at the state and local levels to spread technological information. The centers make information available to the public and also offer consultant services.

Combining scientific research with production

Collaboration needs to be organized in various ways among R&D institutes, enterprises, and universities. A number of combinations have been suggested: technological development institutes could be merged with major enterprises or an enterprise group; enterprises and R&D institutes could set up joint ventures for technological development; design institutes and R&D institutes could collaborate in joint engineering ventures with related enterprises; and engineering departments of universities could operate pilot plants funded by major enterprises. All such projects are patterned after the Soviet Union's science and production complexes.

The research institutes and design institutes belonging to the State Council ministries were originally intended to serve the technological needs of their respective ministries, and therefore were prohibited from having direct relations with specific enterprises on grounds that such relationships would lead to the neglect of their proper duties. However, the State Council's new rules set forth in 1987 decreed that the ministry-based research institutes and design institutes are to be absorbed by large and medium-size enterprises or enterprise groups in order to strengthen the development capacities of large enterprises and to facilitate application of research results to production.[13] However, after absorption, these institutes still have the task of meeting the technological development needs of their respective ministries. Their former identity has thus been partly preserved, although the ministries however gradually reducing subsidies to these institutes in the expectation that the enterprises they now belong to will eventually take over full responsibility for them. A typical example of this type of merger is the one between the Panjihua Iron and Steel Institute, formerly owned by the Ministry of Metallurgy, and Panjihua Iron and Steel Mill. Similarly, the Changchun Automobile Institute, which belonged to the Ministry of First Machinery Industry merged with the Changchun No.1 Automobile Plant.

Strengthening of technological innovation capacities of enterprises

Intra-enterprise R&D organizations (design, research, and technological development offices) are being expanded in order to strengthen enterprise-level technological capacity. Depending on the size of the enterprise, intra-enterprise integrated institutes, specialized institutes, or product development institutes may be introduced.

The following measures are to be taken in order to make new product development and technical improvement affordable.

(1) Enterprises will set aside from their profits (retained profit) funds for production development, trial production of new products, and promotion bonuses. Money for production development is to be used mainly for raising the technological level of the enterprise while that for trial production is to be appropriated for development of new products. Promotion bonuses will be paid to workers for contribution to technological progress.

(2) Enterprises can apply for low-interest bank loans to develop new products. If a new product is recognized by the state, the enterprise can expect additional funds from the science foundation.

(3) An enterprise can recoup the raw material and personnel costs incurred in the development of a new product by adding them to the price of the product. The price of the new product is to be set in accordance with its quality (*youzhi youjia*, or "high quality, high price system"). A new product recognized by the government will be exempt from product taxes and value-added taxes for three years after marketing.

(4) An enterprise recognized as an economic unit which "endeavors to expand its autonomous decision-making power" can deduct from its pretax profits (sales) a certain portion (1 per cent) for its own R&D costs. Part of the "fund for fixed asset replacement and technological innovation" provided by the government can also be incorporated into the enterprise's R&D funds.

(5) To eliminate outmoded low-quality products, high commodity taxes will be levied on substandard products.

Expanding the autonomous powers of R&D institutes

Administrative intervention in research institutes will be reduced and powers of decision-making are to be transferred as much as possible from administrative bodies to the institutes. The system of transferring responsibility to the institutional directors is to be carried out so as to leave decisions on research planning, budgeting, personnel management, and staff organization to the institutes concerned. The research institutes and their members will be permitted to conduct their own R&D and technological service businesses.

Improving the management of scientific and technological personnel

The working and living conditions of scientific and technological personnel shall be improved. The technical title system is to be restored accompanied by proper remunerations for title-holders. Scientific and technological personnel shall be allowed to engage in more than one job, be permitted to mutually exchange knowledge, and be guaranteed the freedom of academic expression.

To promote the rational distribution of personnel, scientific and technological personnel are to be encouraged to move from major cities to inland areas, border areas, and rural villages; and from heavy and defense industries to energy, transportation, light industry, and agricultural branches. To accelerate this process promotional salaries will be paid and family registration obstacles removed.[14]

Reform in R&D systems in national defense

The following measures are to be taken to increase cooperation between military and civilian industries and to encourage the transfer of defense industry technology to the civilian sector:

(1) The Ministry of Ordnance Industry and the Ministry of Machine-Building Industry will be merged to form the State Machine-Building Industry Commission. Also, the weapons production by the Ministry of Nuclear Industry, the Ministry of Aviation Industry, and the Ministry of Astronautics Industry will be placed under the control of the State Council, thus integrating defense industries with the general framework of the national economy.

(2) Enterprises producing a single type of weapon will be reorganized for the production of both weapons and goods for civilian use, and some of them will be turned over totally to civilian production. To facilitate this process inter-enterprise coalitions are to be encouraged cutting across ministry and district lines.

(3) State managerial subsidies will be slashed for defense-related R&D institutes, and these will have to gradually increase their technological contract revenues. The savings on subsidies thus made are to be pooled by the Commission of Science, Technology and Industry for National Defence to be used for expenditures on defense R&D trial productions and for meeting general development needs.

(4) Defense technology belongs to the state, and its transfer to the civilian sector will be made free of charge.

Results of the Reform

These reform measures were quickly put into practice following the Party Central Committee's decisions on the reform of the scientific and technological system taken in 1985. The progress of budgetary reform is shown in Table 2-13, which indicates figures for 1986. As the state's science and research working expenses were reduced, their weight in the total expenditures of R&D institutes went down. R&D institutes had to seek out alternative sources for revenues turning technology transfer, services, and other so-called *hongxiang shouru* ("income earned from horizontal relationship between enterprises"). Financial independence had to be speeded up particularly for the R&D institutes of first-level regional administrative districts.

TABLE 2-13
COMPOSITION OF TOTAL REVENUE FOR R&D INSTITUTES, 1986
(100 million yuan)

	Number of R&D Institutes	Total Revenue (A)	Scientific and Technological Subsidies and Their Percentage of (A)	Technology Sales and Other Self-generated Revenue and Their Percentage of (A)
Above county-level institutes	5,271	110.42	71.22 (64.5)	n.a.
Institutes belonging to ministries under the State Council or the Chinese Academy of Sciences	1,044	70.97	48.83 (68.8)	14.55 (20.5)
of which: Institutes following technological contract system	472	41.49	7.63 (18.4)	7.51 (18.1)
Institutes having achieved economic independence	42	n.a.	0	n.a.
Institutes belonging to the first-level administrative districts	4,227	39.45	22.33 (56.6)	6.51 (16.5)
of which: Institutes following the technological contract system	1,438	18.4	3.61 (19.6)	4.69 (25.5)
Institutes having achieved economic independence	491	n.a.	0	n.a.
County-level institutes	3,369	2.13[a]	n.a.	n.a.

Source: The science and technology official report for 1986, *Keji ribao*, June 7, 1987.
Note: Total revenue includes not only scientific research subsidies from the state budget and sales of technology but also subsidies from the national science fund, bank loans, and other incomes.
[a] Total expenditure is shown here in lieu of total revenue which is not available.

The reform changes are shown by the sudden increase in the value of technology transactions. Since the national technology market was opened in 1984, technological transactions all over the country have increased very rapidly, reaching 700 million yuan in 1984, 2,370 million yuan in 1985, and 2,060 million yuan in 1986.[15] These figures indicate that R&D institutes have been rapidly casting away their passive attitude toward income earning and have started to actively sell their technologies and obtain research contracts. The figures also show that there is already a great potential demand for technology in the Chinese society and economy.

An opinion poll in 1986 on the effects of the reform on 379 independent research institutes gave the following results:[16] the reform (1) increased the number of subjects under research, 75 per cent; (2) raised the level of research, 61 per cent; (3) increased the number of difficult subjects being researched, 57.6 per cent; (4) increased the institute's autonomous power, 50.1 per cent; (5) raised the living standards of researchers and staff, 82.1 per cent; and (6) increased opportunities for researcher and staff training, 47.9 per cent. Number (1) above reflects the expanded earnings from technological contracts, and number (2) indicates that this expansion has a stimulus to research activities. The increased retained profits for manufacturing and mining enterprises have led to larger bonuses for workers and increased earnings for research institutes which show up in number (5) as improvements in the living conditions for the researchers and staff.

By 1986 more than 10,000 science and production complexes had been established, including 571 university-R&D institute-production complexes. It is now fashionable for enterprises to annex research institutes or set up their own research organizations in order to strengthen their own R&D capacities. Of the 379 enterprises 316 were sampled for data about their R&D organizations. Ninety-two per cent said they had set up their own R&D organizations of one kind or another.

Increasing personnel mobility is as important in promoting technology transfer as the technology market and information services. To promote mobility manpower interchange centers have been set up all over the country. Rationalization in personnel assignments is oriented toward rectifying the job mismatches caused by the system of "ownership by industrial ministries." It is to encourage the movement of personnel from overstaffed to understaffed sectors, and rectify the geographical imbalances in personnel distribution. National data show that by the end of 1985 the 1,203 manpower interchange centers across the country had interviewed about one million researchers and technological experts and helped 130,000 of them to move to new jobs.[17] This shows immediately how serious the job mismatch situation is in China today and how difficult it is to find proper jobs for qualified persons.

A survey of personnel movement from January through September 1985 at 350 independent research institutes produced the following results (the ratio of inflowing persons to 1 outflowing person):[18]

Total	0.84
R&D institutes in large cities	0.77
R&D institutes in medium and small cities	0.76
R&D institutes at the county level	2.58
R&D institutes in manufacturing and transport sectors	0.49
The Chinese Academy of Sciences	0.52
R&D institutes in the East China region	0.77
R&D institutes in Southwest and Northwest regions	outflow > inflow

The above table indicates a number of trends. First, there has been a net outflow of R&D personnel from urban areas into counties; this is in line with state policy requirements. Second, the manufacturing and transportation R&D institutes have suffered from a net outflow which runs counter to the state's policy of building up R&D capacities in industrial enterprises. Third, the human resources-rich East China region has lost personnel which is in harmony with state policy; however, the personnel-sparse Southwest and Northwest have lost personnel, a disappointment from the perspective of state policy point.

Contradictions during the Period of Transition

Legacies of the Old System

The Chinese R&D system currently suffers from various difficulties that characterize the transition period from the old to a new framework. One obstacle is the legacy of the old system of "ownership by industrial ministries" and "vertical, single-line control." Active personnel interchange between educational organizations, enterprises, and government agencies is a must for an environment conducive to higher research efficiency and better researcher ability. The United States for instance has a long tradition of collaboration between industry and universities, and the exchange of personnel between the two undoubtedly provides individual researchers with opportunities to develop their talents and abilities.

China is still at an early stage in the search for a system of properly assigning jobs, and as yet personnel mobility cannot be said to exist. This is a problem deeply rooted in Chinese society. Like the state-owned enterprise, the Chinese R&D institute is a rigid unit (*danwei*) of society. A researcher assigned to it is subject to the conditions and requirements of that institute, ranging from family registration, housing, and marriage to the children's education and job opportunities. In more open countries one takes into consideration the new working and living conditions offered when one is asked to transfer to a new job. But in China such conditions are fixed. Most Chinese researchers anticipate worse housing conditions at new jobs and greater difficulties in sending children to good schools, and thus hesitate to move to new units.

There are serious imbalances in the number of R&D personnel assigned to units. These exist between the center and periphery, the coastal region and inland, defense and civilian industries, heavy and light industries, and large and small enterprises. The former are always favored, a reflection of the wide disparities in living conditions when compared with the latter.

In the tightly controlled environment of the unit, a researcher who volunteers to transfer to another unit cannot move unless the authorities of the sending and receiving units agree on the transfer. The R&D institutes for their part lack motivation to encourage personnel interchange. Except for a few institutes partially self-reliant in funding, most R&D institutes had been taken care of by the state. The inertia of the past still lingers, and most institutes retain the habit of passively spending the allocated funds for the allocated projects. Even now research institutes continue to be strictly bound by detailed instructions from their higher echelon administrative units regarding the personnel strength, salaries, and other matters of staff, and lack discretionary powers to hire and fire in accordance to their own research needs.

Because of the difficulties involved in transfers, the central government has started to emphasize better social utilization of researchers by allowing them to take up sideline work during their free hours. But there is still a strong prejudice against researchers doing sideline work. Corruption charges are often brought by the unit leadership against those experts who, at the request of other enterprises or government agencies, have designed goods or make other contributions for remunerations. Such cases are frequently reported in the press.[19] The individual in China is not connected to his or her unit by contract, but is assigned to a unit which then totally manages the individual's life. This system has produced a closed society lacking the individual freedom to move and choose jobs. This aspect of Chinese society will need to be reformed if the country hopes to fully develop its R&D; the free movement and interchange of personnel and information are the premise for dissemination and diffusion of technology.

Another problem arising from the reform is that research has tended to become unduly utilitarian. The reform reduced by an average of 10 per cent the state's science and research working expenses for applied and development projects. Consequently research institutes now have to strengthen their dependence upon contract projects. A negative by-product of this is that they have been shifting emphasis to subjects bringing quick money and shunning high-level and long-term research projects. Predilections for *duan, ping, kuai* ("short-term, easy subject, quick returns") is now seen even in those basic research institutes which still receive the same amount of science and research subsidies from the government as before. They too wish to increase their revenues by doing such short-term projects.

For many years R&D institutes concentrated on advanced research programs (so-called *gao, jian, rui*, or "high, pioneer, and vanguard" projects) in order to obtain top-priority *gongguan* projects. In past years they were indifferent to production needs and market requirements. Compared with those times their new attitude is probably an improvement. In fact before 1978 only 20 per cent of the research results used to find applications in production, and now the rate is reported to have gone up to 60 per cent.[20] This high application rate is in all probability due to the preferential choice of R&D institutes for easily applicable subjects.

But the problem is one of whether there is a proper balance between applied and basic research projects. At a time when basic research still makes up a very small share of total research expenditures (Figure 2-5), Chinese researchers are increasingly orienting their work toward pragmatic or utilitarian studies. Wu Jinsheng, a professor of Chinese birth now teaching at Maryland University, strongly warned against this tendency in an article he wrote for the newspaper *Keji ribao* [Science and technology daily].[21] He pointed out that the now widely accepted slogan, "Science and technology must serve economic construction," put difficult pressure on Chinese scientists engaging in basic research. Wu went on to say that China should not too hastily carry out its science and research funding and expenditure reform. He emphasized the immediate need for an institutional reform that could fully utilize China's research personnel within the existing R&D structure. R&D institutes still do not have proper salary and job promotion systems, and the present salary and living conditions for researchers fall well below those for factory workers. The system of job titles is also not working adequately. For such reasons, Wu argued, promotion opportunities are few, the intra-unit atmosphere is stagnant, and the average age of researchers is going up. Overcoming these weaknesses which limit opportunities for the young and talented will require a general reform in the social system.

Another problem plaguing the reform process is the insufficiency of managerial personnel who can cope with the current scientific and technological requirements at the enterprise level. This problem is gradually being dealt with as relatively young people in their forties with high educational backgrounds and competence in managerial and technological matters are increasingly appointed as plant managers and chief engineers.[22] This is in line with the central government's policy of rejuvenation.

Defects in the Incentive System at the Enterprise Level

Most enterprises still use total output and total output value as the most important production guidelines, and incentives (retained profits and researcher and staff incomes) are linked with these. New product development and quality improvement are not sufficiently linked with enterprise interest as the price system is skewed and market mechanisms are immature.

The predominance of quantitative indicators is a legacy of an economy of short supply. According to a 1986 survey on 100 steel, machinery, chemical, electronics, and light industrial enterprises across the country, 48 per cent of them were producing goods which were in short supply, 38 per cent were producing goods whose supply and demand were balanced, and only 14 per cent had to worry about oversupply.[23] Thus close to half of the enterprises could expect profits without any marketing effort. This means that there is little incentive for technological innovation.

The large state-owned enterprises manufacturing standardized products prescribed in the national economic plans are always under great pressure to achieve their assigned quantitative goals but are not sufficiently motivated to improve their products. Though the technology market is functioning and stimulating technology transactions, very few large state-owned enterprises are active in such transactions. In contrast, small enterprises and collective enterprises (including village and town enterprises) are active in developing new products and introducing new technology. Since most of their products are for sale in the marketplace and not purchased by the state, they have to take strong interest in developing new goods to meet consumer needs. They are the main participants in the technology market.

The large state-owned enterprises do establish their own R&D institutes out of fear that they may be left behind the scientific and technological reform, but given the existing institutional framework, such institutes are not working effectively as many survey reports have pointed out. Complaints persist that large enterprises do not accord their research institutes and staff proper treatment. Therefore opposition exists to the policy of encouraging merger between independent research institutes and state-owned enterprises.

Shortage of Fund for Enterprise-level Technological Innovation

The ongoing funding reform program which allows enterprises to retain funds for new product development and R&D is meant to encourage enterprise to engage more actively in product development and technological innovation. Despite the reform, however, Chinese enterprises suffer from a scarcity of funds for technological development. Chinese newspapers and magazines often deal with this issue, and the present author found the same situation while visiting twenty-five enterprises in the Northeast and Southwest regions during 1986 and 1987.

Under the present system, the profits of state-owned enterprises are divided as shown in Figure 2-9. Higher echelon administrative agencies are in the habit of appropriating large portions of these profits for themselves. These agencies often act as though enterprise profits were their own pocket money. Added to this is the much too heavy tax burden on state-owned enterprises as well as the local administrative functions required of them such as providing housing, medical services, education, and cultural services for their researchers and staff. The money for these expenditures come out of the "enterprise fund." Though 10–15 per cent of pre-tax profits are permitted to be retained as the enterprise fund, the actual amount available for its own development is far smaller than the nominally allowed enterprise fund.

Under pressure to expand production and to meet social costs from their own finances, enterprises are inclined to appropriate funds more for the expansion of short-term production capacity and for increased welfare to its researchers and staff rather than for R&D on a long-term basis. This is indeed a problematic situation, and to rectify it the government is using its influence to have state-owned enterprises earmark 1 per cent of their sales for R&D. This author inquired into this matter at the enterprises he visited, and all invariably answered

Fig. 2-9. Allocation of Gross Profit by Machinery Enterprise

10–17%	Value added tax (applied to enterprises in the machinery industry as of 1982; levied on sales; tax rates differ in accordance with business category)		
45–55%	Income tax (this replaced profit payment)		
10–13%	Adjustment tax (levied on enterprises obtaining large profits due to their paticularly high product prices)		
7–8%	Energy, communications funds, and others (pooled as state funds and used for energy development and road and railway construction)		
10–15%	Enterprise fund	Production development fund (including new product development fund)	40–50%
		Welfare fund for staff and workers; Promotion bonuses fund for staff and workers	50–60%

Note: Based on interviews this author had in 1986 and 1987 during his visits to machine entrprises in the Northeast region.

that they were using 1 per cent of their sales for R&D. One per cent is indeed a very low figure when compared with R&D investments in advanced industrial countries. But some argue that 1–2 per cent is a proper level given the low level of development for Chinese industry and the extreme financial difficulties it faces.[24] But in setting a 1 per cent of sales limit for R&D, the government has made a unilateral decision for the whole country irrespective of the actual needs of the individual enterprises and thus daddling them with yet another serious limitation on research.

Personnel Shortage at Enterprises

As already mentioned, researchers and experts in China are distributed very thinly and unevenly among the country's enterprises with most of them concentrated in government-run research institutes. In 1986 150,000 researchers were working for R&D organizations inside enterprises, or a mere 17 per cent of the total research personnel for the country. Moreover, enterprise-based researchers are not accorded proper treatment, and there are many reports of leading researchers aged thirty to fifty preferring to move to independent R&D institutes controlled by the government.

The quality of the work force at state-owned enterprises is not satisfactory either. The majority of the workers at large and medium-size state-owned enterprises are junior middle school graduates. This was also true of the large enterprises this author visited. The schooling of workers at small and collective enterprises is lower still. The poor education level is due to the general backwardness of Chinese education as well as to the Cultural Revolution which kept the education system in shambles for a decade. According to statistics for 1986, only 1,052 out of the 2,023 counties in China, or 52 per cent, had put into effect the compulsory nine years of education called for by the government.[25]

During the 1980s a large number of young unskilled people have been allowed to join factories as *dingtigong* ("substituted workers") to take over the jobs of their retired fathers or mothers. This has further lowered the technical level of the Chinese work force. With the large number of unskilled young workers, enterprises have had to conduct not only professional training but also provide basic education. This has been another heavy burden on enterprises.

The low skill level of the work force also determines the way an enterprise must organize its labor for production. State-owned enterprises still rely on the "production fractionizing system" in order to maintain stable orderly production with low-skilled workers. Imported from the Soviet Union in the 1950s, the system divides the production process into small segments each being assigned to an individual worker as his or her portion of responsibility. Enterprise managers continue to regard the system as indispensable, but one of its negative byproducts is the inevitable proliferation of intra-enterprise organizations. This leads to complicated systems of management, bureaucratization, and their resultant intricate operational procedures. It is extremely difficult for the fractionizing system to react promptly to changing circumstances. For instance, should there be a proposal for technical innovation, it must be submitted in accordance with a prescribed regulations, and then be screened by the technical, financial, and raw material sections, before it can get final approval. This can be a discouragingly long bureaucratic process. The shortage of professional engineers and skilled workers and the low technical level of workers are major reasons why Chinese enterprises are not enthusiastic about technical innovation.

Before 1985, the year the scientific and technological reforms began, an enterprise would simply wait for a new blueprint to descend from the design institute of its supervisory organization. The enterprise was responsible only for the interim-test of the new product and the production of the final product. In a Japanese factory, the usual procedure is for the original blueprint to be tested and revised to make it better suited to actual production processes. In talks with Chinese managers, this author found that there was no such practice in Chinese enterprises. In the factories this author visited in 1986 and 1987, higher echelon supervisory organizations generally ceased to deliver blueprints to the factories though some major factories and major products were exceptions.

Despite the strong push for technological innovation, Chinese enterprises generally have not found ways to do it. This is partly because there are still institutional constraints but also because they do not have enough capacity for innovation. There is also the urgent need to reduce the unduly heavy social and economic obligations that now burden state-owned enterprises and encourage them to take on greater decision-making autonomous powers as economic units.

A Case Study of Tianjin

In the previous sections of this chapter, we examined the Chinese R&D situation from a macro point of view. In this section, we will look at the situation existing at the micro level.

In July and August 1988, this author in collaboration with the Industrial Economic Institute of the Tianjin Academy of Social Sciences conducted a questionnaire survey of 300 small and medium-size enterprises in and around Tianjin. The purpose of the survey was to investigate the impact that competition and market principles introduced by the current reform program have been having on Chinese enterprises and to see how they have been responding to the new realities. The survey was wide-ranging, but here we will be dealing with only the results related to R&D.

The breakdown of the 300 enterprises by ownership and type is shown in Table 2-14. The collective enterprises include thirty-five village and town enterprises. The industrial categorization follows the ministerial division.

Engineers

The percentage of technical staff (engineers) out of the total number of employees was as follows (average for each ownership category):

State-owned	Collective		Joint Venture	Private Ownership
	Total	Village & town		
7	5	3	11	6

Industry-wise, the percentage of engineers was 10 per cent for electronics, 9 per cent for pharmaceutical, 7 per cent for chemicals, 7 per cent for machinery, and 5 per cent for the metallurgy, textiles, light industry, automobiles, and construction materials.

The shortage of engineers is a chronic headache for all levels of enterprises, but management had different perceptions of the problem as shown in Table 2-15. State-owned enterprises are relatively privileged in manpower allocation, nevertheless 66 per cent of them complained about shortage of engineers.

The quality of engineers was also not satisfactory. The education level of existing engineers is given in Table 2-16.

The mainstay of a research organization's engineering staff are the graduates from technical colleges. From the table it can be seen that about half of the engineers were graduates of secondary specialized schools or lower level schools. Village and town enterprises as well as joint-venture enterprises had many high-level engineers because knowing their future depends upon technical know-how and innovation they are very eager to invite good engineers to work with them.

Enterprises were divided over whether or not their engineers were fulfilling their roles. Of 297 respondents, 173 (58 per cent) answered in the affirmative and 124 (41 per cent) in the negative. Enterprises not satisfied with their engineers gave the following reasons in order of frequency: 1. capacity as engineers not enough; 2. not active enough because they are not well treated; 3. insufficient schooling; 4. insufficient leadership exhibited by enterprise managers.

Looking at the R&D system and the changes in Tianjin following the Party Central Committee's 1985 decisions on the reform of the scientific and technological system, the aim of the reforms was to increase the mobility of engineers and researchers thereby enabling the state to utilize them more effectively. This was to overcome the defects in the system of "ownership by industrial ministries." At the time of our survey in Tianjin in 1988, engineer-hiring practices were still heavily weighted in favor of the traditional administrative allocation method (42 per cent). This was followed by enterprises that recruited on their own (26 per cent), and then by enterprises that asked engineers working for other institutions to do jobs for them also (13 per cent). Joint-venture enterprises and private enterprises of course have to recruit engineers for themselves, but state-owned enterprises still got 54 per cent of their engineers allocated by the state. Even collective enterprises got 35 per cent through the state allocation system, and state-allocated engineers formed the largest group of technical personnel in these enterprises. These results indicate that while hiring patterns have diversified to a certain extent, enterprises still depend heavily on the allocation of technical personnel by the state.

It is still not easy for an engineer to leave his job unit and move to another. If he does leave, he can do so either by *diaochu* or by *lizhi*. The former is a transfer where the old and new job units have agreed on the transfer and the person leaving moves into an already secured job. The latter simply means that a person quits his job.

The enterprise regards an engineer as a precious asset, and so it considers

TABLE 2-14
THE 300 SURVEYED TIANJIN ENTERPRISES BY OWNERSHIP AND TYPE

A. Forms of ownership

	State-owned	Collective	Joint Venture	Private Ownership
No. of enterprises	152	128	15	5

B. Types of industry

	Metallurgy	Chemical	Textiles	Machinery	Electronics
No. of enterprises	20	46	47	47	29

	Light Industry	Pharmaceutical	Automobile	Construction Materials
No. of enterprises	89	9	5	8

TABLE 2-15
THE DEGREE OF SHORTAGE IN ENGINEERS AS PERCEIVED BY MANAGEMENT (%)

	Total	State-owned	Collective		Joint Venture	Private Ownership
			Total	Village & Town		
Engineers are:						
enough	9	12	6	9	7	0
short	66	55	78	71	64	60
not too few	25	33	16	20	29	40

Note: 299 respondents.

TABLE 2-16
THE EDUCATION LEVEL OF ENGINEERS (%)

	Total	State-owned	Collective		Joint Venture	Private Ownership
			Total	Village & Town		
University	10	12	4	24	33	20
Technical college	41	51	31	50	40	0
Secondary specialized school	27	27	30	14	13	20
Senior middle school	12	3	23	7	7	40
Junior middle school	6	1	10	5	7	20
Others	4	6	2	0	0	0

his transfer to another enterprise an unacceptable conduct. The engineer on his part also finds it very difficult and unusual to move to another unit since the unit he belongs to provides housing and other facilities, and usually takes care of the whole family. Table 2-17 shows how little movement there has been among the engineers in Tianjin.

There are few who quit their jobs (*lizhi*). In this survey which covered 300 enterprises, 275 experienced no engineers quitting and only 24 had such experiences. The average per enterprise was 0.15 engineers quitting their jobs.

In conclusion, there are still obstacles to the mobility of engineers in Tianjin. Probably the "unit-based system" of Chinese society itself needs to be reformed if mobility is to be increased for effective utilization of technological talent.

Technology Transfer

Technology is now considered a commodity, and the government is encouraging commercial technology transfers. The inter-enterprise transfers and purchases of technology in Tianjin in recent years are shown in Table 2-18.

For decades state-owned enterprises had the understanding that the introduction of new technology simply meant a new blueprint delivered to them from their supervisory organization. Technology transfer between enterprises was an idea totally alien to them. Now that they cannot expect any blueprints handed down, they have to get their needed technological know-how by purchasing it. Table 2-18 shows that half of the enterprises have purchased technology or otherwise experienced technology transfer, and this indeed represents a major change. But the same figure shows that the other half have had nothing to do with technology transfer.

Vast quantities of technology are available from overseas. To the question on whether or not foreign technology had been purchased, 292 enterprises responded to the survey, and their answers are shown in Table 2-19.

Overall more enterprises answered no than yes, but a fairly large number of state-owned enterprises had introduced foreign technology, probably reflecting their greater access to foreign exchange. It is no surprise that joint-venture enterprises have actively introduced foreign technology, but it is surprising that as many as 65 per cent of village and town enterprises have done so. These enterprises have shown themselves strongly interested in introducing technology; nevertheless the figure seems incredibly high, and this author has reservations about the accuracy of their responses.

Table 2-18 indicates that only 50 enterprises covered in the survey had purchased technology from other Chinese firms. By contrast, as many as 134 enterprises replied that they had bought foreign technology. This may indicate that the domestic channels of technology transfer are clogged, and Tianjin enterprises are compensating for this weakness by purchasing foreign technology.

TABLE 2-17

NUMBER OF ENTERPRISES WHICH RECRUITED ENGINEERS AND ENTERPRISES WHICH HAD ENGINEERS LEAVE

Enterprises Recruiting Engineers	No. of Engineers Recruited	Enterprises Having Engineers Leave	No. of Engineers Leaving
95 (36%)	0	119 (48%)	0
87 (32%)	1–5	82 (33%)	1–5
34 (13%)	6–10	29 (12%)	6–10
50 (19%)	11–	18 (7%)	11–
266 respondents		248 respondents	

Note: Figures represent the number of engineers recruited or leaving during the several years before 1988.

TABLE 2-18

THE NUMBER OF INTER-ENTERPRISE TRANSFERS AND PURCHASES OF TECHNOLOGY

	Total	State-owned	Collective		Joint Venture	Private Ownership
			Total	Village & Town		
1. Enterprises having transfered technology to others	91	56	2	2	2	0
2. Enterprises having purchased technology	50	22	26	5	1	1
3. Enterprises having done neither	148	65	74	22	6	3

TABLE 2-19

ENTERPRISES PURCHASING/NOT PURCHASING FOREIGN TECHNOLOGY

	Total	State-owned	Collective		Joint Venture	Private Ownership
			Total	Village & Town		
Yes	134 (46)	81 (54)	41 (33)	26 (65)	11 (73)	1 (20)
No	158 (54)	68 (46)	82 (67)	14 (35)	4 (27)	4 (80)

Note: 1. 292 respondents.
2. Figures in parentheses are percentages.

TABLE 2-20

ENTERPRISES POSESSING/NOT POSESSING THEIR OWN R&D ORGANIZATIONS

	Total	State-owned	Collective		Joint Venture	Private Ownership
			Total	Village & Town		
Yes	196	108	82	26	4	2
No	94	39	42	15	10	3

Note: 290 respondents.

When asked if the foreign technology had been utilized, the 134 enterprises gave the following answers:

Failed to utilized it	3 enterprises,
Only insufficiently utilized it	56 enterprises,
Fully utilized it	56 enterprises,
No answer	19 enterprises.

Enterprise Organization and Expenditures for R & D

To our question, "Does your enterprise face pressure for technological innovation?" 283 enterprises answered yes and 11 answered no. Asked in which areas the pressure is most keenly felt, 86 per cent mentioned new product development and 58 per cent quality improvement. If results are limited only to village and town enterprises, then the percentage giving these two answers rises even higher.

When asked what they were doing to cope with such pressure and step up their R&D efforts, the enterprises answered that the government was urging them to set up their own R&D organizations to enhance their technological capacity. This advice seems to have been taken seriously as indicated by Tables 2-20.

Of the 300 enterprises, 196 (65.3 per cent) had set up their own specialized R&D organizations. This could indicate their strong interest in technological innovation. But they might have set up such organizations simply to honor government policy. How active and effective these organizations are is still to be seen.

Concerning R&D funding, 189 enterprises said that funds were insufficient; only 63 said that they were sufficient. A shortage of funding was felt generally by enterprises of all types of ownership.

Given this general shortage of funding, it would seem that enterprises are willing to spend more on R&D than they are allotted. Is this true? The government policy is to let enterprises set aside a certain percentage (the percentage differs according to industry but usually 1 per cent) of the sales for R&D or to accumulate a certain percentage (10 per cent in the case of Tianjin) of the retained profit as "trial manufacture of new products" or "new product development fund."

For the 300 enterprises in Tianjin, the development fund / sales ratio varied from 0.1 per cent to 5 per cent depending on the kind of industry. The average was 0.5 – 1.5 per cent. The close correspondence of this average with the government's guideline figure of 1 per cent seems best explained as resulting from most enterprises automatically putting the guideline amount from sales income into R&D funds rather than from any need felt by enterprises to spend the funds for R&D. What this author learned from interviews was that at most of the enterprises the funds subtracted from sales in order to satisfy the government rule were used for other purposes such as investment in new equipment. Actual R&D expenditures were far smaller than the amounts earmarked for the purpose.

The reforms in the scientific and technological system are part and parcel of the Chinese government's effort to accelerate the country's industrial and technological progress. The government in fact has been whipping the state-owned enterprises to make them pay more attention to technological innovation. Consequently, as the Tianjin case shows, a major change has been introduced into the environment surrounding enterprise technological reform. The introduction of competitive markets has impelled enterprises to take a stronger interest in technological progress. But the Chinese market remains a seller's market, and most enterprises still lack a real sense of urgency over the need to make technological reforms. And those that do sense the urgency are frequently ill-equipped with the required technological personnel. As a consequence the government's effort thus far has not produced the desired results.