

# **Telecommunications, Technology and China's Modernization**

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## Abstract

Focusing on China's telecommunications manufacturing sector, this paper first reviews the major theoretical debates regarding political and economic systems and technology development. The paper then analyses the history of China's R&D system and the current players and their R&D strategies in China's telecommunications industry. It concludes that government funded programs, foreign investments and technology transfer, and aggressive R&D efforts by newly emerged indigenous manufacturers have jointly contributed to R&D expansion and technology development capacity upgrade in China's telecommunications industry. The paper also suggests a close relationship between China's technology development in telecommunications with the political and economic environment in China and in the world.

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## 1. Introduction

Telecommunications industry has been tied to political needs in China for decades. As a result, some telecommunications systems such as public broadcasting services reached to almost every family in cities as well as remote villages. Other systems such as public telephone services were kept only for political elite to serve as a communication tool as well as a political status symbol in society. They were mostly available only in cities and some towns, but rarely in villages.

As China gradually shifted its top priority from political struggle to economic development since 1978, telecommunications industry was officially recognized as one of the critical infrastructures for achieving economic development. China has gradually emerged as a significant player in the global telecommunications industry both as a buyer and as a supplier with its telecommunications infrastructure experiencing rapid expansion. On average, more than 10 million telephone lines were added to China's telecom network each year in the last decade. Total telephone lines in China reached to 180 million in 2001. While China's telephone penetration rate was only 0.3 per 100 capita in 1980, it rose to 25.9 in the year 2001. Wireless phone network in China has experienced an even higher growth rate than its fixed phone network since the first TACS cellular phone system was installed in 1987. In July 2001 China's 120.6 million mobile phone users made it the largest mobile communication market in the world, surpassing the 120.1 million users in the United States. The wireless phone users in China reached to 145.2 million by the end of 2001. In 1998, there were 360 million television sets used by Chinese consumers, equivalent to about 28 TVs per 100 capita. Cable TV has enjoyed an impressive growth in China since the early 1990s. Starting from only 13 million families in 1990, China's CATV industry penetrated into 90 million families in 2001. In 2000 total PCs in China reached to 29 millions while the penetration rate (per 100 capita) remained as low as 2.3.

Table I-1: Telecom Infrastructure

|   | 1990 | 1995 | 1996 | 1997 | 1998  | 1999  | 2000  | 2001  |
|---|------|------|------|------|-------|-------|-------|-------|
| Total telephone users (million)         | 16.3 | 40.7 | 55.0 | 70.3 | 87.4  | 109   | 145   | 180   |
| Tele-density (per 100 capita)           | 1.11 | 4.00 | 6.33 | 8.11 | 10.5  | 13.0  | 20.1  | 25.9  |
| Total Mobile phone users (million)      | n/a  | 3.63 | 6.85 | 13.2 | 24.9  | 43.8  | 85.2  | 145.2 |
| Annual growth of mobile phone users (%) | N/a  | 131  | 88.8 | 93.1 | 88.8  | 75.3  | 94.6  | 72.2  |
| Total PCs (million)                     | .500 | 2.80 | 4.50 | 7.50 | 11.20 | 17.78 | 28.96 | n/a   |
| PC per 100 capita                       | 0.04 | 0.24 | 0.36 | 0.60 | 0.90  | 1.42  | 2.32  | n/a   |
| Total CATV Users (family in million)    | 13   | 42   | 61   | 65   | 70    | 77    | 80    | 90    |
| Total Television Sets (million)         | 160  | 300  | 321  | 340  | 360   | n/a   | n/a   | N/a   |

Source: MII's statistics 2001; China Information Almanac 2002; ITU statistics 2000.

Internet users has boomed since its firts adoption in China. The number of total Chinese Internet users grew from only 600,000 in 1997 to 59 million in 2002. Computers with an Internet connection increased from 340,000 in 1997 to 20.8 million in 2002. Total bandwidth to the global Internet increased to 9,380 Mbps in 2002 from 30 Mbps in 1997. Domain names under the .cn also climbed from 5,000 in 1997 to 179,500 in 2002.

Table I-2: Internet Infrastructure in China

|  | 1997 | 1998 | 1999 | 2000  | 2001  | 2002  |
|--|------|------|------|-------|-------|-------|
| Internet Users (million)                     | 0.62 | 2.10 | 8.90 | 22.50 | 33.70 | 59.10 |
| Computers with Internet connection (million) | 0.34 | 0.75 | 3.50 | 8.92  | 12.54 | 20.83 |
| International gateway bandwidth (Mbps)       | 30   | 143  | 351  | 2,799 | 7,597 | 9,380 |
| Domain names (.cn) (thousand)                | 5    | 18.4 | 48.7 | 122.1 | 127.3 | 179.5 |

Source: CNNIC (China Internet Network Information Center at <http://www.cnnic.org.cn>)

In general, China's infrastructure was extremely poor before the 1980s, compared to other nations. Significant expansion has happened mostly in the past two decades, which makes China one of today's largest infrastructures in the world. However, China's huge population drags the per capita share of

every perspective of its infrastructure to a very low level close to that in most developing countries. There is still great potential for its telecommunications industry to further expand.

Linked with the infrastructure expansion, China's technology and manufacturing capability in telecommunications has upgraded to a much higher level. China's enormous market size has attracted nearly all the significant telecommunications manufacturers in the world to engage in various trade and production activities. Direct imports from these multinational corporations continue to support most of China's high-end market. However, local subsidiaries and joint ventures of multinational telecom manufacturers currently supply a large percentage of the medium-end of Chinese market. Meanwhile, indigenous producers have recently emerged to dominate the low-end market and to aggressively compete in the medium-end market.

The expansion of China's telecommunications infrastructure and the upgrade of China's technology capability in telecommunications industry result from a dynamic and complex interaction among multinational corporations, government policies, and China's indigenous industry. Focusing on the technology development in China's telecommunications industry, this paper analyses the history of China's R&D system and the current players and their R&D strategies in China's telecommunications industry. It aims to understand the interaction among government funded R&D programs, foreign investments and foreign technology transfers, and aggressive R&D efforts by newly emerged indigenous manufacturers. The paper will also examine the relationship between China's technology development in telecommunications with the political and economic environment in China and in the world.

## 2. Theoretical Debates on Technology Development in Telecommunications

Technology development has a complex relationship with political and economic systems. We have no adequate theories for explaining and predicting this relationship (Suttmeier, 1989). There are strong arguments that technology advances could cause the change of political and economic systems and to a large extent contribute to society's modernization. On the other hand, politics and society have been suggested to determine science and technology development. In case of the communications industry, since information and communication is critical for politics and society, technology advances tend to be determined by political needs. This is especially true in authoritarian countries such as China, where central controlling of communication and information by government remains as the top priority.

Examination on the Chinese case suggests that its technology development and infrastructure expansion in telecommunications reflect, rather than determine, broader political and economic processes. Since 1949 the first 30 years of China's communication development focused upon the mass media. It was apparently driven by political imperatives including unification, propaganda, and mobilization. Loudspeakers mounted on poles in public places in cities and on the walls of peasants' homes in villages were wired to stations in counties. All of these county stations were then connected to a national network capable of receiving and retransmitting programs from central, regional, and local governments (Liu, 1975). This national network served to aid the political control. Other systems such as public telephone services were suppressed. Technologies for China's telephone services lagged far behind Western nations and considered as obsolete in Western standard. They were only installed

for political elite such as high-level government officials and top factory managers. Owning a telephone was more of a symbol for political status in society than a communication tool.

Since 1978 Chinese government has shifted its top political priority to foster economic construction and development. One of the major changes is to gradually move into market-dominated economy from the previous central planning economy. This move leads to the penetration of Chinese economy by market forces, which has boosted technology development and infrastructure expansion in telecommunications. Firstly, communications infrastructure, together with transportation, is critical to China's change from a central planning economy to a market one in order to meet the demand for mobile labor, capital, resources, and products (Mueller & Tan, 1997). Secondly, telecommunications industry was an under-developed sector under the previous political ideology. There was a huge unsatisfied demand.

This technology development and infrastructure expansion follows a combination of various paths and models. On one hand, central government continues its support for R&D by providing financial funding and planning guidance. This is mostly the reflection of technological nationalism and the continuation of self-reliance philosophy and central planning ideology. However, limited central financial resources makes supporting a full-range of R&D activities impossible. It often leads to strategies such as only funding highly selective projects. On the other hand, market forces have added dynamics to the technology development. Foreign technologies, together with foreign products and investments, have started to be directly imported into China. Some multinational corporations begin to localize and even develop their technologies in China. State-owned and private enterprises have increased their R&D budgets and activities in order to meet the market needs and to survive the fierce

competition. The changing global business environment allows China's indigenous manufacturers to outsource technologies from Western nations. All of these factors contribute to a dynamic and complex Chinese scenario.

### **III. Industry Evolution and Technology Development in Telecommunications**

For the purpose of this paper, we take the years between 1949 and 1978 as a historical period and the years from 1978 to now as a contemporary time. The historical period between 1949 and 1978 could be best described as closeness, self-reliance and central planning. Except receiving some technology aid in the 1950s from the former Soviet Union, China had a very limited contact with global technology community and had developed an isolated but sophisticated domestic R&D system for its technology needs. Funds were mostly controlled and distributed by central government agencies and, to a less extent, by provincial governments. R&D activities were mostly conducted by research institutes and universities, with some limited participation from manufacturers. There were very limited information exchanges with Western R&D community. Technology acquisitions from overseas were rarely conducted. As a result, self-reliance and technology nationalism were achieved for China's R&D system, with the cost of having low-level and obsolete technologies, equipment, and services to be deployed in China's backward and poor telecommunications infrastructure. The gap between Chinese technologies and the most advanced Western technologies were often a few decades apart. China's telecommunication carriers had no other options but to buy these out-of-date technologies and products, which partially led China to be one of telecommunications networks with the least-efficiency, lowest-quality, and lowest user penetration rate in the world.

As China made its political decision to open its market to foreign technologies and products in 1978, foreign technologies held an absolute competitive advantage over almost all the Chinese technologies in telecommunications. For example, advanced Stored Program Controlled (SPC) switches were widely deployed in Western nations as central office switches and Private Automatic Branch eXchanges (PABX) while China was entirely relying on the out-of-date step-by-step and cross-bar switches, and even manual switches in some cases. Western nations had mostly switched to digital technologies for their long-distance transmission systems over microwave systems, satellite links, coaxial cables and sometimes fiber optic cables while China were mostly using low-speed analog technologies. As a consequence, foreign suppliers were not confronted by any domestic competitors with similar technology capacity when they entered into Chinese market. Foreign technologies were often directly imported and then established as leaders in the market. This was true for central office switches, digital microwave systems, first generation cellular phone systems, and almost every new technology introduced into Chinese market.

While the technology gap was clearly recognized, one of China's agenda of opening its market to multinational corporations was to acquire technologies for domestic manufacturers in order to upgrade China's technology capability. In the early 1980s, multinational corporations were actively pursued through negotiating Joint Ventures (JV) and linking JV to equipment procurement contracts, termed as the strategy of "combining technology transfer with trade". The effort led to the establishment of many large-scale joint ventures in China's telecommunications industry, including the first JV - Shanghai Bell Telephone Equipment Manufacturing Corporation (Shanghai Bell) in 1984. After successfully attracting the attention of many multinational corporations, China updated its policy from 'attracting and accepting whatever advanced technology that is available' to 'selectively promoting and accepting

certain technologies' in 1987. For each type of product, this 'selection' policy 'picks up the best partners and limiting the number of JVs and other foreign ventures'. For the entire telecommunications sector, the 'selection' is translated into an enforcement that only advanced high technology with significant economic benefits were imported, while products using out-of-date technology or conflicting with China's interests were discouraged or prohibited. The potential of the huge Chinese market had successfully continued luring advanced technologies and products into China. While this process helped to upgrade China's technology capacity, it was definitely not the case that all of them were translated into Chinese technologies.

There are many roadblocks and many technologies are strictly protected for commercial as well as political reasons. For multinational corporations, the decreasing profit margin of old technologies pushes them to rely on newer products for higher margin revenue. They are more willing to transfer the old technologies to Chinese market in exchange for other strategic benefits such as the market share for their new products as well as the support from Chinese government and their local business partners. Sometimes it may serve their interests to shift production of old products to China in order to take advantage of low labor cost and to compete with other multinational firms. The rising technological sophistication and manufacturing capability of a developing country like China in low-to-medium-end products might not be a serious threat to themselves in China and in other markets. However, multinationals are more cautious about transferring advanced technology to China in fear of losing their competitive advantages and creating more competitors.

Meanwhile, China's central government has continued its financial support for R&D through several national agencies. The most significant ones include the 863 high tech program organized by the

Ministry of Science and Technology and the national science and technology development program coordinated by State Development and Planning Commission. There are other R&D programs organized by various ministries, agencies, and provincial governments. All of these centrally organized programs could be best characterized by two features. First, they tend to be selective because of the limited funding. By 'selective' it means that projects with either significant political and economic value or strong local strength have a higher chance to be funded. By any means, the number of projects and the range of projects are limited. Secondly, more attention has been shifted to economic benefits and the final outcome is often required to be a product to meet market demand. This is often implemented by encouraging research institutes and universities to team together with manufacturers to apply for the R&D funding and to commercialise research findings. In some cases, overseas Chinese are also encouraged to join the R&D projects.

Another group of players recently emerged in technology development community are state-owned and private enterprises. A large amount of internal R&D funding have been budgeted by these firms from their own sales revenues which have been boosted by the impressive market growth in recent years. These firms actively and aggressively develop technologies and new products to meet market demand and to survive the intensive competition in Chinese market.

The above-mentioned three major efforts for technology acquisition and development lead to a gradual but steady growth of China's technology capability. In general, after a new technology from global market is imported and deployed in Chinese market, it would be gradually turned into local production by joint ventures, local subsidiaries of multinational corporations, and indigenous manufacturers. Table III-1 illustrates the localization timetable of central office switches for traditional telephone services.

Table III-2 details the evolution of cellular phone technologies in Chinese market. While the general localization trend holds true, the actual pace and the extent of technology localization vary from one technology to another. For example, the localization of high performance router technology turns to be very slow mostly because of the software complexity of router technology and its lack of eagerness for suppliers to transfer their technology to Chinese producers.

Table III-1: Market Shares of Central Office Switches among Three Groups.

|                      | 1982 | 1987 | 1992 | 1997 | 2000 |
|----------------------|------|------|------|------|------|
| Direct Import        | 100% | 89%  | 54%  | 5%   | 0%   |
| Joint Venture        | 0%   | 11%  | 36%  | 63%  | 57%  |
| Indigenous Suppliers | 0%   | 0%   | 10%  | 32%  | 43%  |

Source: The former MPT & MEI, the MII, suppliers' annual reports, and author's estimate.

Table III-2: Market Share of China's 2G Wireless Market.

| Year   |                                  | 1994 | 1999 | 2000 | 2001 | 2002 |
|--|----------------------------------|------|------|------|------|------|
| Infrastructure Equipment<br>(Base Stations & Mobile<br>Switches) | Direct Import                    | 100% | 31%  | 25%* | 23%* | n/a  |
|  | Subsidiaries & Joint<br>Ventures | 0    | 66%  | 70%  | 67%  | n/a  |
|  | Indigenous<br>Producers          | 0    | 3%   | 5%   | 10%  | n/a  |
| Terminal Equipment<br>(mostly handsets)                          | Direct Import                    | 100% | 5%   | 2%   | 2%   | 2%   |
|  | Subsidiaries & Joint<br>Ventures | 0    | 92%  | 88%  | 83%  | 59%  |
|  | Indigenous<br>Producers          | 0    | 3%   | 10%  | 15%  | 39%  |

Source: Survey by MII's Telecommunications Information Research Institute. \*: estimated by author.

Overall, the catching-up of China's technology capacity could be best described by Figure One. On one side technology suppliers are characterized by four types: (1) direct-import dominated; (2) direct-import and JV shared, supplemented by local suppliers; (3) JV and local suppliers shared; and (4) local suppliers dominated and supplemented by JVs. On another side technology sophistication is indicated, which roughly matches the time when the technology is introduced into Chinese market. This figure

indicates that technologies introduced into Chinese market have been transformed from a direct-import dominated scenario to a local supply dominated scenario while the process takes different time period for different technologies. Meanwhile, new technologies have been constantly added to the category of the direct-import domination, which makes the catching-up process keeps going on. While a concrete quantitative measurement of this catching-up process is beyond the scope of this paper, there is a general trend that the average time for China's indigenous suppliers to supply a new technology is getting shorter and shorter.

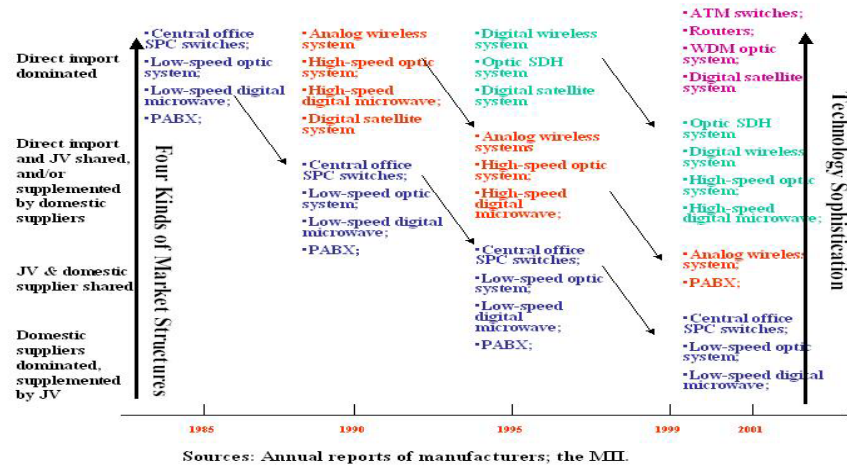


Figure III-1: Technology Catch-up.

## IV. R&D Strategies/Players

### IV-1. The Selective R&D Funded by Central Government

Chinese government has continued its policy of supporting R&D through central government budget. The 863 High Tech Development Program and the national key technology R&D program serves as the best example to analyse the principles and impacts of government funded R&D activities.

China's 863 High Tech program was launched in 1986. It was claimed to be a Chinese reaction to the United States' Strategic Defence Initiative (the Star Wars Initiative) and European EURICA as well as Japan's high tech program. "How China, as a large developing socialist country, keeps abreast of the new situation of rapid development of high technologies in the world, traces the world advanced level and reduces the gap between China and foreign countries has become the focal point attracting the attention of scientists and also the Party Central Committee and the State Council." (MOST, website) However, it is widely recognized that China is a developing country that could not afford large amounts of manpower, materials and financial resources to comprehensively develop high technologies on a large scale and in a full range. Therefore, 863 Programme has been instructed to follow the principle of "limiting objective range and focusing on core projects." Based on the official government announcement, 863 Program intends to achieve the following objectives (MOST, website).

- Track the global technology development in the selected fields and try to achieve some breakthroughs in the areas where China has some comparative advantages and experiences.
- Train a new generation of skilled researchers and engineers.
- Promote science and technology development in the related fields via spin-off effects.
- Prepare for the technology and economic development and national defence system development in the 21<sup>st</sup> century.
- Commercialize any research findings and harvest the possible economic benefits.

Information technology is among the seven chosen fields while telecommunications is one of the four focal areas within the information technology field, together with intelligent computing, electronic-optic components and their integration, and information obtaining and processing technologies. The telecommunications area covers topics including network and switching technology, optic fiber transmission technology, technology for personal communication network, multimedia communication technology, and the integrated broadband digital network technology. These topics seem to be very up-to-date and broad, which have reflected the intention of 863 Program of tracking and following the global technology development.

Another program is China's key technology R&D program that is coordinated by State Development and Planning Commission, together with other government agencies. The current five-year program has only included high performance (40Gbps) optic fiber transmission systems and optic fiber manufacturing technologies for telecommunications field, which suggests that optic fiber system is one of China's current focuses for technology development and product commercialization from the central government's perspective.

In general, government funded technology development in telecommunications serves two purposes. On one hand, it helps to track the global trend in technology development, maintaining information exchange between Chinese R&D community and the global community. It uses government funding to support forward-looking R&D where enterprises are less willing to pay attention. On the other hand, it trains students, researchers, and engineers and keeps them upgraded in their knowledge and skills.

These students, researchers, and engineers serve as a manpower pool for enterprises to hire to enhance indigenous R&D and China's overall technology development.

#### ***IV-2. The Diversified R&D Strategies by Multinational Corporations***

Multinational corporations have played significant roles in boosting China's technology capacity in telecommunications. This is where different models, motivations, and outcomes are all mixed up.

Initially, foreign corporations were pressured to transfer their technologies into China in some kind of formats when they started to directly sell their products to China. Establishing joint ventures started as the most popular format of both serving the multinational corporations' interests of selling their products into China and meeting China's desire for technology transfer. When foreign central office switches were imported into China in 1980s, Alcatel and Siemens first started their joint ventures with their Chinese partners. In fear of losing the market entry opportunity, NEC, Lucent Technologies, Nortel, and Ericsson have all followed the suit to set up their own joint ventures to produce and sell central office switches. As a result, all of the major central office switch suppliers in the world have established their joint ventures in China. Similar kinds of patterns have happened to many other technologies including optic fiber systems and wireless communication systems. These joint ventures are significant players and enjoy a substantial market share in China.

Unlike many other industries such as color TV and even Integrated Circuits (IC), there have never been a large scale technology transfer from multinational corporations in the format of licensing technology or selling production/assembly lines to Chinese indigenous producers, except several

isolated and less significant cases. Some multinational corporations choose to set up their sole owned subsidiaries in China to satisfy China's desire for technology transfer in exchange for market entry and other favourable terms. The most significant example of this kind is Motorola who established its huge sole owned facility to manufacture wireless products and semiconductor products in Tianjin Development Zone in early 1990s. In some other cases, multinational corporations ignore China's request for technology transfer and insist on directly selling their foreign made products into Chinese market. This is often the case for technologies where there are a very small number of competitors both in the world market and in the Chinese market. CISCO's high performance router is an example fitting into this category. CISCO has an absolute domination in Chinese market and in the world market in high performance router. There are not any competitors powerful enough to pressure CISCO to transfer technology to Chinese producers in order to exchange for favourable market terms from Chinese side.

In later 1990s, many multinational corporations launched their R&D centers or institutes in China. Nortel established a joint R&D center with Beijing University of Post and Telecommunications. Lucent technologies set up its R&D center in Beijing. Microsoft has also established Microsoft China R&D Institute. These R&D centers hire Chinese researchers and engineers. They have fostered the dissemination of information and knowledge in China, which either directly or indirectly helped China's technology capacity upgrade. However, these R&D centers mostly study how the existing technologies from their parent companies could be deployed in China and be compatible in Chinese environment, rather than engage in developing new technologies for Chinese and global market.

In summary, multinational corporations are not motivated to transfer their technologies to China and help China to upgrade its technology capacity. Some forms of technology transfer are often part of their marketing strategies with the ultimate goal of sell more products and make more profits. In many cases technology transfer is a by-product of the product selling. Nevertheless, the appearance of multinational corporations in Chinese market has helped to disseminate information and to train local engineers. Some of these engineers left the multinational corporations later on. They either start their own business or join indigenous firms, which contribute to overall technology development in China.

### ***IV-3. The Rising R&D by Indigenous Enterprises***

As outlined before, the traditional centrally planned Chinese system allocated most R&D activities to research institutes and university. Production was assigned to backward factories. There was a broken link between R&D and commercial production, which partially contributed to the slow technology development in China. Manufacturers in China conducted very limited R&D.

#### ***IV-3-1. The Emerging of Powerful Indigenous Manufacturers***

As China started to shift from planned economy to market economy in 1978, market forces have required the close link between R&D and commercial production for players to meet the customer demand and to survive the fierce market competition. As shown in Table IV-1, many indigenous manufacturers emerged in recent years.

Table IV-1: Top Indigenous Telecom Manufacturers in China (2002)

|                                    | Revenue<br>(Million<br>RMB) | Profit<br>(Million<br>RMB) | R&D<br>(Million<br>RMB) | Export<br>(Million<br>RMB) | Background  |
|------------------------------------|-----------------------------|----------------------------|-------------------------|----------------------------|---|
| CHINA<br>PUTIAN                    | 64,248                      | 2,644                      | 613                     | 14,533                     | Founded in 1980, it is originally called China Posts and Telecommunications Industry Corporation, and affiliated to the former MPT and the current MII. It is the No. 1 of Top 100 Chinese Electronic & Information Enterprises in 2001 and 2002. It ranks the 10th among the overall listing of China's largest enterprise groups. |
| Huawei<br>Technologies             | 16,229                      | 2,654                      | 3,050                   | 999                        | A private corporation established in 1988 by several entrepreneurs.   |
| ZTE<br>Telecommu-<br>nications     | 10,926                      | 797                        | 1,130                   | 353                        | A joint corporation sponsored by No. 691 Factory under former Ministry of Aerospace Industry (MAI), Changcheng Industrial Co. Ltd. (Shenzhen office), and Yunxing Electronic Trading Co., Ltd. in February 1985.  |
| Xi'an Datang<br>Telephone<br>Corp. | 3,163                       | 90                         | 390                     | 5                          | A joint venture established in 1993 by China Academy of Telecom Technology (CATT), the tenth Research Institute of former MPT and International Telephone and Teledata Incorporation (ITTI).  |
| Wuhan P&T<br>Institute             | 2,744                       | 241                        | 116                     | 178                        | Wuhan Research Institute of the former Ministry of Posts and Telecommunications (MPT)   |
| Jinpeng<br>Telecom                 | 2,262                       | 15                         | 23                      | 0                          | Sponsored by the 54 <sup>th</sup> Research Institute of the former Ministry of Electronics Industry (MEI).  |

Source: MII's List of Top 100 IT and Telecom Enterprises in China (2002).

These indigenous manufacturers share some common features.

- They are all newly established after 1978, which marks the transition of Chinese economy from central planning to market oriented.
- Many of them spend a significant portion, often more than 10%, of their revenues for R&D activities, which is driving technology development in China's telecommunications industry.
- Many of them are sponsored by China's research institutes. This has reflected the success of China's national R&D programs in training engineers and researches and in tracking global technology development through funding R&D in research institutes and universities.

The emergence of indigenous manufacturers could be further illustrated through their financial statements. Taking Huawei Technology as an example, its revenues experienced a 62% CAGR

(Combined Annual Growth Rate) between 1998 and 2001 as shown in Figure IV-1. R&D expenditures were almost doubled every year in the same period.

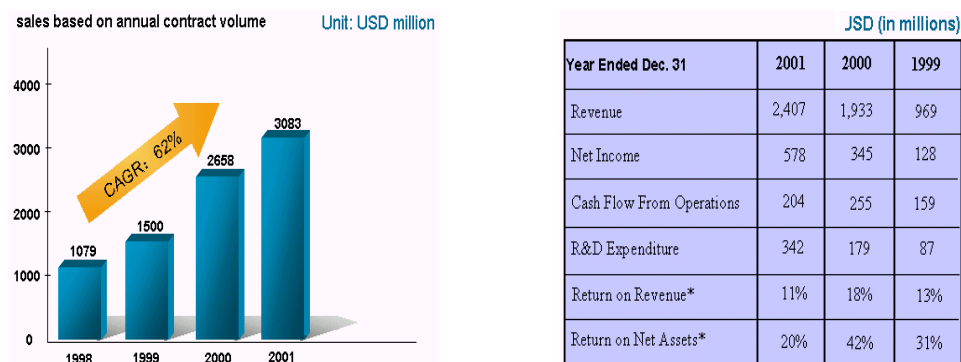


Figure IV-1: Huawei Technology's Financial Statements (source: Huawei's Annual Reports).

#### IV-3-2. R&D Strategies of Indigenous Manufacturers

Purchasing production/assembly lines and licensing a complete set of technology for one product have played important roles in upgrading some industries in China, such as color TV and refrigerator.

However, they are not successful strategies for telecommunications industry because the complexity and high R&D expenditures of telecommunication products often means the formidable sky-high licensing fee and the owners' unwillingness to sell production lines to others.

Technology imitation and reverse engineering are working strategies for China's telecommunications industry. This is true especially for matured technologies that have been deployed for years. One example is the development of Stored Program Control (SPC) based central office switches. Every multinational corporation including Lucent, Nortel, Alcatel, Siemens, and others spent more than 10 years and billions of R&D expenditures to develop their own switches. In the middle of 1990s, newly emerged small Chinese manufacturers including Great Dragon, Huawei, and Zhongxing developed

their own switches in just a few years with a very small amount of R&D expenditures. While technology advances have made the development easier and cheaper, imitation and reverse engineering have played significant roles in rolling out indigenous switches. This strategy seems to work and will keep working in the near future since China is far behind the global R&D capabilities in many perspectives. This strategy serves to short the gap between China and the western world. However, imitation and reverse engineering would keep China as a technology follower rather than enable China to be a technology leader.

Another strategy could be termed as “partial technology outsourcing” from developed countries, combined with aggressive in-house R&D innovation. Compared with multinational corporations, indigenous manufacturers are often strong in some aspects, especially in Chinese market. They are close to the local market that is often protected by government industrial policies including regulations on foreign investments, procurement rules, and favourable financial incentives. They are capable of designing and assembling their own systems at a lower cost. They are often able to make many components and subsystems, especially on the low-end and middle-end. However, indigenous manufacturers are often weak in developing and manufacturing some core technologies such as some Application Specific ICs (ASICs) and some sophisticated software systems. By conducting the overall system designing and assembling, product marketing and selling while outsourcing some core technologies to multinational corporations, indigenous manufacturers are able to roll out their own products in a fast pace comparable to multinational competitors. This strategy is further illustrated in Figure IV-2.

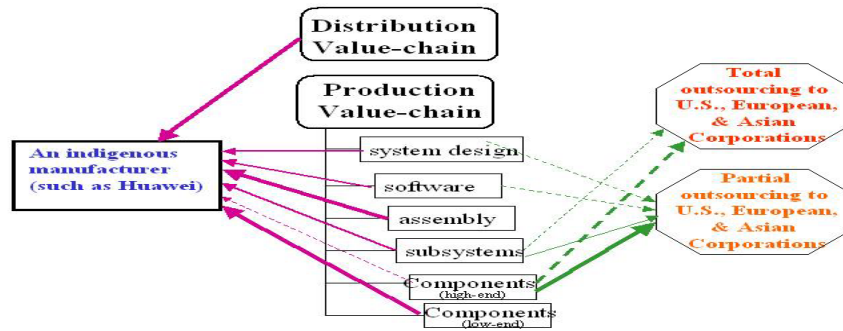


Figure IV-2: The Model of Partial Technology Outsourcing

Emergence of this partial technology outsourcing strategy is based on some fundamental changes in global political and economic environment and ideologies. First, global telecommunications and IT industry has been fundamentally changed by dis-integration coined as Winterlism (Borrus & Zysman, 1997). “Wintelism has indicated that traditionally integrated system elements in the production value-chain could be dis-integrated. Elements, including components, subsystems, system assembly, operation software, and applications software, become separate and critical competitive markets. It is argued that Cross-national Production Networks make it possible for the production of any elements in the value-chain to be contracted out to independent producers” anywhere in the world (Tan, 2002). This dis-integration enables China’s indigenous manufacturers to outsource technology and production to IC makers like Texas instruments and to technology developers like Qualcomm and Avici System, who are not necessarily their direct competitors.

Secondly, current global political environment favors the free flow of technology between China and most other nations. This political change leads to the loosening of many previous restrictions on technology import and export, which makes technology outsourcing possible. Thirdly, many Chinese have abandoned their ideological belief on technology nationalism and technology self-reliance. These ideologies argue that indigenous Chinese commercial products should rely on Chinese and that the

ultimate goal of working with foreign suppliers is to develop 100% China based technology. Theory of globalisation and global labor division has started to be positively accepted, which views China's economy as part of the global one and argues that China could rely on foreign suppliers on certain technologies while focusing on developing other technologies.

There are many examples where technologies are outsourced successfully, which creates a win-win situation for China's indigenous manufacturers and foreign suppliers. Huawei contracts Texas Instruments and others for its ASIC production. Qualcomm has licensed its CDMA technology for wireless communications to Zhongxin and Huawei. The most recent example is the agreement between Avici Systems in the United States, a rival to CISCO corporation, and Huawei Technologies to deliver next-generation IP solutions. Both Avici and Huawei recognize each other's strength and try to create a win-win deal. "Huawei 'recognize Avici's technology leadership in scalable, high performance, high-availability products. By combining Avici's products with our own portfolio, Huawei is positioned as the leading provider of telecommunications solutions for the Chinese market. We will combine our technical knowledge and efforts to leverage Avici's superior carrier-class products to offer best of breed routing solutions that will support the rapid growth of services being deployed across China.' 'We are pleased that China's leading networking solution provider has chosen our routing platform as a key element in its plans for building a next-generation Internet in China,' said the CEO of Avici Systems. 'Huawei's existing customer relationships and support capabilities offer a great opportunity for our joint family of products to deliver a new generation of high-availability, cost-effective routing solutions to the Chinese marketplace.'" (Avici Systems, 2003).

#### *IV-3-3. Consequences of Indigenous Manufacturers' R&D Efforts*

There have been two obvious and significant consequences directly from indigenous manufacturers' R&D efforts. First, the time gap between the rollout of some technologies/products by multinational corporations and the rollout of similar technologies/products by indigenous manufacturers has become shorter and shorter in the past two decades. This is overall well illustrated in Figure III-1. Experiences of many indigenous firms support this consequence. As claimed by Huawei's CEO when China's Premier visited Huawei on July 1, 2003, Huawei did not achieve any technology progress after 1<sup>st</sup> generation of wireless communication system was launched in the world in 1980s. Huawei was about 5-10 years behind and had a very small market share when 2<sup>nd</sup> generation wireless system was deployed in 1990s. Now the world starts to see the deployment of 3<sup>rd</sup> generation wireless system, Huawei is almost at the same starting point together with other multinational corporations to roll out their own products (MII, website). This is also true for companies like Zhongxin and for some other technologies such as optic fiber transmission system. However, it is not necessarily true for all the technologies across the border.

Secondly, there are some rare cases where China has developed original technology innovations that could compete with multinational corporations around the world. One example is the 3<sup>rd</sup> generation wireless systems. There are three major technologies positioned to compete in the global market - CDMA2000 from the U.S., WCDMA from Europe, and TD-SCDMA from China. The TD-SCDMA technology developed by China's Datang Telephone Corporation has officially been recommended by the International Telecommunications Union as one of the three global 3<sup>rd</sup> generation wireless technologies. Although there are many hurdles remaining for TD-SCDMA in order for it to be adopted in Chinese and global market, it has demonstrated that China is ready to develop original world-class technology in some cases. However, this is only a special case at this moment. What remains to be

seen is whether China could go beyond imitation and grow into a strong technology innovator in the entire telecommunications industry.

## **V. Conclusion**

As China changes its political and economic environment by shifting from centrally planned and closed economy to market-oriented and open economy since 1978, R&D efforts have been expanded and technology development capacity has been significantly upgraded in China's telecommunications industry. Our analysis of the successful upgrade in technology points to the consequence of a joint contribution by government funded programs, foreign investments and technology transfer, and aggressive R&D efforts by newly emerged indigenous manufacturers, which is consistent to conclusion by other researchers (Hu, 2003). Government funded R&D programs have succeeded in tracking the global technology development and training researchers and engineers with limited funding and selective objectives. Multinational corporations have reluctantly helped to disseminate information and knowledge, train local talent, transfer some technology, and boost local production capability when selling their products to Chinese market. These activities are often forced by both government policies and the fierce market competition. Newly emerged indigenous manufacturers have succeeded in driving China's technology development by different strategies including imitation, reverse engineering, partial technology outsourcing, and strong in-house R&D. Analysis of this paper suggests a close relationship between China's technology development in telecommunications with the political and economic environment in China and in the world. Any future fundamental political and economic change in China and in the world could result in significant positive or negative impacts in China's future for its technology development.

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