China's Science & Technology Policy and the Implementation of Technology Transfer

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ABSTRACT

China's scientific development has gone through several phases over the past 50 years, In 1956, the first generation of leaders called on the whole country to "march towards science," drafting China's first scientific development plan. The country made considerable progress in atomic energy, electronics, semiconductors, automation, computing and rocket-launching technology. In 1978, the then Chinese leaders sponsored a national science conference and mapped out scientific development strategies for a new period of reform and opening-up policies. China has accomplished more than 460,000 major scientific and technological achievements since then, 20 per cent of them reaching world advanced levels. In 1985, the central government issued a "Decision on the Reform of Scientific and Technological Systems," with the aim of accelerating the application of technological discoveries to promote productivity. Since then, China has implemented a series of projects to spur the take-off of the rural economy through technological innovation as well as developing high-tech industries. upgrading traditional industries, enhancing basic research, commercializing applied technologies and advancing technological innovation. In 1995, at a national conference on science and technology, the Chinese leaders put forward the strategy of "revitalizing the country through science, technology and education." The central government listed this strategy along with the policy of sustainable development as the basic principles for China's long-term economic and social development.

Technology Transfer has been considered by Chinese leaders as a main measure to obtain updated cutting-edge technology in the global market. Joint imports by research institutes and manufacturers began to replace unilateral imports by companies. The main usage of the imported technology will be shifted from the production and the replacement of China-invented technology to international co-operation. The case study on TiO2 technology transfer illustrated in this thesis demonstrated the trend.

SOMMAIRE

Le développement scientifique de la Chine a connu plusieurs phases depuis 50 ans. En 1956, la premiè re génération de dirigeants demanda au pays de 'marcher vers la science', en rédigeant le premier plan de développement scientifique. Le pays fit des progrè s considérables dans les domaines de l'énergie atomique, de l'électronique, des semi-conducteurs, de l'automatisation, des ordinateurs et des missiles.

En 1978, les dirigeants d'alors mirent sur pied une conférence scientifique nationale et préparè rent des stratégies de développement scientifique pour une nouvelle période de réforme et d'ouverture. La Chine a connu plus de 460,000 réalisations scientifiques et technologiques majeures depuis lors, dont 20 % avaient une portée mondiale.

En 1985, le gouvernement central émit une 'Directive sur la Réforme des Systè mes Scientifiques et Technologiques' avec l'objectif d'accélérer l'application des découvertes technologiques pour augmenter la productivité. Depuis lors, la Chine a mis en oeuvre une série de projets pour accélérer le développement de l'économie rurale par l'innovation technologique; ces projets visaient aussi à développer les industries de haute-technologie, mettre à jour les industries traditionnelles, améliorer la recherche de base, commercialiser les technologies appliquées, et avancer l'innovation technologique.

En 1995, à une conférence nationale sur la science et la technologie, les dirigeants chinois mirent de l'avant une stratégie pour 'revitaliser le pays par la science, la technologie et l'éducation'. Le gouvernement central a placé cette stratégie et la politique de développement durable comme principes de base pour le développement économique et social de la Chine.

Les Transferts Technologiques sont considérés par les dirigeants chinois comme un élément-clé pour obtenir les technologies de pointe sur les marchés mondiaux. Les importations conjointes par les instituts de recherche et les manufacturiers commencèrent à remplacer les importations unilatérales par les compagnies. L'utilisation principale de la technologie importée évoluera de la production et du remplacement de la technologie chinoise vers une coopération internationale. L'étude de cas du transfert de la technologie du TiO_2 présentée dans cette thè se démontre cette tendance.

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Table of Contents

Abbreviations

CAS	Chinese Academy of Science
CAE	Chinese Academy of Engineering
GCF	General Chemical Factory of Fuzhou
GNP	Gross National Product
IPR	Intellectual Property Rights
IT	Information Technology
IME	Institute of Mechanical Engineering
j-v	Joint Venture
MST	Ministry of Science and Technology
NDSTIC	National Defense Science, Technology, and Industry Commission
NBS	National Bureau of Statistics
PLA	People's Liberation Army
PRC	People's Republic of China
R & D	Research and Development
RMB	*Ren Ming Bi*
SAS	Soviet Academy of Sciences
SIPO	State Intellectual Property Office
SRI	Stanford Research Institute
SRIC	Stanford Research Institute Consulting
STLG	State Council's Leading Group
TiO2	Titanium Dioxide
UN	United Nations
USSR	Union of Soviet Socialist Republics
WTO	World Trade Organization

Introduction

1.Introductory

Since 1949, China has made impressive achievements in many fields of science and technology. Although China is still a low-income, developing country in the 1990's, it has by its own efforts developed nuclear weapons, the ability to design and produce a variety of orbital vehicles, a supercomputer, and two-line hybrid rice[1]. In 1999, China became the third country in the world to launch spacecraft. The development of science and technology, however, has been uneven, and significant achievements in some fields are matched with low levels in others.

For more than a century, China's leaders have called for rapid development of science and technology, and science policy has played a greater role in national politics in China than in many other countries. Since 1956, six national science and technology development plans have been launched.[2] "We should vigorously push forward the development and application of high and new technologies, which are crucial to China's modernization drive and future prosperity." China's Premier Zhu Rongji said on the occasion of the National Congress of Science & Technology Innovation on Aug 1999 in Beijing. China will commit more efforts to technological innovation and the development of advanced technologies to improve the country's comprehensive strength and bolster its position in

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[1] *Cox Report :A Complete Fabrication* (07/16/99, *China Daily*). "In fact, China's space sector has independently accomplished development from scratch to the world's most advanced level by totally relying on its own scientific forces. Under the circumstances of an all-round blockade and embargo imposed by the United States and other Western countries, China successfully developed intermediate and short-range missiles in 1964, and succeeded in launching its first man-made earth satellite in 1970 and a recoverable satellite in 1975. There were further developments between the late 1970s and the early 1980s. For example, China successfully launched a long-range rocket into the Pacific Ocean in 1980, and a solid-propellant rocket from a submarine in 1982, and further inserted a communications satellite into a geostationary orbit in 1984. These achievements had all been made before China entered the international commercial satellite launching market, and, again, were accomplished without any foreign assistance."

[2] *The Abstract of Our Country's Science and Technology Development Plan since 1949(in Chinese).*

global competition during the next century.[3]

Uneven development, wide variation in quality of work, a high level of involvement with politics, and a high degree of policy discontinuity have been the marks of science in China. The only areas of Chinese science that reflect a concentration of resources are those with military applications. Another distinctive characteristic is the combination of evolving structure of science and frequent reversals of policy.

China's leaders have involved themselves in the formulation of science policy to a greater extent than have the leaders of most countries.[4] Science policy also has played a significant part in the struggles between contending leaders, who have often acted as patrons to different sectors of the scientific establishment.[5] Party leaders, both previous non-scientifically trained and members of the present technological bureaucracy, have taken science and scientists quite seriously, seeing them as keys to economic development and national strength. Party efforts to control science to "serve production" and generate economic and military payoffs, however, have met with repeated frustration. The frustration in turn has contributed to frequent reversals of policy and has exacerbated the inherent tension between the scientific and political elite over the goals and control of

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http://www.most.gov.cn/

[3] Dian Tai, *Technology to Push Prosperity* (08/27/1999, *China Daily*)

[4] *Premier Pushes Science and New Technologies* (01/04/99 . *China Daily*). "The premier, who also heads a government leading group for scientific and technological education made the remarks during the group's third meeting, held in Beijing on Thursday. He emphasized that the rapid expansion of contemporary science and technology has fully demonstrated the correct scientific foresight of Deng Xiaoping and his contention that 'science and technology are the primary productive forces. Resolving deep-seated contradictions and problems in economic restructuring and development will depend on improving the level of science and technology and innovation, as well as on improving scientific and technological education. These efforts will determine the extent of the gap between China and developed countries,' according to the premier."

[5] Organization for Economic Co-operation and Development, *Science and Technology in the People's Republic of China, Chapter 1: the Policy Context*, 1977, pp. 19-36.

the nation's science and technology. In any economic system, there are likely to be tensions and divergences of interest between managers and scientists, but in China such tensions had been extreme and had led to repeated episodes of persecution of scientists and intellectuals. In the post-Mao era, the anti-intellectual policies of the Cultural Revolution had been reversed by senior leader Deng Xiaoping, who encouraged the development of science and technology.

China's leaders in 1990's, however, remained, like their predecessors over the past 100 years, interested in science primarily as a means to achieve national strength and economic growth. President Jiang observed: "To establish China's position in the fiercely competitive international arena and ensure its sovereignty and safety, we should spare no efforts to develop science and technology and build up our own technological expert teams."[6] The goal was the creation of a vigorous scientific and technical establishment, which would operate at the level of developed countries, while contributing in a fairly direct way to agriculture, industry, and defense. Since the mid-1980's we have witnessed a major effort in China to reform the scientific and technical system through a range of institutional changes intended to promote the application of scientific knowledge to production.

In late 1999, the Central Committee of the Communist Party of China and the State Council made a joint announcement in Beijing calling for greater efforts in technological

[6] Dian Tai, *Technology Revives Nation* (08/24/1999, *China Daily*). "Nowadays, one nation's level of technological innovation and application of advanced technologies decides its comprehensive national competitiveness. "To establish China's position in the fierce international competition and ensure its sovereignty and safety, we should spare no efforts to develop science and technology and build up our own technological expert teams," Jiang said. The stretch of time between now and the end of the first decade in the next century will be a crucial period for China. Jiang pointed

innovation and high-tech research and development, as well as the commercialization of new technologies. Challenges for China exist in areas ranging from industrial readjustment, rural economic development and revitalization of State-owned enterprises, which all call for solutions backed by technological innovation. The new policies provide guidelines and outline measures regarding infrastructure construction, investment in scientific research, venture capital, technology transfer and other issues crucial to sharpening the country's technological competitiveness. Simultaneously, China's accession to the WTO will open China's high-tech markets to the U.S.A, among others. The new policy calls for implementing a strategy of rejuvenating the country through science, technology and education in a bid to promote the construction and development of China.[7]Throughout the twenty-first century, China's political leaders have had a deeply ambivalent attitude toward science and technology, promoting it as necessary for national defense and national strength, but fearing it as a carrier of threatening alien ideas and practices.

In order to analyze China's science and technology policy, in particular, the implementation of technology transfer, the thesis consists of six chapters. The introduction states the rationales and the objectives of the research, which involve the research method and resources used in this thesis. The first chapter addresses historical development of science and technology policy. In this part, the segment before 1984 will be periodized with an explanation of technology policy in each of the periods. It briefly

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out."

[7] *Zhu Stresses Development in Drafting Five-Year Plan* (10/20/2000, *China Daily*). ""In order to narrow the gap between China and the developed countries and increase comprehensive national strength, we have to use the advancement of science and technology as another strong driving force, further implement the strategy of revitalizing the nation through science and education, accelerate advancement and innovation of science and technology."

introduces Pre-1949 Patterns, Soviet Influence in the 1950's, "Reds" Versus "Experts" in the 1950s and 1960s, the Cultural Revolution 1966-1976, and Rehabilitation and Rethinking, 1977-84. The second chapter focuses on Science and Technology in the 1980's and 1990's, including the Supply of Skilled Manpower, Research Institutes, National Organization and Administration, Integration of Administrative Systems, and International Ties. The third chapter evaluates the Shortcomings of the Science and Technology System Before the Reforms, The "863" Project, Readjustment Policy in the 1990's, and Innovation and Customization of Science and Technology in the late 1990's and 2000. The fourth chapter places emphasis on the Policy, Modes and Linking with Economics of Technology Transfer. The fifth chapter will study a case of technology transfer. In the last Chapter I will present my own views and a comprehensive conclusion.

2. Research Method and Resources

In order to fulfill the requirements for this thesis, I shall combine historical phase review method with case study to state the policy of China's science and technology and the implementation of technology transfer. Resources are from books, journals, newspapers, government's documents, web sites, related firm documents, agreements, faxes, e-mails and personal files.

It is important to note one are of technology transfer that is excluded from this study; China's investment in enterprises in foreign countries aimed at technology acquisition and know how, such as the copper industry in Chile. Data are simply to be fragmented at this time. I shall also leave non-addressed the issue of whether or not China has acquired technology via the process of reverse engineering.

Chapter 1: Historical Development of Science and Technology Policy

1.1 Pre-1949 Patterns

Until the Ming dynasty (1368-1644), China was a world leader in technology and scientific discovery. Scientific and technological activity in China, however, dwindled after the fourteenth century. Under the last two dynasties, the Ming and the Qing , China's ruling elite intensified its humanistic concentration on literature, the arts, and public administration and regarded science and technology as either trivial or narrowly utilitarian. China lost the opportunity to experience the "scientific revolution" and the accompanying "industrial revolution" that transformed the West in the eighteenth and nineteenth centuries.[8]

Jesuit missionaries introduced Western mathematics and astronomy to China in the late seventeenth century but had no impact. Until the 1860's, the trauma of repeated defeat at the hands of Western invaders (in 1840-41 and 1860) finally convinced some Chinese leaders of the need to master foreign military technology. As part of the *Self-Strengthening Movement* [9]in the 1860s, some high-ranking Qing Dynasty officials

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[8]Simon, Denis Fred and Goldman, Merle, Science and Technology in Post-Mao China (The Council on East Asian studies/Harvard University ,1989), p.4.

[9] The rude realities of the Opium War, the unequal treaties, and the mid-century mass uprisings caused Qing courtiers and officials to recognize the need to strengthen China. Chinese scholars and officials had been examining and translating "Western learning" since the 1840s. Under the direction of modern-thinking Han officials, Western science and languages were studied, special schools were opened in the larger cities, and arsenals, factories, and shipyards were established according to Western models. Western diplomatic practices were adopted by the Qing, and students were sent abroad by the government and on individual or community initiative in the hope that national regeneration could be achieved through the application of Western practical methods.

initiated a movement to import "Western novelties" to check the Westerners. Metallurgy, chemistry, mathematics, physics, and foreign languages were taught at a number of foreign-style arsenals, shipyards, and associated training schools. The last decades of the century saw the establishment, under the auspices either of the imperial government or of foreign missionaries, of secondary schools and colleges teaching science, as well as the movement of Chinese students to advanced studies in Japan, the United States, and Europe.

Amid these activities came an attempt to arrest the dynastic decline by restoring the traditional order. The effort was known as the Tongzhi Restoration, named for the Tongzhi Emperor (1862-74), and was engineered by the young emperor's mother, the Empress Dowager Ci Xi (1835-1908). The restoration, however, which applied "practical knowledge" while reaffirming the old mentality, was not a genuine program of modernization.

The effort to graft Western technology onto Chinese institutions became known as the Self-Strengthening Movement. The movement was championed by scholar-generals like Li Hongzhang (1823-1901) and Zuo Zongtang (1812-85), who had fought with the government forces in the Taiping Rebellion. From 1861 to 1894, leaders such as these, now turned scholar-administrators, were responsible for establishing modern institutions, developing basic industries, communications, and transportation, and modernizing the military. But despite its leaders' accomplishments, the SelfS-trengthening Movement did not recognize the significance of the political institutions and social theories that had fostered Western advances and innovations. This weakness led to the movement's failure. Modernization during this period would have been difficult under the best of circumstances. The bureaucracy was still deeply influenced by Neo-Confucian orthodoxy. Chinese society was still reeling from the ravages of the Taiping and other rebellions, and foreign encroachments continued to threaten the integrity of China.

The first step in the foreign powers' effort to carve up the empire was taken by Russia, which had been expanding into Central Asia. By the 1850s, tsarist troops also had invaded the Heilong Jiang watershed of Manchuria, from which their countrymen had been ejected under the Treaty of Nerchinsk. The Russians used the superior knowledge of China they had acquired through their century-long residence in Beijing to further their aggrandizement. In 1860 Russian diplomats secured the secession of all of Manchuria north of the Heilong Jiang and east of the Wusuli Jiang (Ussuri River). Foreign encroachments increased after 1860 by means of a series of treaties imposed on China on one pretext or another. The foreign stranglehold on the vital sectors of the Chinese economy was reinforced through a lengthening list of concessions. Foreign settlements in the treaty ports became extraterritorial--sovereign pockets of territories over which China had no jurisdiction. The safety of these foreign settlements was ensured by the menacing presence of warships and gunboats.

At this time the foreign powers also took over the peripheral states that had acknowledged Chinese suzerainty and given tribute to the emperor. France colonized Cochin China, as southern Vietnam was then called, and by 1864 established a protectorate over Cambodia. Following a victorious war against China in 1884-85, France also took Annam. Britain gained control over Burma. Russia penetrated into Chinese Turkestan (the modern-day Xinjiang-Uyghur Autonomous Region). Japan, having emerged from its century-and-a- half-long seclusion and having gone through its own modernization movement, defeated China in the war of 1894-95. The Treaty of Shimonoseki forced China to cede Taiwan and the Penghu Islands to Japan, pay a huge indemnity, permit the establishment of Japanese industries in four treaty ports, and recognize Japanese hegemony over Korea. In 1898 the British acquired a ninety-nine-year lease over the so-called New Territories of Kowloon (Jiulong in pinyin), which increased the size of their Hong Kong colony. Britain, Japan, Russia, Germany, France, and Belgium each gained spheres of influence in China. The United States, which had not acquired any territorial concessions, proposed in 1899 that there be an "open door" policy in China, whereby all foreign countries would have equal duties and privileges in all treaty ports within

Individual Chinese students had no great difficulty mastering Western science, but the growth in their numbers and potential influence posed a challenge to the Confucian scholar-officials who dominated the imperial government and Chinese society. Such officials were reluctant to grant foreign-trained scientists and engineers a status equal to that of Confucian scholars, and they were suspicious of foreign ideas about politics and social organization, such as professional autonomy, freedom of speech and assembly, and experiments rather than written texts as validation of propositions. Nineteenth-century officials attempted to control the influx of foreign knowledge and values, distinguishing militarily useful technology, which was to be imported and assimilated, from foreign philosophy, religion, or political and social values, which were to be rejected. In the nineteenth century, the self-strengtheners sought to combine Western techniques with Chinese civilization, but again the orthodox Confucian framework overwhelmed the Western technology. China was unable to meet the Western challenge. Therefore, the grafting of modern technology into a conservative, bureaucratic and above all, feudal, system turned out to be a failure, when China's modern naval fleet, the largest of the day in Asia, was defeated by its Japanese counterpart in 1898. In August 1900, the foreign soldiers from eight world powers blew Chinese horse legions armed with swords into pieces with their guns. [10]

In the first two decades of the twentieth century, an increasing number of colleges and universities were founded, and growing numbers of Chinese students were educated

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and outside the various spheres of influence. All but Russia agreed to the United States overture.

[10] He Sheng, *Road of Science Full of Twists and Turns* (09/11/2000, *China Daily*). "While the last saw China, as the third country in the world, successfully launching its first unmanned spaceship into space, the first was illustrated by a painful image of Chinese horse legions armed with swords being blown to bits by the gun fire of foreign invaders. In August 1900, an army made up of soldiers from eight countries invaded China and looted Beijing to crush the so-called

abroad. The membership of Science Society of China included most of the country's leading scientists and engineers, was founded by Chinese students at Cornell University in 1914. In 1915, it began publication in China of a major journal, *Kexue* (Science), which was patterned on the Journal of the American Association for the Advancement of Science. In 1922, the Society established a major biological research laboratory in Nanjing. The Society devoted itself to the popularization of science through an active and diverse publication program, the improvement of science education, and participation in international scientific meetings.

During both the warlord periods following the 1911 Revolution and the establishment of the *Guomindang* government at Nanjing in 1927, there was the creation of several government research and training institutions. The *Academia Sinica*, founded in 1928, had a dozen research institutes, whose personnel did research and advised the government.[11] The late 1920s and early 1930's saw the establishment of many research institutes, such as the Fan Memorial Biological Institute in Beijing and the Beijing Research Laboratory, which eventually formed departments in physics, biology, pharmacology, and other fields. Most of the research institutes were characterized both by very limited funds and personnel and by productive, high quality scientific work. By the 1930's China possessed a number of foreign-trained scientists who did research of high quality, which they published in both Chinese and foreign scientific journals. These scientists worked in the major universities or in research institutes funded by the

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Boxing Uprising, a self-organized movement to drive off foreigners."

[11] He Sheng, *How a Nation Chases a Dream* (12/29/1999, *China Daily*). " However, it was not until the establishment of Academia Sinica in 1928 that China saw the first golden era in the development of its modern science and technology. The establishment of Academia Sinica, the first national academy of science in China's history, was generally seen as the starting point of institutional development of China's modern scientific undertakings. "

government or foreign organizations (such as missionary groups and the Rockefeller Foundation) and were concentrated in Beijing, Nanjing, and Shanghai. This period witnessed the maturing of the first and second generation of self-conscious professional scientists and engineers, which were inherited by the Chinese Communists' institutions and could have served as the basis for developing further modern science and technology.

Between 1937 and 1949, China's scientists and scientific work suffered the ravages of invasion, civil war, and runaway inflation. Funds to support research, never ample, almost totally disappeared, and most scientists were forced to devote most of their energies to teaching, administration, or a government job. In a change from the earlier pattern, many students opted not to return to China after foreign education, choosing instead to seek careers abroad.

1.2 Soviet Influence in the 1950s

Mao Tse-tung once said: "Class struggle, the struggle for production, and the struggle for scientific experiment are the three great revolutionary movements for building a mighty socialist country." [12]After the establishment of the People's Republic in 1949, China for the first time had a government that took direct and explicit responsibility for developing science and technology. It reorganized its science establishment along the Soviet Stalinist Model--a system which tended to de-emphasize the role of research in the universities and stress the centralization of research in institutes under an Academy of Sciences, with high priority given to research related to military and heavy industry needs. This line remained in force until the late 1970s, when China's leaders called for major reforms. The Soviet model is characterized by a bureaucratic rather than a professional principle of organization, the separation of research from production,[13] the establishment of a set of specialized research institutes, and a high priority on applied science and technology which mainly includes military technology. It also emphasized excellence in highly specialized and narrow fields with the expectation that the bridging of specialties would be done by the senior scientific bureaucrats.

On November 1, 1949, the Chinese Academy of Sciences (CAS) was founded, amalgamating research institutes under the former *Academia Sinica* and Beijing Research Academy (the former Beijing Research Laboratory). At the beginning of the new regime, CAS was to have two main functions. The first was to be an institution actively engaged in scientific research primarily to serve the requirements of the production sector of the economy and to adjust scientific research to meet those requirements. The second was to have an administrative function as that agency of the government in charge of all matters relating to science and to social and historical studies. Scientists were to engage in research with significant and fairly immediate benefits to society and to work as members of collectives rather than as individuals seeking personal fame and recognition.

The CAS was explicitly modeled on the Soviet Academy of Sciences (SAS), whose director, Sergei I. Vavilov, was consulted on the proper way to reorganize Chinese science.

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[12] Suttmeier, Richard P., *Research and Revolution* (D.C Heath and Company,1974), p.29.
[13] "The separation of research from production" means the research and the production in civilian industry vertically led by different higher-levels and little communications happened between the two sectors, details see "3.2 Shortcomings of Before Reform" and "6 Conclusion")

His book, *Thirty Years of Soviet Science* was translated into Chinese to serve as a guide.[14] Soviet influence also was realized through large-scale personnel exchanges. During the 1950's, China sent about 38,000 people to the Soviet Union for training and study. The Soviet Union dispatched some 11,000 scientific and technical aid personnel to China. In 1954, China and the Soviet Union established the Joint Commission for Cooperation in Science and Technology, which met annually until 1963 and arranged cooperation on over 100 major scientific projects, including those in nuclear science. When the CAS completed a draft twelve-year plan for scientific development in 1956, it was referred to the SAS for review. In October 1957 a high-level delegation of Chinese scientists accompanied Mao Tse-tung to Moscow to negotiate an agreement for Soviet cooperation on 100 of the 582 research projects outlined in the twelve-year plan. [15]

Since China's initial industrial system was established with technology, equipment, and a management system introduced from the Soviet Union, China unavoidably followed the same ideological line. The influence of the Soviet Union had both positive and negative sides. It did play an important role in the formation of the initial industrial system. China obtained the most comprehensive technology transfer in modern industrial history. The Soviet Union provided aid for 156 major industrial projects concentrated in mining, power generation, and heavy industry. Following the Soviet model of economic development, these were large-scale, capital-intensive projects.[16] By the late 1950's, China had made substantial progress in such fields as electric power, steel production, basic chemicals, and machine tools, as well as in production of military equipment such

[14] *Soviet Influence in the 1950s*. *Library of Congress*.http://lcweb2.loc.gov/frd/cs/cntoc.html

as artillery, tanks, and jet aircraft.[17] Soviet standards for materials, engineering practice, and rigid and inefficient management, however, were adopted. In a move whose full costs would not become apparent for twenty-five years, Chinese industry also adopted the Soviet separation of research from production.[18] Moreover, the various institutes, concentrated primarily in CAS and the industrial ministries, were guided by a central plan and funded by an annual budget from the central government. Consequently, power over research was concentrated in the hands of political leaders who had little understanding of science or how to combine research and production.

A central planning economic system adopted by China right from the outset of economic construction, was based on the belief that it was the ideal operational system for a socialist country. The Soviet Union, the first socialist country in the world, with decades of experience in implementing a planned economy, was certainly recognized as the example for China to follow. Simultaneously, the adoption of the Soviet model meant that the organization of Chinese science was based on bureaucratic rather than professional principles. Under the bureaucratic model, leadership is in the hands of non-scientists, who assign research tasks in accordance with a centrally determined plan. The administrators, not the scientists, control recruitment and personnel mobility. The primary rewards are administratively controlled salary increases, bonuses, and prizes. Individual scientists, seen as skilled workers and as employees of their institutions, are

[15] *Soviet Influence in the 1950s, op.cit.*
[16] OECD, *Science and Technology in the People's Republic of China* (OECD, 1977), p.21
[17] *Soviet Influence in the 1950s, op.cit.*
[18] "The separation of research from production" means the research and the production in civilian industry vertically led by different higher-levels and little communications happened between the two sectors, details see "3.2 Shortcomings of Before Reform" and "6 Conclusion")

expected to work as components of collective units. Information is controlled, and is expected to flow only through authorized channels, which were often considered proprietary or secret. Scientific achievements are regarded as the result primarily of "external" factors such as the overall economic and political structure of the society, the sheer numbers of personnel, and adequate levels of funding.[19] Under professional principles, which predominate as a goal in Western countries, scientists regard themselves as members of an international professional community that recruits and rewards its members according to its own standards of professional excellence. The primary reward is recognition by professional peers, and scientists participate in an elaborate network of communication, which includes published articles, grant proposals, conferences, and news of current and planned research carried out by scientists who circulate from one research center to another.

1.3 "Reds" Versus "Experts" in the 1950s and 1960s

During the Great Leap Forward[20] of 1958-1960 and the Cultural Revolution[21] period (1966-1976), however, the encrusted Soviet Model was damaged by Mao's own vision of

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[19] Simon, Denis Fred and Goldman, Merle, *Science and Technology in Post-Mao China* (Published by The Council on East Asian studies/Harvard University,1989), p.7.

[20] A drive to increase industrial and agricultural production following the suspension of Soviet aid and the desire to catch up with the advanced nations of the world. The campaign was conceived by Mao tse-tung in late 1957, adopted by the National People's Congress (q.v.)in 1958; it continued through 1960. Emphasis was placed on accelerated collectivization of agriculture, national self-sufficiency, and labor-intensive methods. The campaign resulted in widespread waste of resources and was partially responsible for famine in 1960 and 1961.

[21] A slogan introduced by Mao tse-tung in 1940, noted again by Liu Shaoqi in 1958, and used more frequently in connection with leftist attacks on the "cultural front" in late 1965 and early 1966. The expression was used to denote the Great Proletarian Cultural Revolution, a political campaign officially inaugurated in August 1966 to rekindle revolutionary fervor of the masses outside formal party organizations. The Cultural Revolution decade (1966-76) can be divided into three periods: 1966-69, from the militant Red Guard (q.v.) phase to the Ninth National Party Congress; 1969- 71, the period of the zenith and demise of Lin Biao; and 1971-76, the period of Mao's declining health and the ascendancy of the Gang of Four (q.v.). At the August 1977 Eleventh National Party Congress, the Cultural Revolution was declared officially to have ended with the arrest in October 1976 of the Gang of Four.

scientific and technological development. Mao imposed his own theory on technological and economic activities and emphasized mass participation, egalitarianism, self-reliance, and the principle of indigenous development. Party cadres and representatives of the masses were to take over technological and scientific tasks from the professionals, who were criticized for their "ivory-tower" mentality and were sent to the countryside or factories to learn again from the masses.

In the early 1950's, Chinese scientists, like other intellectuals, were subjected to regular indoctrination intended to replace bourgeois attitudes with those more suitable to the new society. Many attributes of the professional organization of science, such as its assumption of autonomy in choice of research topics, its internationalism, and its orientation toward professional peer groups rather than administrative authorities, were condemned as bourgeois. During the Hundred Flowers Campaign[22] of 1956-57, some scientists used the brief period of free expression to air complaints of excessive time taken from scientific work by political meetings and rallies, or of the harmful effects of attempts by poorly educated party cadres to direct scientific work. However, those people later were criticized for their "antiparty" stance, labeled as "rightists" in the "Anti-rightists Campaign", and sometimes dismissed from administrative or academic positions.

The Great Leap Forward was an audacious and misplaced experiment. China tried to

[22] Hundred Flowers Campaign also is Double Hundred Campaigns. Party-sponsored initiative to permit greater intellectual and artistic freedom. Introduced first into drama and other arts in the spring of 1956 under the official slogan "Let a hundred flowers bloom, let the hundred schools of thought contend." With Mao's encouragement in January 1957, the campaign was extended to intellectual expression and, by early May 1957, was being interpreted as permission for intellectuals to criticize political institutions of the regime. The effect was the large-scale exposure and

accelerate its growth in both agriculture and industry using both modern and indigenous methods. The terminology of the period distinguished between being "red"[23] and "expert".[24]Although party leaders spoke of the need to combine "redness" with expertise, prime stress was placed on local initiative and the role of the "masses," who were regarded as "Red". The period of the Great Leap Forward saw efforts to reassign scientists to immediately useful projects, to involve the uneducated masses in such research work as plant breeding or pest control, and to expand rapidly the ranks of scientific and technical personnel by lowering professional standards. The direct result was a far-reaching decentralization of central planning and the statistical apparatus. The Great Leap Forward and the accompanying Commune[25] program represented radical attempts to solve real and scientific problems. The economic depression and three-year natural disaster (1959-1961) following the Great Leap Forward, and the need to compensate for the sudden withdrawal of Soviet advisers and technical personnel in 1960, brought a renewed but short-lived emphasis on expertise and professional standards in the early 1960's.

While it is generally argued both inside and outside of China that Mao's policies were both inappropriate and unsuccessful, his objectives were: (1) to broaden the base of scientific recruitment; (2) as a consequence, to raise the scientific level of the base in society, on the assumption that by so broadening the base China would ultimately produce a larger number of scientists.

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purge of intellectuals critical of party and government policies.

[23] A term referring to political and ideological attitudes prescribed by Maoist doctrine. Usually juxtaposed with "expert" (q.v.), the term was seldom used in the 1980s.

[24] A term referring to political and ideological attitudes prescribed by Maoist doctrine. Usually juxtaposed with "red" (q.v.), the term was seldom used in the 1980s.

1.4 Depression, "Readjustment" and Recovery, 1961-1965

Instead of producing an economic breakthrough, the Great Leap Forward resulted in a crisis of massive proportions in economics. Nationally there was widespread malnutrition.[26] Agricultural output dropped precipitously, in part as the result of bringing on stream virgin lands which were not productive. The crisis also had effects on the Chinese leadership. Mao Tse-tung was forced to a less active leadership role, instead, Liu Shaoqi came to the fore. In order to cope with the existing crisis and to stimulate recovery, a series of new development policies, which were pragmatic and experimental, neither the rigid Soviet model, nor the Maoist concepts of radical egalitarianism, were pursued. Many measures were taken such as to restore a sense of order and rationality in economic policy, and to repair the planning and statistical apparatus, and to close some unsuccessful small-scale industries, more broadly, to renew attention to efficiency and technical improvement. As a result, "experts" as well as professional managers rose to prominence once again.

One of the most important decisions by Liu Shaoqi's group was to restore fundamental national economic priorities. Agriculture was assigned to top priority, similarly, light industry second, and heavy industry third. Of course, military industry was different. During this period, due to the practical policy of Liu's group, the Soviet model was gradually split and China's own pattern emerged. Foreign trade with non-communist

[25] A term referring to low-level township and countryside government organization.
[26] *Science and Technology in the People's Republic of China*, 1977, *op.ctp*, p.23.

countries began to pick up and increased significantly.[27] Economy was recovered and growth sustained to upward. This situation continued until 1966.[28]

Two things, however, changed China's fate. One was the new Soviet leaders' total denunciation of Stalin, which Mao called Soviet "revisionism". The other, was the approach of the Liu group who obviously compromised Mao's egalitarian values. Starting in late 1962, Mao repeatedly stressed class struggle and the need to combat revisionism. The inner party struggle between two lines became more and more serious. This finally resulted in the Culture Revolution. This was, however, preceded by Mao's counter attack on two fronts (1) his sanctioning of Lin Piao's reorganization of the PLA in 1960, and (2) the launching in 1963 of the Socialist Education Movement in the countryside.

1.5 Cultural Revolution, 1966-1976

The power struggle within the Communist party existed since its foundation. The Cultural Revolution was a relocation of political power rather than a reform of China's superstructure and culture in a certain sense. The senior bureaucratic leaders who stood for a line in opposition to Mao led eventually to an open power struggle. Mao, a talented mass campaign leader, mobilized millions of Chinese youth into the Red Guards[29],

[27] *Ibid.*
[28] *Ibid.*,p.24.
[29] Generally used to refer to young people--primarily students--in their teens and twenties who began in May 1966 to support the leftist intra-party struggle then emerging against Liu Shaoqi and others. They made world famous the "little red book," Quotations from Chairman Mao, and were known for their use of big-character posters (q.v.) during the Cultural Revolution (q.v.). Acting under the leadership of Mao and his radical adherents, Red Guards were the "soldiers" and the vanguard of the Cultural Revolution. The term Red Guard was derived from the early days of the Chinese Communist Party's armed struggle.

backed by the army, launched a frontal attack on both the Party and the state bureaucracies. Liu Shaoqi, Mao's principle opponent, was bitterly denounced as being in command of the capitalist class. The immediate impact of the Cultural Revolution upon the Chinese economy was the temporary breakdown of authority, the resulting bureaucratic confusion, the widespread political turmoil, and a significant drop in production. The Army eventually took over, temporarily, many of Party's and state's roles. Marshall Lin Piao, Minister of Defense, may have wanted this role to be permanent.

Because the scientific establishment was attacked, China's science and technology was seriously damaged during the period. Research institutions were dissolved, Research facilities and materials were destroyed, experiment bases were sabotaged, the regular working order was disturbed and the structure was broken down and paralyzed. A large number of individual scientists were labeled as "reactionary authorities" and made the objects of public criticism and persecution. Accompanying decentralization and local initiative, rural development became a new focus. Large numbers of urban intellectual youth were transferred to the countryside in the "rustication" movement. The entire staffs of research institutes commonly were dispatched to the countryside for months or years to learn political virtue by laboring with the poor and lower-middle peasants. Work in the military research units devoted to nuclear weapons and missiles presumably continued, although the secrecy surrounding strategic weapons research makes it difficult to assess the impact of the Cultural Revolution in that sector.

As soon as the worst turmoil of the period 1966-68 ended, an upturn in the economy began in late 1968 with[30] order restored and Party leadership's rebuilt. Although egalitarian values were asserted, it was very important that policies in economy continued with old approaches that dated back to the early 1960's, i.e, to policies that had been originated by Liu Shaoqi and others which were denounced during the Cultural Revolution. Equally important, the basic scientific institutions and incentive systems clearly resembled those of the early 1960's. Beijing's basic approach was now in many respects essentially pragmatic once again rather than ideological. Although an argument can be made that pragmatism itself is ideological, but a different one than that of Mao. Some outside researchers described the policy trends as "Liuism without Liu"[31].

In the most general sense, the Cultural Revolution represented the triumph of anti-intellectualism and the consistent, decade-long deprecation of scholarship, formal education, and all the qualities associated with professionalism in science. During the decade between 1966 and 1976, China's leaders attempted to create a new structure for science and technology characterized by mass participation, concentration on immediate practical problems in agriculture and industry, and eradication of distinctions between scientists and workers. Mao's idea was that by solving the technological problems while working upon them one could accumulate knowledge, which, in turn, would help in making further technological innovations.

The early 1970's were characterized by mass experimentation, in which large numbers of peasants were mobilized to collect data and encouraged to view themselves as doing

[30] OECD, *Op.cit*, 1977, p. 24.
[31] *Ibid.*, p. 25.

scientific research. Typical projects included collecting information on new crop varieties, studying the effectiveness of locally produced insecticides, and making extensive geological surveys aimed at finding useful minerals or fossil fuels. Mao Tse-tung took a personal interest in earthquake prediction, which became a showcase of Cultural Revolution-style science. Geologists went to the countryside to collect folk wisdom on precursors of earthquakes, and networks of thousands of observers were established to monitor such signs as the level of water in wells or the unusual behavior of domestic animals. The emphasis in this activity, as in acupuncture anesthesia, was on immediate practical benefits, and little effort was made to integrate the phenomena observed into larger theoretical frameworks.

Mao's idea of having technology first was taken up to improve the living conditions of the masses in the shortest possible time. Although it did give short-term gains in terms of increase in production, the strategy did not seem to work for long. The effects of the extreme emphasis on short-term problems and the deprecation of theory were noted by Western scientists who visited China in the mid- and late 1970s. For example, work in research institutes affiliated with the petrochemical industry was described as excessively characterized by trial and error. In one case, large numbers of substances were tried as catalysts or modifiers of the wax crystals in crude oil, and little attention was given to the underlying chemical properties of the catalytic or modifying agents. The direct result of Cultural Revolution was China lagged far behind the advanced world in scientific and technological research. During the Culture Revolution, it was strictly prohibited to learn from the advanced experiences of foreign countries in respect to science and technology.

Any effort to learn from foreign advanced experiences was repudiated as " slavish comprador philosophy" or " crawlism ". What prevailed was a closed-door policy that isolated the country from the outside world and broadened the gaps in science and technology between China and the world's advanced levels. However, this period witnessed a shift in China's foreign trade policy in favor of non-communist countries. The pragmatic modernization drive led by party leaders Zhou Enlai and Deng Xiaoping and China's growing contacts with Western nations resulted in a sharp acceleration of trade in the early 1970s. Imports of modern plants and equipment were particularly emphasized. Trade more than doubled between 1970 and 1975, reaching US$13.9 billion. Growth in this period was about 9 percent a year. As a proportion of GNP, trade grew from 1.7 percent in 1970 to 3.9 percent in 1975.[32] The improvement in Sino-American relations had considerable influence on Chinese economy, science and technology policy.

1.6 Rehabilitation and Rethinking, 1977-84

Deng's reappearance on the political stage in 1975 compensated for the damage caused by the Cultural Revolution's attacks on science. In January 1975, Premier Zhou Enlai made a major speech at the session of the Fourth National People's Congress calling for Four Modernizations[33], that is, modernization of agriculture, industry, science and

[32] *Foreign Trade, History of Chinese Foreign Trade.* (*China. Country Studies. Library of Congress*). http://lcweb2.loc.gov/frd/cs/cntoc.html

[33] The core of a development strategy aimed at turning the country into a relatively advanced industrialized nation by the year 2000. The modernizations are those of agriculture, industry, science and technology, and national defense. The concept was embodied first in the Third Five-Year Plan (1966-70), launched in earnest by Zhou Enlai at the Fourth National People's Congress (1975), and adopted as the official party line at the Third Plenum of the Eleventh Central Committee (December 1978).

technology, and national defense.[34] Although the policies proposed in the speech had little immediate effect, they were to become the basic guide for the post-Mao period. In 1975 Deng Xiaoping, then Vice Chairman of the Chinese Communist Party, Vice Premier of the government, and Zhou Enlai's political heir, acted as patron and spokesperson for China's scientists. Under Deng's direction, three major policy documents--on science and technology, industry, and foreign trade were drafted. Intended to promote economic growth, Deng's group called for rehabilitating scientists and experts, re-imposing strict academic standards in education, and importing foreign technology. The proposals for reversing most of the Cultural Revolution policies toward scientists and intellectuals were denounced as "poisonous weeds" by the ideologues and followers of the Gang of Four who had the protection of Chairman Mao. Zhou died of cancer in January 1976, and Deng was dismissed from all his posts in April. Deng was accused of deliberately distorting Mao's directives. Deng's stress on the priority of scientific and technical development was condemned as "taking the capitalist road." This dispute demonstrated the central place of science policy in modern Chinese politics and the link between science policies and the political fortunes of individual leaders.

Both experts and professional managers in science and technology regained their important operational roles after Mao's death and the subsequent overthrow of the Gang of Four in October 1976.The reversals of science and education policies demonstrated again the leader's role in science policy. During 1977, the more vocal supporters of the Gang of Four were removed from positions of authority in research institutes and

[34] Kharbanda, V P and Qureshi, M A, *Science Technology and Economic Development in China* (Navarang, New Delhi, 1987), p.57.

universities and replaced with professionally qualified scientists and intellectuals. Academic and research institutions that had been closed were reopened, and scientists were summoned back to their laboratories from manual labor in the countryside. Scientific journals resumed publication, often carrying reports of research completed before everything stopped in the summer of 1966. The media devoted much attention to the value of science and the admirable qualities of scientists. It denounced the repressive and anti-intellectual policies of the deposed Gang of Four[35], who were blamed for the failure of China's science and technology to match advanced international levels. The news media now characterized scientists and technicians as part of society's "productive forces" and as "workers" rather than as potential counterrevolutionaries or bourgeois experts divorced from the masses. Considerable publicity went to the admission or readmission of scientists to party membership.

The year 1978 was a historical turning point. The Third Plenary Session of the Central Committee of the Eleventh Congress of the Communist Party of China declared that China should shift to taking socialist economic construction instead of class struggle as the central role and to carrying out reform and opening policy.[36] At the same year, the Chinese leaders sponsored a national science conference and mapped out scientific development strategies for a new period of reform and opening-up policies. The conference was considered as a milestone in science policy. Many of China's top leaders,

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[35] Term used by the post-Mao leadership to denote the four leading radical figures--Jiang Qing (Mao's fourth wife), Zhang Chunqiao, Yao Wenyuan, and Wang Hongwen--who played a dominant political role during the Cultural Revolution (q.v.) decade (1966-76) until Mao's death in September 1976 and their arrest several weeks later. Their "antiparty" deeds are often linked with Lin Biao, an early leader of the Cultural Revolution, who also has been discredited.

[36] Yu, Q.Y., *The Implementation of China's Science and Technology Policy* (QUORUM BOOKS,

as well as by 6,000 scientists and science administrators attended the conference. Its main purpose was to announce publicly the government and party policy of encouragement and support of science and technology. Science and technology were assigned a key role in China's development goal toward the creation of a modern socialist society by the year 2000. A major speech by Deng Xiaoping reiterated the concept of science as a productive force (later on, it was further emphasized as "first force of production") and scientists as part of the working class, [37]an ideological formulation intended to remove the grounds for the political victimization of scientists. Speeches by Premier Hua Guofeng and Vice Premier Fang Yi, the top government figure involved in science and technology, urged that scientists be given free rein in carrying out research as long as the work was in line with broad national priorities. Basic research was to be supported, although stress would continue to be placed on applied work, and China's scientists would be given wide access to foreign knowledge through greatly expanded international scientific and technical exchanges.

In late 1978, the main aim was to resurrect the Soviet-style system or so-called pre-Cultural Revolution model. Leaders with special responsibility for science and technology joined recently rehabilitated senior scientists in looking ahead and framing sweeping and very ambitious plans for further development. The draft known as the "Outline National Plan for the Development of Science and Technology, 1978-85" discussed at the 1978 National Science Conference. The broad objectives of the plan called for a rapid increase in the number of research workers, for narrowing the gap with

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1999) p.8.

[37] *Ibid.* Yu.Q.Y.

advanced international countries by the mid-1980s, and for completing a nationwide system of scientific and technological research.

Both political leaders and media personnel seemed captivated by the vision of rapid economic growth and social transformation made possible by the wonders of science. Further, many leaders, not themselves scientifically trained, tended toward unrealistic expectations of the immediate benefits from research. For some scientists, and perhaps for their political sponsors as well, mastering technologies and developing Chinese capabilities in the most advanced areas of science were goals in themselves, regardless of the costs or of the likely benefits to the peasants and workers. Both of them hoped to obtain substantial success in such fields as lasers, manned space flight, and high-energy physics in a relative short time. This attitude, while different from the hostility to science exhibited during the Cultural Revolution, was based on a misunderstanding of the nature of scientific work and was therefore a poor foundation for science policy.

The plans for rapid advance in many scientific areas were associated with equally ambitious calls for economic growth and the large-scale import of turnkey factories. During 1979 it became increasingly clear that China could not pay for all the imports or scientific projects wanted by all the ministries, regional authorities, and research institutes. It also became increasingly evident that those promoting the projects had overlooked financial constraints and severe shortages of scientific and technical manpower and the absence of a comprehensive plan. In February 1981 a report of the State Science and Technology Commission reversed the overly ambitious 1978 eight-year scientific development plan and called for renewed emphasis on the application of science to practical problems and on training more scientists and engineers.[38]

Gradually the reform leadership moved away from both the Soviet and Maoist Models, which it regarded as obstacles to the development of advanced science and technology. Attention shifted to reforming the existing system and promoting greater efficiency and better use of scarce resources, such as trained manpower. Between 1981 and 1985, a number of journals and newspapers such as *Guang Ming Ri Bao* discussed China's scientific system and suggested improvements, while national and local administrators sponsored a wide range of experimental reforms and reorganizations of research bodies.[39] The extensive discussion and experimentation culminated in a March 1985 decision of the party Central Committee calling for thorough reform of China's science system.[40]

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[38]The Ministry of Science and Technology of PRC, *The National Development Plan of Science and Technology from 1978-1985 (in Chinese)* http://www.most.gov.cn/
[39] *Op cit.* Yu, O. Y. pp.14-17.
[40] *Ibid.* Yu,O.Y.

Chapter 2: Science and Technology in the 1980's and 1990's

2.1 The Supply of Skilled Manpower

In the 1980's, one of the fundamental stumbling blocks facing China's drive for modernization was the shortage of high-level scientific and engineering personnel. Research and development is a labor-intensive endeavor, in which the critical resource is the size and quality of the pool of trained personnel. China suffered both from an absolute shortage of scientists, engineers, and technicians and from mal-distribution and misuse of those it had. Chinese statistics on the number and distribution of scientific personnel were neither complete nor consistent. According to the State Statistical Bureau, at the end of 1986 there were some 8.2 million personnel (out of 127.7 million workers) in the natural sciences working in state-owned enterprises, research institutes, and government offices. These numbers probably excluded military personnel and scientists in military research bodies, but they included support personnel in research institutes. "Scientific and technical personnel" comprised about 1.5 percent of all employed persons, but only about 350,000 of them were "research personnel." [41]Their number had increased markedly from the 1970's as well-trained students began graduating from Chinese colleges and universities in substantial numbers and as postgraduates began returning from advanced training in foreign countries. Between 1979 and 1986, China sent over 35,000 students

[41] *Chapter 9 : Science and Technology* (*China, Country Studies, Library of Congress*), http://lcweb2.loc.gov/frd/cs/cntoc.html

abroad, 23,000 of whom went to the United States.[42] More significant than sheer numbers of scientific personnel were their quality and distribution. The total numbers masked wide variations in educational background and quality lumping together graduates from two years colleges and major institutions in the early 1960's or the 1980's, that is, before or after the period of the Cultural Revolution. The Cultural Revolution had removed an entire generation from access to university and professional training, creating a gap in the age distribution of the scientific work force. The scientific community included a small number of elderly senior scientists, often trained abroad before 1949, a relatively small group of middle-aged personnel, and a large number of junior scientists who had graduated from Chinese universities after 1980 or returned from study abroad. In the mid-1980's, many of the middle-aged, middle-rank scientists had low educational and professional attainments. Generally they could be neither dismissed nor retired (because of China's practice of secure lifetime employment); nor could they be retrained, as colleges and universities allocated scarce places to younger people with much better qualifications. Scientists and engineers were concentrated in specialized research institutes, in heavy industry, and in the state's military research and military industrial facilities, which had the highest standards and the best-trained people. A very small proportion of scientists and engineers worked in light industry, consumer industry, small-scale collective enterprises, and small towns and rural areas. During the period between 1978 and 1984, the average annual increase in scientific and technical personnel was 6.5%. By 1987, the total number came to 8,894,000, including 4,172,000 scientists

[42] *Ibid.* http://lcweb2.loc.gov/frd/cs/cntoc.html

and engineers.[43]

While in the 1990's, the situation has been greatly improved. Today China has 21,663 scientific and technological institutions with more than 2.8 million researchers, according to a report from the National Bureau of Statistics (NBS).[44] China has accomplished more than 460,000 scientific and technological achievements since 1978, 20 per cent of them reaching world advanced levels. Chinese scientists published 35,000 theses in world-renowned academic journals in 1997, bringing China's rank in global thesis publication to ninth from 15th in 1989, according to the latest NBS statistics.[45] And acquiring a patent has become less difficult, resulting in over 1 million new patents being issued. According to the annual report of the State Intellectual Property Office (SIPO), applications for patents nationwide have surpassed 1 million in November 1999, and 530,000 among them have been authorized by the SIPO. In 1999, patent applications received by the SIPO were 134,239, a 10 per cent increase over 1998. Among them, there were over 35,000 invention patent applications, according to a SIPO report. [46]

2.2 Research Institutes

In the late 1980's, most Chinese researchers worked in specialized research institutes rather than in academic or industrial enterprises. The research institutes, of which there were about 10,000 in 1985, were, like their Soviet exemplars, directed and funded by

[43] *Op cit.* Yu, Q.Y, p.37.
[44] Cui Ning , *Scientific Advances Spur Nation* (08/24/1999, *China Daily*)
[45] *Ibid.* Cui Ning.
[46] Jia Hepeng, *Patent Exhibit Draws Many Viewers* (04/03/2000 , *China Daily*)

various central and regional government bodies. Their research tasks were assigned by higher administrative level as part of an overall research plan; the research plan was, in theory, coordinated with an overall economic plan. Research institutes were the basic units for the conduct of research and the employment of scientists, who were assigned to institutes by government personnel bureaus. Scientists usually spent their entire working careers within the same institute. Research institutes functioned as ordinary Chinese work units, with the usual features of lifetime employment, unit control of rewards and scarce goods, and limited contact with other units not in the same chain of command. Each research institute attempted to provide its own staff housing, transportation, laboratory space, and instruments and to stockpile equipment and personnel. The limited channels for exchanges of information with other institutes often led to duplication or repetition of research. Eighty percent of all research institutes that were affiliated to ministries of the State Council and provincial government were considered as low in quality. Central planners and administrators considered the proliferation of low-quality research institutes a waste of scarce research funds, but as of mid-1987, they had not been able to overrule powerful ministries or local governments. Such institutes, which employed the majority of China's scientists and engineers, were expected to devote themselves to the application of science and to useful innovations and improvements to industrial processes and products. They had little direct contact with factories, and they reported their research results up the chain of command of their department or ministry, which was responsible for passing them on to factories. The scientists and engineers had little opportunity for interchange with research institutes that were doing similar work but that were subordinate to a different ministry or commission.

In 1999, the central government made a decision that 242 scientific research institutes, which were affiliated with the 10 bureaus of the State Economic and Trade Commission, would operate under market-oriented management systems.[47] Under the new policy, institutes could freely conduct import and export business, and the State would publish government-designated and specialized research projects each year. The institutes are encouraged to apply for funding to undertake these projects. The aim of the policy is to further stimulate the institutes to accelerate the industrialization and commercialization of technological discoveries. The Government promised to create a favorable climate to help the institutes become listed companies. The institutes are permitted to join enterprises, become technological firms, operate as intermediate technological institutions, be merged into universities or other corresponding sectors, or be turned into large, State-level technological enterprises. These institutes, seen as the backbone of China's science and technology, would propel their development as well as that of the economy. Technological firms will be key forces in fostering new pillar industries. [48]The State Council gave approval for 131 of the institutes to join enterprises, 40 to become technological firms, 18 to function as intermediate technological institutions, 24 to be merged into universities or other corresponding sectors and the remaining 29 to be turned into large, State-level technological enterprises.[49] The reform of the institutes' systems will finally pave the way to restructure governmental institutions. The Chinese leadership hopes the institutes will take the lead in furthering the reform of other research institutions. Those institutes who engaged in applied science and technology research would be partly or wholly transformed into enterprises or agencies to maximize resources

[47] *State Pushes for Reforms of Research Institutions* (12/30/1999, *China Daily*)
[48] *Ibid.*

and speed up the commercialization of scientific achievements.[50]The 270 institutions which were previously attached to the Ministry of Land Resources, the Ministry of Water Resources, the Ministry of Agriculture, the State Forestry Administration, the State Seismological Bureau, China Meteorological Administration, the State Bureau of Surveying and Mapping and other governmental departments were transformed into enterprises or agencies according to the plan. More than 100 government-subsidized research institutions would be required to support themselves beginning in late 1999. Another 170 such institutions which conducted academic research under the planned economy would follow suit in 2000.[51] The isolation of research institutions from industry has hindered the application of discoveries to commercial activities. These institutions would adopt new management systems, salary standards, pensions, and insurance systems in line with market practices to stimulate researchers' enthusiasm by increasing salaries and bonuses according to individual contributions. Many of the independent institutes have greatly improved efficiency over the past year. The Beijing Iron and Steel Research Academy, for example, has become a large technology enterprise and set up a subsidiary Antai Technology Shareholding Company. The company has been listed on domestic stock markets.[52]

2.3 National Organization and Administration

The research institutes belonged to larger systems or hierarchies, defined by the

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[49] *Ibid.*
[50] Cui Ning, *Adapt to Market Economy Research Institutes Restructured* (05/27/99. *China Daily*)
[51] Cui Ning, *Institutions required to turn profit* (07/11/2000. *China Daily*)
[52] *Ibid.*, Cui Ning, *China Daily*

administrative bodies that directed and funded their subordinate institutes. Research institutes were grouped into five major subsystems that were administratively distinct and had little contact or communication among them. The five major subsystems are Chinese Academy of Science (CAS)/Chinese Academy of Engineering (CAE), The Ministry of Science and Technology (MST), National Defense Science, Technology, and Industry Commission (NDSTIC), Universities, and Enterprises.

Chinese Academy of Sciences (CAS)

The CAS is the highest academic organization supporting and controlling a number of research institutions and is a comprehensive research center in natural science. The CAS is mainly concerned with basic research. It has five departments: (1) mathematics and physics, (2) chemistry, (3) biology, (4) earth science, and (5) technical science. Its main task is to study and develop new theories and techniques and to solve scientific and technical problems involving many sectors in cooperation with relevant government departments and universities. In the late 1980's and 1990's, the CAS still remained the most prestigious research agency in the natural sciences. It administered about 120 research institutes in various parts of China, with major concentrations in Beijing and Shanghai. In 1986, the Academy employed 80,000 persons, over 40,000 of who were scientific personnel. It also operated the elite Chinese University of Science and Technology located in Hefei, Anhui Province, as well as its own printing plant and scientific instrument factory. Its institutes concentrated on basic theoretical research, manufacturing scientific instruments, operating scientific information services, and providing training and postgraduate research facilities. It also served as an advisory body to the Party and the State in scientific and technical policy. The CAS institutes employed China's best-qualified civilian scientists and had better laboratories, equipment, and libraries than institutes in the other four research systems. The academy's concentration on basic research was intended to be complemented by the work of the more numerous institutes affiliated with industrial ministries or local governments, which focused on applied research.

The CAS in practice reported directly to the State Council. Before 1956, the Academy was directly responsible for overall science planning, and since 1987 it has retained a fairly high degree of institutional autonomy and influence on national science policy. The Academy provided expert advice, when asked, to the State Council and its ministries, commissions, and agencies. Its specialized institutes also did work for the military research and development program. Additionally, it had responsibility for multidisciplinary research, monitoring the level of technology in Chinese industries and suggesting areas where foreign technology should be purchased. During the 1980's and 1990's, the Academy repeatedly was asked to pay more attention to the needs of production and the application of knowledge while CAS strengthened its basic scientific research. In 2000, health issues and development of agricultural and information technology will top the Chinese Academy of Sciences' (CAS) research agenda in the new century. CAS and the government will emphasize research involving energy, the environment, ecology, space, new materials, and geo-sciences according to Lu Yong-xiang, President of CAS. CAS will provide special support to 15 scientific research programs which may achieve breakthroughs in the next two or three years. These research programs involve high-performance computers, industrial robots, fuel cells, small satellites, human genome and genetic research into diseases, oil and gas exploration, gallium-nitrogen nano-rods, high-yield rice and climate research. In addition, high-tech enterprises under CAS generated 985 million yuan RMB (US$119 million) in revenue in 1999, up 82.96 per cent from 1997.[53]

The Scientific Council is the highest decision making organ of CAS. The membership of the CAS includes the nation's most senior and best-known scientists, some of whom had long-standing personal ties with senior political leaders. For example, Qian Xue-sheng, the father of Chinese atom bombs and missiles, has kept this type of relationship with the leaders of three generations of the Party. Such ties and the prestige of the Academy help it win favorable treatment in the state budgetary process and operate with relatively little outside interference. Its relatively privileged position generates resentment among those working in less well-funded institutes under the industrial ministries, whose workers--as well as some planners in the state administration--reportedly considered the academy both over-funded and overstaffed with theoreticians who contributed little to the national economy.[54]

Chinese Academy of Engineering (CAE)

The CAE, established in 1994. is China's ranking consulting institute for engineering science. It is attached to the State Council. The CAE had 437 academicians, including 12

[53] Cheng Liang, *Top Science Body Outlines Agenda* (01/26/99, *China Daily*)
[54] Cui Ning, *Scientific Study Funds Increased* (03/23/2000, *China Daily*)

foreigners. It added another 113 academicians in 1999 to help provide scientific support for China's infrastructure projects in the new century. The CAE mainly provides advisory services for government on such projects as power, transportation, water conservancy, flood prevention and telecommunications. The present CAE president is Song Jian, the former State Councilor and the head of State Science and Technology Commission. [55]

The Ministry of Science and Technology (MST)

The Ministry of Science and Technology (MST), an organ of the State Council, was established in 1958 and named the State Science and Technology Commission. The Zhu Rongji government renamed it the Ministry of Science and Technology. Its major responsibility is the formulation and execution of the State science and technology policy. It is also responsible for a number of additional functions, such as development of petro-chemicals, computers and machinery, foreign affairs, planning and policy research related to science and technology. Among its other functions are coordination of national R&D activities, planning of science and technology and establishing national standards. [56]MST evolves its own plans and presumably provides specialized advice to the State Planning Commission in the formulation of national plans. MST had responsibility for overseeing the work of civilian research institutes subordinate to the various industrial ministries, such as the State Economic and Trade Commission, or to provincial-level,

[55] Cui Ning, *Academy to Select New Academicians* (01/07/99, *China Daily*)
[56] The Ministry of Science and Technology of PRC, *Organization and Structure* (in Chinese), http://www.most.gov.cn/

prefectural, or municipal bureaus. More than 80 percent of China's 10,000 research institutes fell in this category, and their range of quality was considerable.

The importance of science and science policy can be inferred by the high state and party rank of the Ministers and Vice Ministers placed in charge of the MST. Provincial-level units, responsible for budgeting, planning, and coordinating across administrative hierarchies, have their own science and technology bureau. The demarcation between the responsibilities of the Chinese Academy of Sciences and the MST in policy formulation and consultation is not entirely clear, and there is probably a certain degree of ambiguity and competition in their dealings with each other. The MST is apprised of the research being done at the academy institutes and approves the academy budget as a whole, but it could not direct the allocation of funds within the academy.

National Defense Science, Technology, and Industry Commission

Since the 1950's, the quality of scientific and technological achievement is uneven. Much of China's research and development effort has been channeled into military work. Military research facilities and factories are reported to have China's best-trained personnel, highest level of technology, and first priority for funding. Although the military sector has been shrouded in secrecy, its work evidently has resulted in the largely independent development of nuclear and thermonuclear weapons, intercontinental ballistic missiles, nuclear submarines and submarine-launched ballistic missiles, and the successful launch and recovery of communications and reconnaissance satellites. Little information on the military research sector had been made public until the mid-1980's. Secrecy had been reinforced by physical isolation of many military research centers in the remote deserts and mountains of China's western regions. The overall level of China's military technology is not the highest by international standards, however, the achievements in nuclear weapons and missiles had apparently resulted from concentrated resources, effective coordination of distinct specialties and industries, and firm leadership directed at the achievement of a single, well-defined goal. Innovations in the weapons industries, suggests that a military mission could create a climate for rapid advance and technological breakthrough. The 1940's Manhattan Project in the United States, and the Soviet military accomplishments demonstrate the effectiveness of the "big push" breakthrough mode of organizing research and development. On the other hand, the general level of technology in Chinese industry and the quality of Chinese science at universities and civilian research institutes remained at a consistently low level between the 1950's and the mid-1980's. One logical explanation is that science activities to support the military differed in a very important way from purely civilian scientific and technological activities. During much of the Mao period both military strategy and the role of the People's Liberation Army (PLA) were conceived as extensions of the guerrilla based struggle for liberation.

The military sector had developed in comparative isolation from the civilian economy, and until the 1980's, its higher level of skills made little contribution to the national economy. Throughout the 1980's, efforts had been made to break down some of the administrative barriers separating the military and civilian research and development systems. The military sector had been relatively privileged, and the spirit of self-reliance had been strong. Nevertheless, the rapid development of electronics and computer applications in the 1970's and 1980's rendered much of China's military industry obsolete. Consequently, pressure for more contact between the military research units and civilian institutes (which, with foreign contact and up-to-date foreign technology, likely surpassed the technical level of the military institutes) was generated. Since the mid-1980's, many military industries such as aircraft, electronics, and telecommunications have been transferred to civilian sectors.

In 2000, the work of the military research institutes continued to be directed by the State Council's National Defense Science, Technology, and Industry Commission (NDSTIC). The NDSTIC was created in 1983 with the merger of the National Defense Science and Technology Commission, National Defense Industries Office, and Office of the Science, Technology, and Armament Commission of the Party's Central Military Commission. The NDSTIC functioned in a manner similar to the Ministry of Science and Technology, concentrating on high-level planning and coordination across the vertical chains of command in which military research institutes and factories are organized. In 2000, the Chinese leadership stressed that the defense industry should be combined with the civilian sector, and their co-operation should be market-oriented.[57]

Research in Colleges, Universities, and Enterprises

Chinese universities had engaged in little research until the mid-1980's because universities had mainly played a role in education and training. This fact was based on China's adopting the Soviet model for the organization of science and industry that featured strict separation of research, production, and training. The Ministry of Education had provided only limited funding to support research, and through the 1980's the scale of research at most colleges and universities has been very modest. Since 1980, a few academic research institutes have been established in such areas as computer science and telecommunications. The World Bank has supported a major effort to increase research in Chinese universities and to make better use of the scarce skills of faculty members. Since 1986, however, universities began to play a greater role in scientific research. "Key" state laboratories have been established in a number of selected universities. For instance, a genetic engineering laboratory was set up in Fudan University. A laser technology laboratory can be found at the Central China Science and Technology University. Likewise, the Oceanography Laboratory was located at Shanghai Jiaotong University, the Tribology laboratory appeared in Qinghua University, and the Protein Engineering and Plant Genetic Engineering laboratory was initiated at Beijing University[58].

Research institutes associated with or organized as constituent parts of productive enterprises have been quite rare and represent the smallest of the five systems of research institutes. Only the largest state-owned enterprises such as the Bao Shan Iron and Steel Group in Shanghai or the Yanshan petrochemical complex in Beijing in the late 1980's and 1990's, had their own R&D units, dedicated to solving immediate problems in production. Enterprises concentrated on production, and their managers had little

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[57] *Jiang Urges Army, Civil Co-operation* (07/17/2000, *China Daily*)
[58] Yu, Q. Y., *op.cit.* p. 170.

incentive to take the risks associated with innovation.

2.4 Planning Scientific Research, and Management System Reform

Since 1949, China has attempted, with mixed success, to organize research and development according to a centralized national plan. The six main plans for scientific development adopted since 1957 have been broad--listing topics and areas of priority without going into much detail or attempting to issue targets or dates to specific research institutes. From the 1950's through mid-1980's, the employment and funding granted to research institutes and researchers had been as much as to any other enterprise or state-sector workers. No institute ever had its budget cut for failing to make a planned discovery, and no scientist was dismissed for failing to publish or to make progress in research.

Much of the initiative in research seems to have come from below, with institutes submitting proposals for projects and funding to the State Science and Technology Commission. The commission's plans were drawn up after conferences in which scientists and directors of institutes suggested work that seemed feasible and worthwhile. The commission communicated with and coordinated with other elements of the central administration, such as the State Planning Commission and the State Economic Commission. The core of the responsibility and power of the State Science and Technology Commission was in its allocation of funds for research and approval of projects. It possessed neither the human resources nor the expertise to monitor the work of the several thousand research institutes it oversaw. Of necessity it concentrated on major projects and relied on the advice of expert scientists and the regional scientific and technological commissions, which processed reports and applications for new projects. Much of its work consisted of "balancing" the competing requests for limited funds, and its decisions often were made on grounds other than scientific merit. [59] Although China's leaders have addressed the rhetoric of centralized planning to scientific research, research activities have been more decentralized and more subject to pressures from powerful ministries and provincial-level governments

Since 1985, however, China launched the "Decision of Central Committee of the Communist Party on the Reform of Science and Technology Management System", a diversified system of funding has been carried out in accordance with the nature of different categories of research activities. [60] Funding sources have been broadened. Enterprises, organizations, even private institutions are encouraged to invest in science and technology research. The commercialization of technology achievements and the development of a technology market have been promoted in a way that fits the market economy structure. The combination of research, education, and design institutes with enterprises has been strengthened. The personnel management system has been reformed which allows scientists and technologists to move to the position that can fully display their talents. Some scientists and technologists resigned their positions in state-owned institutes to open their own semi-private research laboratories and enterprises.

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[59] Yu, Q.Y., *op.cit.* pp.15-17.
[60] *Ibid.* Yu.Q.Y.

2.5 Integration of Administrative Systems

The two forms of organizational remedies, high-level coordinating bodies and mass scientific associations that cut across administrative boundaries, were adopted by Chinese policy makers to solve the following problems: lopsided distribution of skilled personnel; pervasive fragmentation; compartmentalization; and duplication of research. Due to the Soviet model and historical factors enduring until the late 1980's two of the five research subsystems--the Chinese Academy of Sciences and the military system--were still relatively privileged in receiving government financing and allocation of scarce resources. They formed closed, self-sufficient domains. The system under the State Science and Technology Commission, which included the largest number of research institutes, was marked by wide variations in quality and a vertical, bureaucratic mode of organization that inhibited collaboration and exchange of information. Both the universities and the research institutes attached to large industrial complexes were short of funds and out mainstream research.

State Science and Technology Leading Group

The growth of China's scientific system and the tendency of compartmentalization inherent in the Soviet mode of scientific and industrial organization, were matched by the creation of administrative bodies intended to coordinate the activities of vertically organized administrative hierarchies. Both the State Science and Technology Commission and the NDSTIC, which were formed by the amalgamation of earlier coordinating bodies founded in the mid-1950's, had been charged with coordination. Efforts to fill the need for progressively more authoritative and comprehensive coordination culminated in the establishment of the State Council's Leading Group (STLG) for science and technology in January 1983. [61] The leading group, a special-purpose task force formed by the State Council to address problems that cut across administrative boundaries, was China's highest-level policymaking organ for science and technology. Its Chairperson was the Premier. Its membership included Deputy Premier, Head of the State Science and Technology Commission and the Chinese Academy of Sciences, and leading members of the State Science and Technology Commission, NDSTIC, State Planning Commission, State Economic Commission, State Education Commission, Chinese Academy of Sciences, and Ministry of Labor and Personnel. That the leading group was headed by the Premier indicated both the significance China's leaders attached to science policy and the level of authority necessary to settle disputes and to encourage cooperation. The fact that the current and immediately past Premier are engineers gives them a special role in the process.

China Association of Science and Technology

At the lower end of the administrative hierarchy, it is expected that communication and cooperation will be promoted by professional organizations, whose membership cuts across administrative boundaries. The primary organization is the China Association of Science and Technology, a non-government mass organization. It is funded by the

[61] Simon, Denis Fred and Goldman, Merle, *Science and Technology in Post-Mao China* (The Council on East Asian Studies, Harvard University, 1989), p.75.

government and, like all organizations in China, and directed by party cadres, its autonomy has strict limits. The China Association of Science and Technology is an umbrella organization: as of 1986, comprising 139 national scientific societies organized by discipline, and 1.9 million individual members. It succeeded earlier scientific associations that had been founded in 1910-20. The China Association of Science and Technology serves three major purposes. First, like professional associations in most countries, it brings individual scientists and administrators together with their professional peers from other work units to conferences, lectures, and joint projects, and it promotes communication across administrative boundaries. Second, the China Association of Science and Technology has a major role in the popularization of science and dissemination of scientific knowledge to the general public. This latter function is accomplished through the publication of popular-science journals and books aimed at an audience with a high-school education and through lecture series, refresher training for technicians and engineers, and consultation for farmers and rural and small-scale industries. Throughout the 1990's, the China Association of Science and Technology and its constituent associations served increasingly as consultants to government officials. Third, the China Association of Science and Technology played a major role in China's international scientific exchanges and hosted delegations of foreign scientists, sponsored international scientific conferences in China, participated in many joint research projects with foreign associations and scientific bodies, and represented China in many international science societies. [62]

2.6 International Ties

[62] *Ibid.* Simon, Denis Fred and Goldman, Merle

The introduction and assimilation of foreign advanced technology is an important part of China's opening policy. Since 1978, China has greatly strengthened its participation in international conferences and the extent of cooperation in projects with foreign scientists. China has sent thousands of Chinese graduate students and senior researchers to foreign universities for training and joint research.

Scientific cooperation has come to play a significant part in China's foreign relations and diplomatic repertoire. In 2000, China had diplomatic relations with 150 countries and formal, government-to-government agreements on scientific cooperation with 95 of them.[63] When diplomatic relations were established between China and the United States in January 1979, the Joint Commission in Scientific and Technological Cooperation was founded. Since then, the two governments have signed twenty-eight agreements on more than 1000 scientific and technical cooperation projects in fields ranging from earthquake prediction to industrial management.[64] China has mutually beneficial scientific exchange programs with both technically advanced nations and those having only a minimal scientific capability. Although China tended to receive aid from more scientifically advanced nations and to render aid to the less developed, the equality implied in scientific exchange made it a useful diplomatic form.

By 2000, China had scientific-exchange relations with 150 countries--usually in the form of agreements between the China Association of Science and Technology and a foreign

[63] The Ministry of Science and Technology of PRC. *International Co-operation* (in Chinese). http://www.most.gov.cn/
[64] *Ibid.* http://www.most.gov.cn/

equivalent.[65] Incomplete statistics indicated that by 1997 almost 120,000 Chinese scientists had completed over 35,000 joint projects with scientists in the United States, West European countries, Eastern Europe, and Japan.[66] In June 1986, the Chinese Academy of Sciences signed an agreement with the Soviet Academy of Sciences for scientific cooperation in unspecified fields. [67]Many exchanges with the United States involved Chinese-American scientists and engineers, who collaborated with visiting Chinese researchers in the United States and visited China to lecture on their specialties and to advise scientific bodies. [68]

By 1986, the China Association of Science and Technology or its constituent associations were full members of 96 international scientific societies and committees, and over 300 Chinese scientists held office in international scientific bodies. [69] China also was an active participant in United Nations scientific activities in the 1980's and 1990's. Luoyang, Henan Province, is the site of the United Nations Educational, Scientific and Cultural Organization's International Silt Research and Training Center, which specializes in problems of river silts. Apart from the 340,000 students China sent abroad for studying and training between 1979 and 1999, approximately 300,000 Chinese scientists took part in various international exchanges[70]. Between 1980 and 1986, China hosted 155 international academic conferences, which were attended by 10,000 foreign scholars and 30,000 Chinese participants.[71] By 1999, China also has employed about

[65] *Ibid.* http://www.most.gov.cn/
[66] *Ibid.* http://www.most.gov.cn/
[67] *Ibid.* http://www.most.gov.cn/
[68] *Ibid.* http://www.most.gov.cn/
[69] *Ibid.* http://www.most.gov.cn/
[70] *Ibid.* http://www.most.gov.cn/
[71] The Ministry of Education of PRC, *International Co-operation and Exchange* (in Chinese), http://www.moe.edu.cn/moe-dept/guoji/index.htm

700,000 foreign experts, often, retired scientists or engineers, as short-term consultants.[72]

International exchanges represent one of the most successful aspects of the Chinese government's efforts to raise the level of science and demonstrate the strength of the centralized direction and funding possible under China's bureaucratic organization of science. The weaknesses of that mode of organization are evident in the less successful efforts to improve the internal functioning and productivity of the domestic science and technology establishment and have generated a major effort to reform that establishment.

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[72] *op.cit.*, http://www.most.gov.cn/

Chapter 3: From Reform and Opening to Innovation and Commercialization

3.1 Shortcomings of the Science and Technology System before the Reform

From the perspective of China's leaders, the entire science and technology system of the late 1980s, with its 8 million personnel and 10,000 research institutes, represented an expensive, underutilized and not very productive capital investment. Dissatisfaction with the system had become pervasive by the early 1980s, and both scientists and political leaders agreed on the necessity for fundamental reform.[73] The primary complaint of the leadership was that, despite thirty years of policy statements, central plans, and political campaigns directed at the attitudes of scientists and engineers, science still was not serving the needs of the economy. Reformist political leaders and senior scientists identified a number of organizational problems that were inherent in the system adopted from the Soviet Union and that had been compounded by Chinese work-unit and lifetime job assignment practices.

The primary problems before the reform were listed as the following:

. Uneven development and lack of coordination among scientific fields,

. Lack of communication between research and production units,

. Duplication of research and facilities, rivalry among institutes,

. Too many administrative bodies, and hierarchies,

. Mal-distribution of personnel,

with some units and fields overstaffed and others very short of skilled personnel,

. Poor management,

. Poorly educated managers,

. Absence of incentives for good work or of penalties for poor performance,

. Absence of direct communication between research units and productive enterprises,

All these problems resulted in the failure of the science and technology establishment to serve production and economic growth. [74]

In the 1980's research institutes, like all Chinese work units, responded to an economic system in which supplies were uncertain by attempting to be as self-sufficient as possible. Exchanges of information, services, or personnel across the very strictly defined administrative boundaries were difficult, resulting in failure to share expensive imported equipment and in widespread duplication of facilities. The absence of information on work being done in other research institutes, even in the same city, frequently led to duplication and repetition of research.

Like all other workers in China, scientists were assigned to research institutes or universities by government labor bureaus. Such assignments frequently did not reflect specialized skills or training. Assignments were meant to be permanent, and it was very difficult for scientists or engineers to transfer to another work unit. In many cases, talents or specialized training were wasted. Institutes that may have had the funds to purchase advanced foreign equipment often had no way to hire a Chinese chemist or mathematician. Not only were China's scientists and engineers in short supply, many

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[73] Yu, Q. Y., *Op cit.*, p.9.
[74] Ibid., pp.14-17.

were underemployed or misemployed.

3.2 The Reform Program

In March 1985, after extensive discussion, consultation, and experimentation, the party's Central Committee called for sweeping reforms of science management. The reforms proposed in the "Decision on the Reform of the Science and Technology Management System" represented a major break with past practices, and they assumed corresponding reforms in the nation's industrial and economic systems. Chinese leadership pointed out that China's former science and technology management system was formed under specific historical conditions that it was inadequate in meeting the demands of building Four Modernization. One of the major faults of the former management system was the misapplication of science and technology to production. There should be manifold cross channels between the both. Under the old management system, research institutes were under a vertical system in which they were responsible only to their higher level departments, without any channel to lead to the society and serve enterprises. Scientific research institutes had long failed to conform to the demands of enterprises. Even research results needed by enterprises had been difficult to apply and extend to production, because of either high cost or inability to outfit technology into a whole set. The industrial community had developed hostility to the scientific community, seeing it as uselessness, and the scientists on their side had also come to see their work as the laboratory. The only way was to remove the old one and build a new one. By changing the method of funding research institutes, encouraging the commercialization of technology and the development of a technology market, and rewarding individual scientists, the reforms of the mid-1980s were meant to encourage the application of science to the needs of industry. It was envisaged that most research institutes would support themselves through consulting and contract work and would cooperate with factories through partnerships, mergers, joint ventures, or other appropriate and mutually agreeable means. The ultimate goal was to encourage exchange and cooperation and to break down the compartmentalization characterizing China's research and development structure. The policy also encouraged young scientists by providing research awards, and not giving grants to scientists above a specified age.

The principal means for accomplishing the reforms was changing the funding system to force research institutes to establish contact with productive enterprises and to do work directly supporting those enterprises. Direct allocation of funds to research institutes was to be phased out and replaced by a system under which institutes sold their services in the marketplace. The distinctions among institutes subordinate to the Chinese Academy of Sciences, the industrial ministries, provincial-level governments, colleges and universities, and even the NDSTIC were to be minimized, and all were to compete and collaborate in a single market-oriented system. Institutes doing basic research were to compete for grants from a National Natural Science Foundation (which was subsequently established).[75] The reforms were not intended as a budget-cutting measure and total state funding for science and technology was to be increased. The central government's 1985 Decision on Science and Technology System Reform began a restructuring. The decision encouraged institutes to do business freely, to support themselves rather than relying on

State funds. As a result, non-state technology companies opened. Today, China has more than 7,000 non-state companies working with chemicals, electronics, communications, machinery, computers, biotechnology and environmental protection, according to the China Promotion Association for Non-State Technological Enterprises.[76]

A technology market and the commercialization of technology in the late 1980s were to be developed to encourage the transfer of technology and the transformation of research results into products and services. Direct centralized administration and supervision of research were to decline, and institutes were to be headed by younger, technically qualified directors, who were to be given broad powers to select their own research topics and to seek out partners for cooperation and consultation. Scientific personnel were to receive better pay and benefits, recognition of their achievements, and the right to do supplementary consulting work and to transfer to units where their talents could be better utilized.

3.3 The 863 Project

Amidst the tide of commercialism, a couple of top scientists sent a suggestion to China's leadership in March 1986, calling for a high-tech project of China's own. The famous "863 Project" was launched,[77] which kept China close on the heels of international advances in the high-tech research arena, such as in computer science, high-energy physics, and marine science. The first phase of the project was completed by the end of

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[75] The Ministry of Science and Technology of PRC, *Scientific Funding* (in Chinese). http://www.most.gov.cn/
[76] Cui Ning, *New Economy Rewards Science* (09/11/2000, *China Daily*)

1999 with many substantial achievements, such as the discovery of the Hepatitis B vaccine and robots for deep-sea exploration. The second phase of the project, titled "super 863," is now under way and focuses on the application of the research results.

3.4 Readjustment in 1990's: From Basic Research to High Tech Research

In the 1990's, China readjusted its policy of science and technology because of rapid economic growth as well as growth in people's demands for an improved standard of living. China participated in international economic exchange to a greater extent than ever before and was confronted with strong international competition. The entry of a large number of global corporations such as IBM intensified such competition. Although low technology and labor intensive products had helped China develop a good export market, now the market was saturated. In addition, exporting products in large volume was equivalent to exporting resources and energy. The high consumption of resources and the increase in labor cost made it impossible to sustain the market for the long run. For instance, China exported to Japan every year about 20 billion pairs of disposable chopsticks, which account for the entire consumption of chopsticks in Japan. Disposable chopsticks as a commodity have a very low value added and high timber consumption. China is seriously short of forestry resources, with a green rate as low as 14%. The green rate of Japan is more than three times than China. Actually, the importation of disposable chopsticks had helped Japan preserve its forestry resources even though its green rate is much higher than that of China. In addition, Japan had cycled the used chopsticks into

[77] The Ministry of Science and Technology of PRC, *The 863 Project, Science Plans*, http://www.most.gov.cn/

raw materials for making recycled paper. What Japan received from exporting this recycled paper had nearly covered its payment for importing disposable chopsticks. Therefore, for China's industrial upgrade, the export industry of chopsticks should be eliminated. Furthermore, the upcoming participation in the World Trade organization (WTO) would finally result in removing or reducing in tariff rates and the withdrawal of non-tariff barriers. The Chinese leadership realized the situation and called for reform again. The specific measure was to readjust the industrial formation and enhance high technology and high-tech industry. The more important change was recognizing the interaction between scientific and technological development and the economic mechanism. Stagnation of the large and medium state-owned enterprises had been a negative factor for scientific and technological development in the industrial sector.

Transformation of the economic growth model was dependent on scientific and technological progress. China imported a large number of advanced technologies and equipment from abroad since the implementation of reform and opening policy. According to China's Third Nationwide General Industry Survey by the State Statistical Bureau, the current technologies and equipment were still generally obsolete. Aside from the obsolescence of technological equipment, higher consumption of materials and energy as well as lower quality in products also came from the lower levels of technology.

The emphasis of the readjustment policy was the transition from basic research to high tech research. High-tech industry is in the forefront of international economic, scientific, and technological competition. The development and industrialization of high technology is a fundamental way to upgrade industrial formation and substantially improve productivity and economic benefit. Since China carried out the 863 Project in 1986, China has given priority to the development of high–tech industry in State industrial policy and development planning. Efforts have been made to improve performance, quality and market competitiveness of domestic high-tech products and to increase the scale-up benefits of high-tech industry and its proportion in the national economy. In 2000, high-tech industries have grown into mainstay industries. In the realm of industry, further development of information technology (IT) will be the country's primary focus. Specific sectors within the general IT industry that will receive particular attention include micro-electronics, computer software, communications, electronic business, long distance learning, and computerized finance, insurance and taxation services. Other industrial sectors that will continue to be emphasized are space and aviation technology, bioengineering and new materials. [78]

3.5 Technology, Innovation and Commercialization, 1999-2000

Technological innovation and commercialization is an important strategy adopted by China in the late 1990's. Nowadays, one nation's level of technological innovation and application of advanced technologies determines its comprehensive national competitiveness. Without technological progress, China would not be able to maintain steady social and economic progress, nor achieve its strategic development goals for the modernization drives. China has made great efforts to develop science and technology and build up her own technological expert teams. Governments, instead of meddling in

[78] Cui Ning, *Ministry's science plan put under microscope* (10/31/2000. China Daily)

enterprises and institutes, help create a healthy climate for scientific workers to exploit their full potential. Scientific researchers are encouraged to make breakthroughs in some key industries and important fields determined by the science development strategy for the 10th Five-Year Plan period (2001-05) by giving full play to their wisdom and creativity. China will develop high-tech industries with their own Intellectual Property Rights (IPR) and promote renovation of the traditional industries with high technology. Most scientific research institutes are being turned into enterprises and scientific researchers encouraged carving out their careers in the competitive market. [79]

China is making efforts to cultivate and improve the innovative consciousness and ability of the whole nation by reforming the education system and practicing quality-oriented education. The role of small and medium-sized enterprises, which are based on science and technology, will be upgraded in intensifying technology innovation and developing high technology. Such businesses are highly specialized and flexible with smaller burdens. A further move is the establishment of state-level technological innovation systems, as well as measures to speed up technological application and the establishment of a nationwide mechanism that encourages technological innovation and supports the application of scientific discoveries and inventions.

Scientific development for the 10th Five-year Plan (2001-05) will focus more on nurturing high-tech industries and boosting agricultural production through advanced technology. In regard to agriculture, strategies will be geared towards accelerating the

[79] Cui Ning, *Ibid.*, " By the end of next year, all academic institutes attached to ministries or commissions and regional governmental departments will either become technological firms, merge with enterprises or universities, or function as

transition from a traditional labor-intensive mode to modern technology-based production. This of course will have the consequence of freeing up substantial numbers of agricultural workers, for whom employment will have to be found. For high-tech industry, measures will be taken in such fields as agriculture, information science, environmental protection and the comprehensive use of natural resources, medicine, energy, transportation, materials, machinery, building, textiles and the light industry, sources from the ministry revealed.[80] Scientific departments will launch a group of projects involving ecosystem conservation, environmental protection and disaster prevention or mitigation to sustain the harmony between economic growth and population and natural resources and the environment. Another important task is to upgrade tertiary industry, mainly the service sector, through advanced technology. Efforts will also be made to develop technologies for national defense and civil industries. To upgrade traditional industry through high technology, scientific administrations across the country will help spread computer-aided, energy saving and cleaner production technologies among industrial sectors [81]

Supplementary regulations will be worked out to spur the development of high-tech

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intermediate technology agencies."

[80] *Ibid.*, "In the future, the country's researchers will pay greater attention to such issues as population, health care, environmental protection, and work place safety in a bid to improve people's living standards, the Ministry of Science and Technology announced yesterday. " "This increased research and the attendant creation of new technologies are just part of the science development strategy for the 10th Five-Year Plan period (2001-05), according to the Minister of Science and Technology Zhu Lilan, who spoke at a national conference on science and technology which opened in Beijing yesterday. In the realm of industry, Zhu said further development of information technology (IT) will be the country's primary focus. Specific sectors within the general IT industry that will receive particular attention include micro-electronics, computer software, communications, electronic business, long distance learning, and computerized finance, insurance and taxation services. "

[81] Cui Ning, *Scientists Told to Aid Development* (01/25/2000, *China Daily*). "He urged scientists to focus on upgrading traditional industries with modern technology. Technicians and engineers should help businesses accelerate their technology innovation. The breakthroughs could then be marketed, Wen said. Another important task is developing high-yield agriculture, Wen added. Scientists are responsible for developing new energy-saving technology that can be used in agricultural production, he said. "

industrial zones and reform personnel administration systems in research institutions. High-tech firms will be listed on the stock exchange to pool funds directly from the stock market The government has already adopted measures to help build a national innovation system and support high-tech ventures. It announced earlier in 1999 that it would allocate 5 billion *yuan RMB* (US$600 million) for the system. It will also provide 600 million *yuan RMB* (US$72.3 million) for outstanding Chinese scientists overseas to participate in related research programs. The government has established the State Supreme Science and Technology Award that provides winners with 5 million *yuan RMB* (US$588,000) to encourage scientists to work for major breakthroughs in research.[82] There are various plans and inducements aimed at Chinese who are overseas to return and establish high-tech enterprises. For example, Guangzhou, one biggest city in South China, held the '99 China Overseas Chinese Scholars Science and Technology Exchange Convention to help the nation secure more high-tech projects and encourage more overseas Chinese students and scientists to come back to work in the country. The convention allowed overseas Chinese students and scientists to promote their high and new technology projects, allowing them to network with domestic enterprises. About 800 overseas Chinese students and scientists with doctoral degrees. registered for the convention. They were presenting 602 high and new technology projects for which they were seeking institutional support. Attending the convention were representatives from 28 provincial and municipal governments, 40 universities and some research institutions.[83] Other plans included Chinese universities, research organizations and high-tech enterprises provided

[82] Cui Ning, *New Economy Rewards* Science (09/11/2000,*China Daily*). "Last year China set up a national award to honor scientists who contribute to scientific progress and lead to the commercialization of their findings. Called the National Top Scientific and Technological Award and nicknamed "China's Nobel Prize," the award will give 5 million yuan (US$602,400) to outstanding scientists".

[83]Zhan Lisheng, *Fair lures Overseas Scientists Back Home* (12/29/1999, *China Daily*)

competitive salary, benefit and good work environment to recruit overseas high-tech personnel.

3.6 The Relation with Economic Reform

Implementing the reforms of the science and technology system, however, presupposed reforms of the economic, industrial, and local administrative systems. In general, science and technology reforms represented the application to that sector of the principles underlying the sweeping reforms of the economy proposed in the October 1984 "Decision of the Central Committee of the Chinese Communist Party on Reform of the Economic Structure." [84] Both reform "decisions" emphasized greater autonomy for institutions, a greater role for the market, more competition, and rewards for the successful introduction of improved products and processes. In every case, the goal was increased productivity and economic benefit.

The central provisions of the 1980's reform related to funding, the technology market and cooperative ventures, and the rights and potential job mobility of individual researchers. The intent of the reformers was to change the basic conditions of the economic system. So that the self-interest that had pushed managers of factories and research institutes toward compartmentalization, duplication, and hoarding of resources would henceforth push them toward cooperation, division of labor, and orientation toward the needs of the market. Because these reforms represented a radical departure from the procedures developed since the 1950's, the leadership anticipated that their implementation would be slow, and it planned to phase them in over a number of years.[85]

Perhaps because of the centrality of funding to the whole reform scheme and because the administrative machinery for handling budgets was already in place, many concrete provisions for funding research were adopted following the March 1985 Central Committee decision. In February, 1986 the State Council promulgated provisional regulations under which science and technology projects listed in the annual state economic plan were to be completed as contract research, in which there would be nationwide open bidding on the contracts. Banks were to monitor expenditures under the contract. Institutes conducting basic research were to have their regular operating expenses, a base budget, guaranteed by the state, but all other income would come from competitive research grants. The government was to continue to fund completely the institutes working in public health and medicine, family planning, environmental science, technical information, meteorology, and agriculture. In 1986 the newly established National Natural Science Foundation, explicitly modeled on the United States National Science Foundation, disbursed its first competitive awards, totaling 95 million *yuan RMB*, to 3,432 research projects selected from 12,000 applications. [86] The amount of money awarded to individual projects was not large, but the precedent of competition, disregard of administrative boundaries, and expert appraisal of individual or small-group proposals was established and widely publicized. And, early in 1987, the NDSTIC announced that henceforth weapons procurement and military research and development would be

[84] *China: Reform of the Economic System, Beginning in 1979*, http://lcweb2.loc.gov/
[85] Ibid., http://lcweb2.loc.gov/
[86] *Ibid.*, http://lcweb2.loc.gov/

managed through contracts and competitive bidding.[87]

The deteriorating situation in resources and environment has drawn serious attention from the Chinese government in the 1990's. The government has worked out a whole set of strategies, policies and countermeasures. [88] The scientific community has also engaged in serious study of the issue. The options for China are either to gain fast economic growth at the expense of high consumption and even a serious waste of resources and the sacrifice of the environment, or to closely integrate economic development with the conservation of resources and the protection of the environment and society. Chinese economic and social development policy in the 1990's has been based on optimizing state-owned enterprises and coordinating between economy, society and environment. China attended the U.N. Conference on Environment and Development in 1992. The Chinese government has taken an important step to cover the sustainable development strategy and the measures for its implementation into the Ninth Five Year Plan for the national economic and social development and the Outline of the Long Range Goal up to 2010 of the PRC.[89] The economic policy on sustainable development will motivate scientific innovation and commercialization.

3.7 Technology Markets and Joint Ventures

[87] *Ibid.*, http://lcweb2.loc.gov/

[88] Cui Ning, *Ministry's Science Plan Put Under Microscope*, (10/31/2000, *China Daily*). "In the future, the country's researchers will pay greater attention to such issues as population, health care, environmental protection, and work place safety in a bid to improve people's living standards, the Ministry of Science and Technology announced yesterday. One product of this research is expected to be the development of new technologies to help prevent natural disasters, reduce the spread of serious diseases and improve safety on work sites."

[89] *Outline of the Nineth Five-year Plan for National Economic and Social Development & the Long Term targets Through the Year 2010*, http://www.chinese-embassy.org.uk/economy/outline

Commercializing technology requires markets, and China in the late 1980's had to develop market institutions to handle patents, the sale of technology, and consulting contracts. This was a major endeavor and one that promised to take many years deciding how to set prices for technology and how to write and enforce contracts for technical consulting proved difficult, largely because of the complexity of technology markets. Further, China lacked the legal and commercial frameworks to support such markets. Nevertheless, institutes and factories participated in "technology fairs" and established contractual relations in great numbers, with the total technology trade volume in 1986 reaching an estimated 2.3 billion *yuan RMB.*[90] Research institutes and universities formed companies to sell technical services and develop products. Even the formerly self-contained Chinese Academy of Sciences established companies to export specialty magnets and to develop optical products.[91]

In the late 1980's, China's technology markets and efforts to commercialize scientific and technical knowledge were growing rapidly amid considerable confusion, ferment, and turmoil. Although progressing, the commercialization of technology was proving difficult to implement, and, perhaps for this reason, the State Council announced in February 1987 that most applied scientific research institutes were to be incorporated into large and medium sized productive enterprises to coordinate research with the needs of production.[92]The precise form the technology market would eventually take was not clear, but its development had wide support and was not likely to be halted or reversed.

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[90] *China: Technology Markets and Joint Ventures*, http://lcweb2.loc.gov/cgi-bin/query/
[91] *Ibid.* http://lcweb2.loc.gov/cgi-bin/query/

In the 1990's, technology importation, through various joint ventures, has further expanded not only in scale but also in scope. After a successful joint venture with McDonnell-Douglas for the assembly of airplanes,[93] joint ventures in the production of automobiles have developed rapidly. [94] China has put forward a general guideline for the exchange of technology with market.[95] Almost every province, city, county has its own technology development zone. In the 1980's, a large amount of foreign capital absorbed by China was invested in labor-intensive industries. However, in the 1990's, a relatively larger amount of foreign capital shifted to technology and capital-intensive industry.

3.8 Personnel and Job Mobility

From one perspective, the most important element of China's science and technology system is its human capital--its trained scientists and engineers. By the 1980's it was widely recognized in the Chinese press that scientists like all intellectuals, had been poorly treated, underpaid, and burdened with difficult living conditions that reduced their productivity.[96] In many cases scientists abilities were wasted because they were assigned to jobs outside their expertise or because their institute already had all the professionals in

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[92] *Ibid.* http://lcweb2.loc.gov/cgi-bin/query/

[93] Jiang Chen, *Domestic Aircraft Set to Fly* (11/13/1999, *China Daily*). "The first MD90-30 trunk liner, especially made in China for the 21st century, received certification from the Federal Aviation Administration (FAA) of the United States on Tuesday. The MD90-30, based on the MD82 of the former McDonnell Douglas, is a 150-seat aircraft. Its features are low fuel consumption, low noise and good performance, which meet the airworthiness requirements for the 21st century, according to a spokesman from the corporation."

[94] Shen Bin, *Volkswagen to Expand Business in China* (03/11/99, *China Daily*).

[95] Cui Ning, *Sipo Plan to Enhance Technology Marketing* (02/09/99.*China Daily*). "A project to enhance commercialization of patented technologies will be implemented this year by the State Intellectual Property Office (Sipo)."

[96] He Sheng, *Road of Science Full of Twists and Turns* (09/11/2000.*China Daily*) ."Knowledge was drained and devalued following the opening-up policy and the overall reform of the country. The pain was summed up by a popular saying: "the rocket designer has been impaled by the egg seller, while a doctor with a scalpel earns less than a barber with a razor". Suddenly, Chinese scientists, who were used to the highly-centralized, non-profit-making research model, got their first lesson of market economy by "swimming in the sea of commerce"."

their field it needed and there was no way for them to change jobs. Many Chinese science policy writers were familiar with the conclusion of Western specialists that scientific progress and the effective application of science to practical problems are facilitated by personnel mobility.[97] Accordingly, the March 1985 party Central Committee decision called for reform of the personnel system to promote a "rational flow" of scientific and technical personnel. [98]

Throughout the late 1990's, however, job mobility and attempts to place scientists where their talents could have the greatest effect were the aspect of reform in which least was achieved. Transfer of scientists from one unit to another remained a major step, and a relatively infrequent one. According to the State Science and Technology Commission, 2 percent of scientists and engineers changed work units in 1983, and only 4 percent in 1985. Personnel still required the permission of their work unit heads to transfer, and that permission often was withheld. Many directors of institutes were accused of having a "feudal mentality," that is, regarding personnel as part of their unit's property. [99]

The State Council reiterated in the mid-1980's that scientists and engineers had the right to do consulting work in their spare time. In practice, however, such spare-time consulting often created problems within the work unit, as some institute directors attempted to confiscate payments for consulting or even to charge their personnel in the local courts with corruption and theft of state property. [100] Although the press gave

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[97] Yu. Q. Y. *op.cit.*. p.36-41.
[98] *Ibid.* Yu. Q. Y.
[99] *Ibid.* Yu. Q. Y.
[100] *Ibid.* Yu. Q. Y.

considerable publicity to scientists who had left the "iron rice bowl" [101]of a Chinese Academy of Sciences institute to start their own business or to join a growing collective or rural factory, such resignations remained relatively rare. [102] Possibly more common were practices whereby institutes encouraged their personnel on temporary consulting contracts to productive enterprises.

The difficulties in transferring scientific personnel even when the Central Committee and the State Council made it official policy demonstrated the significance of China's unique work-unit system of employment and economic organization and the obstacles it presented to reform. Allowing personnel to decide for themselves to move out of the work units to which the state and the party assigned them would be a major break with the practices that have become institutionalized in China since 1949. Some observers believe [103]that because of its potential challenge to the authority of the party, which controls personnel matters in all work units, job mobility for scientists, even though it would promote scientific productivity and the growth of the economy, may be too extreme a reform to be feasible.

[101] A Chinese idiom referring to the system of guaranteed lifetime employment in state enterprises, in which the tenure and level of wages are not related to job performance.

Chapter 4: TECHNOLOGY TRANSFER

4.1 Policy

The acquisition of foreign technology is viewed as the key element in China's strategy for entering world markets. The ultimate goal being to absorb, adapt, equal and surpass those of Western countries. In fact, technology transfer has become something of a compulsion among Chinese leaders, who see tremendous opportunities for China to leap ahead through the application of foreign equipment and technical knowledge. Since the late 1970's, China's goals of modernization and rapid economic growth have depended on the large-scale introduction of foreign technology and investment. The task was to import technology to renovate and upgrade several thousand factories, mines, and power stations whose levels of productivity and energy efficiency were far below prevailing international standards. Since 1980 Chinese policy statements have stressed the need to improve existing facilities, to import technology rather than finished goods, and to renovate factories through selective purchase of key technology rather than through purchase of whole plants.[104]This was an unprecedented problem, since China's previous experience with technology transfer, both in the massive Soviet technical-aid program of the 1950's and in the more modest purchases of fertilizer and petrochemical plants in the 1960's and early 1970's, featured large turn-key projects that brought in complete plants. In the 1980's and 1990's, much of the technology to be imported was production or process know-how, with emphasis on electronics, telecommunication, and machinery areas. Such technology was usually based on the proprietary knowledge of foreign corporations, and China demonstrated an unprecedented willingness to cooperate with such firms. With the explicit aim of promoting technology imports, China made great efforts to attract foreign businesses and foreign capital and permitted joint ventures and even foreign-owned subsidiaries to operate in China.

China's economic planners gave priority in technology imports to electronics, telecommunications, electric-power generation and transmission, transportation equipment, and energy-saving devices.[105] The degree of central control over technology imports fluctuated in the last two decades, reflecting changing foreign trade policies and foreign exchange balances, but the overall trend was toward devolution of decision making to those who use the technology or equipment. Bank loans and other means were made available to encourage end users to select appropriate technology. Earlier attempts to have central authorities select technologies proved totally ineffective, as they took no responsibility for whether or not he end product had a market either domestic or foreign, leaving the Chinese recipient enterprise with the burden of paying the cost of imported technology.

4.2 Modes of Transfer

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[105] *Technology Firm to Enforce Role* (10/01/1999,*China Daily*), "CHINA National Technical Import and Export Corp (CNTIC) is to play a more important role in the international technical and service trade as the knowledge economy develops. Founded in 1952, CNTIC, which is owned by General Technology (Group) Holding Ltd, is one of the largest State-owned foreign trade companies specializing in technology imports and exports. Since 1979, CNTIC procured funds for various projects from foreign government loans, World Bank loans, Asian Development Bank loans and other international financial organizations. The company has so far imported 3,500 projects of advanced technology and completed production lines of total contract value of more than US$68 billion in the

Chinese leaders see foreign investment as a means more easily to bring about the transfer of key production and managerial know-how to Chinese industry, though both Chinese and foreign observers acknowledge that many questions remain about the effectiveness of several existing joint ventures for acquiring technology. The transfer of proprietary technology from a foreign corporation is, among other things, a commercial transaction, and such transactions take many forms. Chinese authorities have selected joint-equity ventures as their preferred mode of technology transfer. [106] In such ventures, both the foreign and the Chinese partner contribute capital, or its equivalent in agree to value, each provides what it has the advantage in (usually technology and access to world market for the foreign partner and labor and a factory for the Chinese partner), and management and profits are divided according to percentage of ownership. Many major foreign corporations with technology that China desires have been reluctant to risk their capital in such ventures. There is also concern over intellectual property rights protection and concern over Chinese technicians' reverse engineering of that technology. But enough have agreed to produce such items as jet airliners, computers, and machine tools that Chinese authorities can claim success for their policy.

A series of regulations on technology transfer have been introduced.[107] A patent law was announced in April 1985, in large part to alleviate foreign concerns about violations the integrity of their technology and know-how. Regulations also have been introduced that enhance Chinese access to core technologies, but whose principal aim is to limit the

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fields of energy, Tele-communications, chemical and petrochemical industry."

[106] Simon ,Denis Fred and Goldman, Merle, *op.cit.*., p.290.

amount of control foreign firms can retain over the application of technology once transferred to a Chinese counterpart. The rules announced in May 1985 by the State Council, restrict the use of so–called restrictive business practices by foreign firms in China, such as limiting the geographic export area of products manufactured with the imported technology.[108] Another set of measures was the adoption of the "certificate of approval " to be obtained from the Ministry of Foreign Economic Relations and Trade that the technology-import projects are reviewed in order to ensure that proposals are adequately evaluated before final approval is granted. Other legislation regarding technology transfer included requirements concerning the levels and appropriateness of the imported technology must meet specified criteria.[109] The need for guarantees by the foreign supplier is that the technology is not defective and will allow the recipient to meet its stated objectives. The provisions limit the term of the contract to ten years and stipulate that the Ministry of Foreign Economic Relations and Trade or its stated representative must review and approve the contract. [110]

4.3 Linking Technology and Economics

The gradual integration of the Chinese economy with the world's major market economies stimulated and supported in large part by the transfer and more effective use of foreign technology–could positively serve to make China increasingly interdependent with important segments of the global economy. Throughout two decades, the Chinese economy has become an important site for the production of some key labor-intensive

[107] *Ibid.*, p.301
[108] *Ibid.* p.301

components or products, a supplier of key natural resources and minerals, and even a source of R & D support for foreign corporations. For example, Volkswagen and Tongji University launched an automotive institute in Shanghai, China's largest car making city. Volkswagen has donated more than 1.1 million Deutsche marks (US$550,000) to the institute. The institute has been a forum for German and Chinese experts to conduct an automotive information exchange. The institute is dedicated to automotive research and development projects for both Volkswagen and its joint venture in China.[111] In this context, the evolution of Sino-Japanese, Sino-West European, Sino-American economic and technology relations could take on long-term significance. China entry to the WTO will be a further step in augmenting this trend.

As they have accumulated experience in dealing with foreign corporations, Chinese economic administrators and enterprise managers become better able to negotiate contracts that, while not full joint ventures, still permit the necessary training and consultation in the use of foreign technology. By the late 1980's, the transfer of foreign technology had become a normal commercial transaction. To an increasing extent, policy and practices for technology transfer were becoming part of general economic and foreign trade policies. China faced problems in assimilating technology in the factories that imported it and in deciding which foreign technologies to import. It was becoming clear to Chinese planners and foreign suppliers of technology that these problems

[109] *Ibid.* p.301
[110] *Ibid.* p.301
[111] Gong zhengzheng, *School Studies Automobiles* (06/17/2000, *China Daily*). "SHANGHAI: Volkswagen and Tongji University yesterday launched an automotive institute in Shanghai, China's largest car making city. The launch of the institute symbolized that co-operation between Volkswagen and Tongji University has entered a new phase, said Robert Buechelhofer, president of Volkswagen Asia-Pacific Region. "

reflected overall deficiencies in technical and management skills and that they were general economic and management problems. It was compounded by the fact that many foreign suppliers offered special private bonuses to Chinese decision-makers who were charged with technology selection. The solution to these problems was increasingly provided by Chinese reforms of the economy and industrial management. The effort to import and assimilate foreign technology thus served to help unify technology policy and economic policy and to overcome the problems of the separation of science, technology, and the economy, which China's leaders had been trying to solve since the early 1950s. In addition, China's commitment to the joint venture model on the assumption that a foreign investor was by definition committed to maximizing the profit of the j-v enterprise was subject to some question. Multiple problems were reflected from j-v. For example, Chinese side undervalued their capital instruction and infra structural contribution, neglected international marketing resulting in the final distribution of profit not proportionate to each side's equity contribution, folded transfer price into the "price" set on equipment and related technical support which expressed through the value of equity contribution.[112] These problems negatively reflected that China still lacked experience in dealing with multinational capital and j-v.

[112] Noumoff, SO.I., *Transnational Corporation Investment in China: A view from the Outside*, in Teng Weizao and Wang, N.T (eds), Lexington Books, 1988, p.210.

Chapter 5: Case Study[113]

Those foreign-technology acquisition projects that succeed almost always pass through a decision-making process that takes place in identifiable stages. First, decisions are made about the specific technologies needed on the "demand" side and those can realistically be offered on the "supply" side. Most often, these decisions are made by organizations most directly involved, the Chinese enterprises seeking foreign technologies and the foreign firms offering them. Second, consultations and negotiations typically take place on two levels: discussions within the Chinese enterprises, as various groups came to grips with the implications of the technological innovation. Then discussions between the Chinese enterprises and its constituencies about changing requirements necessitated by the new technologies and the productivity to expect from this technology. Third, the above decisions have to go through a process of authorization by " higher authorities." It is here that decisions are reviewed and new arrangements ratified. Finally, the users put their new technology to work and evaluate the results. If any stage is missed or completed in a partial or slipshod fashion, the acquisition process almost invariably falls through, regardless of the appropriateness or "fit" of the new technology.

I have found from this case study that China's acquisition of foreign technologies is shaped by (1) a multi-tiered *process* that includes a number of distinct and separate stages, and (2) a group of *key players* whose activities shape the workings of the different stages. An important part of whether the foreign technology transfer process works or not in

[113] The information used in this case study is from personal files provided by Dr. S.J. Noumoff.

China depends on how well the key players interact with each other and how successfully they negotiate each stage of the acquisition process. The TiO2 project offers an interesting case study that illustrates the interaction among players and process in a technology transfer in China.

The TiO2 project started when a relationship was established between the Stanford Research Institute and the Institute of Mechanical Engineering of the Chinese Academy of Science. One of the consequences of this relationship was an exploration of the technologies available to SRI and an attempt to match these with China's needs. The first major project agreed to by both sides was a process of Titanium Dioxide (TiO2) coating process for paper, paint and other industrial applications. It was assumed that if clearance could be obtained from the senior levels of the Chinese government it would facilitate the technology transfer process. Taking advantage of the presence in Beijing of Dr. S. J. Noumoff of McGill University, it was agreed that Dr. Thiers (Director, Specialty Materials and Chemicals, SRI Consulting) would join him and a meeting was arranged with then Chinese Vice Premier (Present Premier) Zhu Rongji in 1996. It is of interest to here note that Vice-Premier Zhu increasingly employed the State Bureau for Foreign Experts as an instrument for facilitating technology related acquisitions. Dr. Noumoff is the old friend of Premier Zhu. Two Chinese scientists. Dr. Pu Yikang (Ph. D from McGill University and the person who arranged a visit to McGill University by Zhu Rongji in 1985), and Dr. Jia Fu (who had also studied abroad), both from the Institute of Mechanical Engineering (IME) of the Chinese Academy of Science, played a coordinating role with Chinese clients in this project. Dr. Pu and Dr. Jia have a broad relationship with the Chinese central government, provincial governments, enterprises and financial institutions. The four persons formed a group that initiated the project; Pu and Jia were the bridge inside of China-Thiers the bridge to the U.S. technology community, and Noumoff as the facilitator between the two. Dr. Jia Fu has designed a grinding machine for TiO2, which according to Dr. Thiers is just one step away from permitting China to independently develop its own TiO2 process.

SRI International (SRI), formed in 1946 as Stanford Research Institute, is an independent nonprofit corporation that performs contract research and consulting for business, industry, and government worldwide. SRI Consulting (SRIC), a wholly owned subsidiary of SRI, has a team of professionals who provide strategic management consulting backed by industry and technology know-how to help clients compete more effectively in today's global markets. The main offices of SRI and SRIC in Menlo Park, California, also include extensive data processing and library facilities, as well as a staff of nearly 3,000. The Specialty Materials and Chemicals center, which is part of SRIC's Chemical and Energy Division, is the focal point for resource-related research throughout SRI/SRIC. It has extensive industrial experienced scientists, engineers, managers and economists. SRI/SRIC conducted long-term research on Titanium Dioxide (TiO2) studies and developed a set of TiO2 finishing technology called "dry" method, with know-how based on laboratory and bench scale, different from the traditional " wet" method, and judged to be the next generation of finishing technology.

China has produced TiO2 pigments on an industrial scale for decades. The technology used for TiO2 pigments in China is the "Sulfate" process, which is older and more traditional than the newer "Chloride" process. Because access to this technology originally came from Eastern European nations (including the former USSR), current production facilities in China are afflicted by the same type of problems encountered in Eastern Europe, namely the tendency of the TiO2 product to age when exposed to ultraviolet light and assume a yellow tint. This problem was also observed in the older sulfate plants of Western Europe, but had been largely solved by the early 1980's through adoption of modern pigment finishing technology.

A few years ago, China attempted to independently solve this problem through joint ventures with major TiO2 pigment producers using the chloride process (e.g., DuPont and, Kerr McGee), but negotiations along those lines failed to materialize and, as a result, access to the chloride process and the necessary finishing technology was prevented. Dupont proposed a $50 million project with it retaining control over the technology. Today, TiO2 pigment production in China originates from relatively small sulfate plants, e.g., less than 2,000 metric tons per year.

The SRI/IME interface occurred over a number of years. It took almost two and half years for the group to promote this project. I can only briefly summarize the main facts in this thesis. The first practical potential user–General Chemical Factory of Fu Zhou (GCF)-, with the support of the local government, signed a consulting contract with SRIC in 1997. SRIC would provide GCF with technical data involving the processing of titanium dioxide pigments into finished products solely for the purpose of furthering the work and strictly for GCF's internal use. GCF would construct its own finishing plant to absorb the technology. After the manager of GCF and one local government official visited SRIC, the GCF side cancelled the contract. One possible explanation of GCF was that GCF could no longer obtain sufficient financing from local banking to support this project. The bank committed to invest in this project was dissolved owing to reforms of central financial institutions. Other reasons were less than clear. One possible additional reason was based on information that Dr. Pu obtained from local government, that after visiting SRC the user believed that SRI's technology was still on a laboratory scale and scaling up to production scale was a very difficult job and had greater risk. In order to rescue the project, Dr. Pu and Dr. Jia found another Hong Kong investor, Mr. Barton Lee, who received his MBA from Harvard University and who understood both Chinese and Western business ways. Barton Lee was interested in investing in a pilot plant, thereby permitting him to benefit from license royalty. He visited SRIC and negotiated a price with Dr. Thiers on several occasions. After serious assessment, plus the Asian Financing Crisis of 1997/1998, which damaged his family business, Barton Lee withdrew from the project. The next investor found by Dr. Pu was a state-owned big company. China Metallurgical Equipment Company (CMEC), a subsidy of the former Ministry of Metallurgy Industry. The manager of CMEC, Mr. Wang, was greatly interested in this project when Dr. Pu introduced the whole picture of the TiO2 pilot to him. Both SRIC, as well as CMEC, negotiated the nature of investment and equipment manufacturing for more than a year. At this level the Chinese side had little familiarity with international practice on licensing fees. It seems, however, there is a deadlock. In the SRI, reorganization had taken place reducing Dr. Thiers' authority and giving it to the Head of the Legal Department. Because of SRI internal conflict, the Chinese side, both managers like Mr. Wang and experts like Dr. Pu and Dr. Jia, was confused by the reverse attitude of SRI represented by Dr. Thiers. They were unaware of the internal changes within SRI, until so informed by Dr. Noumoff. As the SRI situation stabilized, yet another enterprise from Shanghai was introduced into the picture which was looking to diversify its investments After discussions in Shanghai with Dr. Pu, and follow up meetings in Beijing with Dr. Noumoff, it was agreed that a price estimate would be sought for the building of an up-scaled pilot from the lab model at SRI headquarters. SRI initially agreed and then withdrew its agreement owing to municipal zoning difficulties in Menlo Park, California. The next step was to identify an equipment manufacturer and decide if the up-grade pilot was to be constructed in the U.S., where any technical "glitches" could more easily be resolved, after which it could be shipped to China, or in the first instance to construct the pilot in China. Dr. Noumoff began negotiations with the largest equipment manufacturer, however, on advice from Dr. Thiers rejected the price as being 3 times what it should be. SRI proceeded to seek a confidential agreement to protect its technology with a number of other equipment companies, which took considerable time, and as of this writing an estimate has been promised by early 2001. China is still in need of the technology, as the cost of foreign supplied TiO_2 keeps rising on the international market.

SRI has offered to sell the technical "recipe" to China, and have Chinese engineers operationalize it. However, lack of confidence on the Chinese side has led to the rejection of this option

From this project, I have found that the Chinese who move through the steps of foreign technology acquisition usually demonstrate some combination of the following abilities:

They recognize the advantages of changes. The impetus for change in Chinese units most frequently originates with some sort of unexpected crisis in the enterprise – the failure of a machine, a new demand for a different sort of production, a serious financial situation, as well as the recognition that there is a rapidly expanding internal market and a potentially lucrative external market. For example, GCF would adopt new finishing line to improve its product quality. Sometimes it occurs when an employee or local official returns from abroad full of new ideas. Managers successfully acquiring new technology know how to turn necessity to advantage and seize the opportunity when changes are forced on them.

They understand the potential disruption that a new technology can cause. Since a new technology may alter working relationships within a unit and therefore cause dissension. It is the Chinese managers who have acquired some experience for dealing with changed circumstances or new inputs that move most easily through the different stages of the acquisition process. The mechanisms for coping with changes are not remarkable. They include procedures recognized by organizational theorists worldwide: staff meetings, specialists-manager forums, and formal channels for the submission of suggestions. In China, as elsewhere, the real importance of these mechanisms is that they convey a sense that the concerns surrounding crisis and new situations are taken seriously.

They build good relationship with technical subordinates and consultants. While the manager is usually responsible for overall coordination of a project, many Chinese enterprises assign a chief engineer in charge of technical decisions. Some small enterprises, for example, GCF, invited experts from CAS and universities to be their consultants. When the manager works easily with technical personnel, the acquisition process proceeds more smoothly, regardless of the " fit" of the new technology.

They are sensitive to the needs of major constituencies. Most Chinese organizations seeking to acquire foreign technologies do not do so in a vacuum. Upstream suppliers and downstream users are also affected by technological changes. Units that move most easily through the acquisition and the implementation process work closely with all their constituencies, involving them early on in many of the discussions and negotiations.

They are relatively autonomous. Managers who are not too closely wedded to any one government agency or Ministry seem to have greater leeway to make the changes required by new technologies. Managers with a strong patron at " higher levels" have initially greater access to foreign technologies by virtue of their patron's position. But, in most cases, the patron also keeps a tighter rein on such an enterprise, thereby limiting the manager's discretionary power to bargain and maneuver.

They maintain multiple lines of communication. The most successful managers have a multiplicity of contacts on the local, provincial, and even national levels. These multiple channels provide information, expertise, and access. They also give managers options: if one channel is closed, others can be used.

They are entrepreneurial. Chinese managers who are most effective in acquiring foreign technologies are entrepreneurial types who play off multiple points of access and control against each other and take a certain joy in the process.

They are venture capitalist. Some excellent Chinese managers have a foresight in some laboratory technology and would like to take more flexible way to acquire foreign technology and even to invest in this kind of start-up project to become one owner of the technology and share potential world markets. CMEC was active in investment in SRI's pilot demonstrated this trend.

Encouragement from the very top can be a great facilitator. When details, however, are left to lower units for implementation, these local units own "enterprise culture" and experience play a significant role.

A new generation of scientists is likely to become less dependent on foreign technology as their scientific formation occurs under the new system.

I will argue here that at the heart of technology transfer is a *personal process* in which change is valued and allowed to proceed in an orderly fashion. The TiO2 case study lend support to my argument and suggest that the most important element in the process of change and development turns out to be the human component rather than structure or finance. The decision and acquisition stages are crucial to the success of technological innovation. If a project is not handled successfully during these first stages, it will almost certainly run into real difficulty later. The decisive elements in successful technology transfer projects involve both *process* and *players*. Responsibility falls increasingly on the actual end users of the new technologies-the Chinese production enterprises, service organizations, and state agencies. These units exist in a rapidly changing world of shifting priorities and volatile bureaucratic alignments although in 2000 they are more autonomous.

Chapter 6: Conclusion

In general, the history of China's science and technology can be divided into two main stages. The first main stage is from 1949 to 1984. During this period, China employed the Soviet Model that tended to de-emphasize the role of research in the universities, and stress the centralization of research in institutes under an Academy of Sciences, with high priority given to research related to military and heavy industry needs. Research activities were isolated from other production activities. Moreover, the various institutes, concentrated primarily in the Chinese Academy of Science (CAS) and the industrial ministries, were guided by a central plan and funded by an annual budget from the central government. Consequently, power over research was concentrated in the hands of political leaders who had little understanding of science or of how to move innovations from the research laboratories onto the factory floor. Because the research system was vertically organized with little horizontal interchange, CAS created rigid, narrow structures that were not conducive to developing theoretical science or its practical application into readily usable production technologies.

The second main stage is from 1985 to the present. A new science and technology management mechanism has been developed to integrate science and technology with industrial and agricultural production. Scientists and engineers took the lead in breaking up the closed loop system and examining the world's advanced level of scientific and technological development. International exchange and cooperation have been a priority in China's science and technology policy. In the 1990's, the country has both achieved rapid economic growth and been confronted with new challenges. More intensified international competition, for example, as associated with China's entry to WTO, has made it inevitable that China needs to upgrade her industrial composition. High-tech R & D and high-tech industrialization have been given attention in the industrial sector, and innovation strategy and commercialization have replaced the original follow-up pursuit in high-tech development. A new emphasis has shifted from basic research to high-tech research. Obviously, China's science and technology policy is furthered with the changing situation. The role of China's leaders in science and technology policy has been strengthened and the new generation of leaders has a better scientific and technological background. China has been following a strategy of "revitalizing the nation through science, technology and education" since 1995. Increasing the technological contribution to economic growth is the first step in implementing this strategy. Technology has contributed 42 per cent to the growth of agricultural production, while its contribution to industrial growth is a bit lower, only about 30%.[114] Its contribution to overall economic growth is estimated to increase by at least 10 percentage points in the next few years.[115]In 1999, the State has already issued a number of regulations to promote technology. Those regulations are the *Decision on Restructuring and Administering Scientific Research Institutes*, [116]a *Provision on Accelerating the Transfer ofTechnology into Production*,[117] a *Regulation on the Reform of National Science and Technology Awards* and a *Regulation on Technological Innovation Funds for Small and Medium-Sized Technology Firms.*[118]These regulations were designed to help encourage scientific researchers to

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[114] Cui Ning. *New Policies Spark tech Innovation* (08/09/99.*China Daily*)
[115] *Ibid.* Cui Ning.
[116] *Ibid.*, Cui Ning..
[117] *Ibid..* Cui Ning.
[118] *Ibid..* Cui Ning.

make their technological projects more industry and commerce-oriented.

It is clear that China has begun to benefit substantially from the growing presence of foreign technology in the local economy. However, China also has encountered a number of serious internal and external problems. Among the domestic problems which stand out are insufficient coordination, excessive duplication, poor assimilation capabilities and consequences of decentralization vis-a-vis the decision-making process for technology import. Some international factors such as Western countries' national-security concerns, increasing global competition, rising protectionism in the West, and cultural discrimination have combined with China's internal constraints to help slow down China's access to technology and equipment and to diminish some of the significance of China's own progress.

Other numerous problems will persist. The prospects for foreign investment will remain largely unimpressive, and, as a result, the value of this mechanism as a vehicle for technology transfer will be somewhat limited, and more selective. In the final analysis, I point out it will be the interface with the international market along with the interaction between foreign buyers and the Chinese firms that will provide the greatest source of technology transfer. This sustained contact with foreign firms in the international marketplace served to improve the understanding of foreign market structure and characteristics among Chinese firms. The more China learns about the intricacies of the markets outside its country, as well as within, and attaches itself to a dynamic "learning curve," the better China will be able to compete. Foreign technology will continue to provide the linkage through which China interacts with the world economy. As a key buyer for technology in the international market, China promises to become more selective as its level of sophistication and its ability to do comparative shopping improve. China has learned about the critical value of feasibility studies, market survey, intellectual property, patent, and so on. Over the past 20 years, China has imported a total of 28,000 items of technology, involving a contractual volume of US$111.379 billion.[119] Imported technology over the past 20 years has helped Chinese firms upgrade their technical level, narrow the distance China lags behind advanced foreign nations in terms of technology, and raise the quality of Chinese goods. Contractual volume for high-technology imports accounted for nearly one-fourth of the total technology and equipment imports in 1999.[120] Multi-lateral industrial co-operation and the protection of intellectual property rights while importing technology have been enhanced. This all suggests that substantial learning has taken place, and that gaining continued and perhaps expanded access to foreign technology on more beneficial terms is likely to remain a high-priority item on the agenda of Chinese leaders for the foreseeable future.

[119] Zhang Yan. *China to Strengthen Technology Imports* (03/25/99. *China Daily*)
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