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Comparative Analysis of Japan and China's
Technology Policies and Industrial Development:
Lessons for Developing Countries

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Abstract

In this paper, I compared Japan and China's experience and analyzed how their technology policies have contributed to the industrial development and what developing countries can learn from their experience. Numerical analysis proves that technological capability has contributed to Japan and China's economic growth, especially during the peak growth periods. A review of technology policies of both countries highlights the role of the government in promoting technological capability, the importance of balancing import of foreign technology and indigenous development, and the engagement of business/private sector as a major force for improving technological capabilities. The examination of the ICT production, adoption, and diffusion of both countries implies that ICT industry development and infrastructure deployment can greatly facilitate the development of technological capability.

The paper provides several policy recommendations to the developing countries. Developing countries should be aware of the important role of the government and the existing policy tools. They should strive for the localized option that fits the country's specific social-economic reality. Balancing import of foreign technology and indigenous development, as well as developing market mechanism that encourage private sector's engagement are two other important dimensions. Finally, ICT can be used as a powerful tool for increasing a country's technological capability.

Acknowledgement

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Table of Contents

I. Introduction

Japan speeded up its economic growth in the 1950s and has since then become one of the strongest economies in the world. China has amazed the world by its stunning GDP growth rate since it launched its economic reform in the 1980s. Both countries are successful examples of catching-up and technology development, albeit in different time periods and to different degrees. In this paper, I compare the two countries' experience and analyze how their technology policies have contributed to the industrial development and what developing countries can learn form their experience.

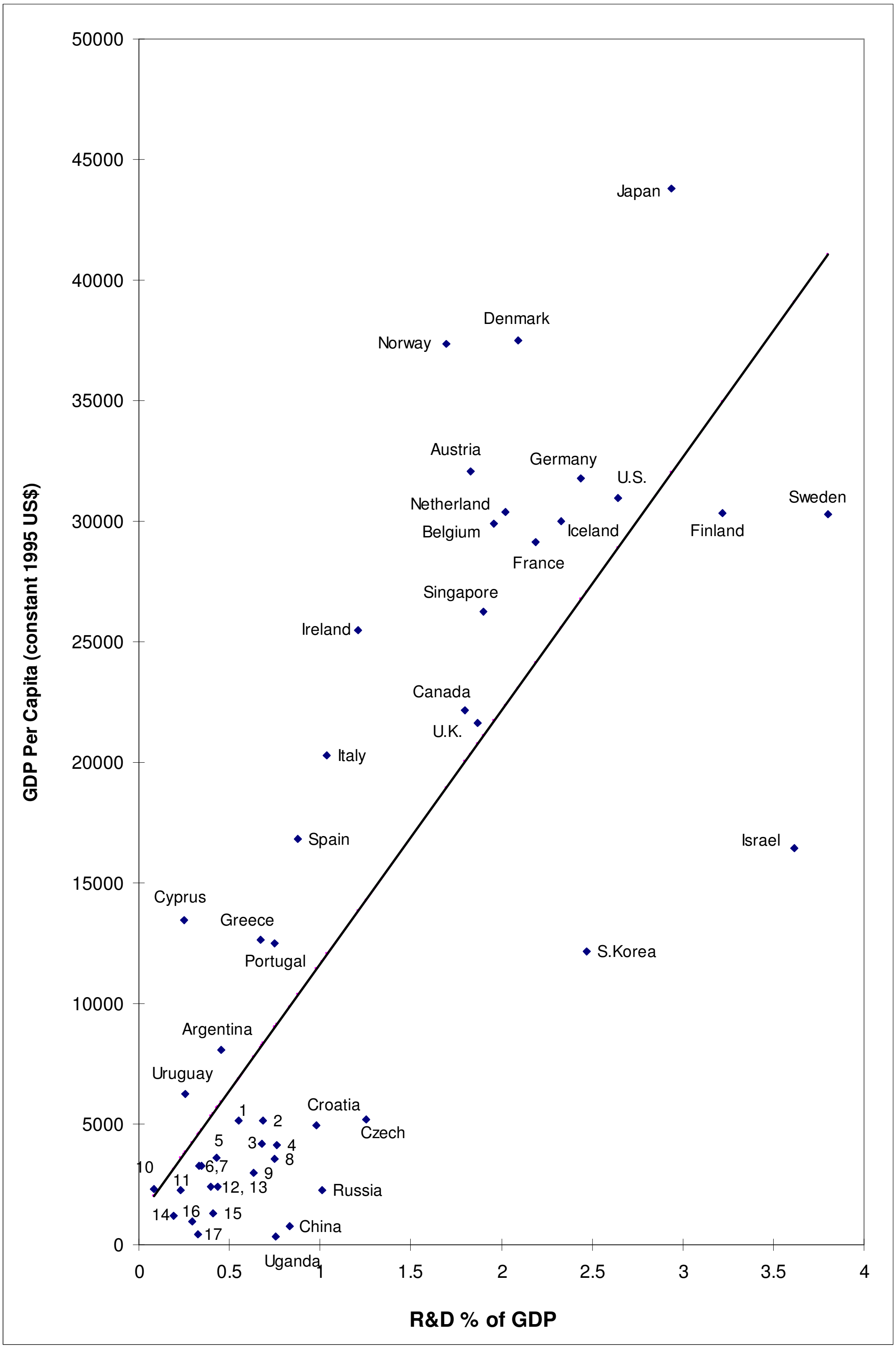
Following the introduction of Section I, in Section II, I employ numerical methods to analyze to what extent technological progress has contributed to both countries' economic growth. After demonstrating the importance of technological progress to economic growth numerically, in Section III, I then investigate how both governments' technology policies have contributed to the improvement of technological capability. We have entered an era of knowledge economy which is based on the development and deployment of information and communication technologies (ICT). Therefore, in Section IV, I focus on the deployment of ICT to analyze how it has facilitated the development of technological capability for Japan and China. In Section V, deriving from the experience of Japan and China, I provide policy recommendations for developing countries that are eager to construct sound technology policies for their industrial development. I state conclusions in Section VI.

1.1 Problems of S&T Development in Developing Countries

In today's economy, knowledge has become an increasingly important production factor. A strong correlation is found to exist between "% of GDP spent in R&D" and "GDP per capita" (Figure 1). On the one hand, acknowledging the importance of technological capability to economic growth, developed countries generally spend a larger portion of their GDP in research and development (R&D). On the other hand, lagging behind the development of every perspective of their socio-economic life, developing countries spend a relatively smaller portion of their low GDP in R&D in particular. For instance, in 1999, Organization of Economic Co-operation and Development (OECD) and other industrialized countries spent over 2% of their GDP in R&D, while most developing countries, spent less than 1% of their GDP (Figure 1-1).

Historically, some regions had flourished with science and philosophy also led in socio-economic development, such as the Islamic countries, India, China, etc. Currently, most regions with glorious ancient cultures were falling behind developed countries. Possessing low level of technological capability, they depend heavily on the west for their technological needs, from the basic needs, such as food and medicine, to military technologies.

Figure 1-1: % of R&D vs. GDP per Capita, 1999



Source: Word Bank. 2003. World Development Indicators CD-Rom.
Note: The numbers in the graph represent the following countries: 1. Chile; 2. Hungary; 3. Slovak Republic; 4. Estonia; 5. Mexico; 6. Venezuela; 7. Panama; 8. Poland; 9: Turkey; 10: Peru; 11. Columbia; 12: Latvia; 13. Tunisia; 14. Egypt; 15. Romania; 16: Bolivia; 17: Georgia;

For instance, about one thousand years ago, the Islamic world had its golden era of science and philosophy and contributed greatly to the development of science and technology of the world. However, currently, the Organization of Islamic Conferences (OIC) countries depend heavily on foreign technologies for most of their needs. OIC countries have about 550 universities in total, while Japan alone has over 1000 universities. Despite the low level of GDP, OIC member states spent 7.1% of their GDP in defense, in sharp contrast with their 0.1-0.2% spending in R&D.

1.2 The Urgent Need to Use S&T as an Alternative Development Path

Science and technology (S&T) are critical for development, especially for countries that have already been far behind the others. Ignoring the importance of S&T is short-sighted – it only makes the gap between the developed and the developing world larger. Realizing the situation, leaders from different developing countries start to call the attention for S&T development. For instance, President Musharraf of Pakistan had been quite outspoken and expressed deep concern over the low level of scientific knowledge especially in the Muslim countries and call to create a fund for education development, especially in the field of science and technology (Pakistan Review, 2003). This foresight and determination is in direct contrast with the short-term vision of the previous leaders in the developing countries.

Furthermore, some developing countries have already started to use S&T as an alternative pathway for development. From the Newly Industrializing Economies (NIEs) such as Korea, Taiwan, Singapore, and Hong Kong, to the recent emerging countries such as China, Malaysia, and India, they all have aggressively developed their technological capabilities which are critical to their economic development. Malaysia, whose world competitiveness was ranked as No. 4 in 2003, has shown the rest of the developing world how S&T can greatly facilitate economic growth.

International organizations have started to offer the help for developing countries for S&T development. For instance, the Science and Technology Policy Option Program at UNU-IAS has specifically targeted how to improve S&T policy-making for developing countries.

The private sector has also joined the international organizations' effort to reduce the divide between the developed and developing countries and to improve technological capability of a country has been sought as an alternative way from financial aid. In January 2004, the

United Nations Development Program (UNDP) and Microsoft Corp. announced a technology partnership to create and implement information and communications technology projects that will help developing countries achieve the Millennium Development Goals. Microsoft has committed $1 billion in cash, software, curriculum, and technology assistance over the next five years to help reduce the global digital divide. The partnership aims to help the capacity building of the developing countries through the advanced technology. (The Tech Report, 2004)

With these available international resources, how can developing countries effectively develop their technological capability by themselves? In literature on using S&T for development, highly debated issues include whether or not FDI is benign to technology development, how to balance technology transfer and indigenous development, how to utilize industrial clustering and networking, globalization and internet for development. It also includes issues on how to utilize existing and new technologies for development, such as ICT, pharmaceutical technology, biotechnology, and nanotechnology. (Hirono, 2001; Gu, 1999; Colecchia and Schreyer, 2002; Kraemer and Dedrick, 2001)

The most controversial issue tends to be the role of the government in technology capability development as institutional settings are the usual drawbacks of developing countries. Underdeveloped institutions within the government is prevalent in the developing countries that caused phenomena such as duplication, inconsistency, or contradiction of policy or decision-making, lack of coordination between different government branches, inflexible institutional settings, and waste of national resources. In particular, lack of good technology policy to guide the development of technological capability of the industries is common to most developing countries.

1.3 Motivation of the Paper

Responding to the need from developing countries and call from the international organizations, I provide two specific countries' experience in technology policy and industrial development in this paper and hope it will help policy makers in developing countries to have a better understanding in terms of how governments can get involved in industrial development through effective technology policies.

This paper intends to empower the developing countries' ability to learn, to absorb, and to improve, i.e., to learn from other successful experience, to absorb those experience to their own institutional settings, and to improve their ability for making self-sustained S&T policies that are instructional for their development.

1.4 Research Question

I intend to answer the following research question in this paper:

How have technology policies contributed to Japan and China's industrial development and what can other countries learn from their experience?

1.5 Hypothesis and Methodology

1. Technological capability has contributed to both countries' industrial development and upgrading.

To prove this hypothesis, I will use numerical method to analyze the contribution of technology to economic growth through total factor of productivity (TFP) of Japan (1960-2000) and China (1983-2000).

2. The governments of both countries have intentionally promoted domestic technological capability by effective technology policies.

To prove this hypothesis, I will focus my analysis on three aspects:

(1) responding to their national needs and envisioning the long-term goals, how have both governments created policy dynamics that have guided their industrial development?

(2) how have both governments utilized both import of technology and indigenous technology development to improve their technological capability?

(3) how have both governments engaged different role-players (public and private, research and business communities) to improve their technological capability?

The analysis of this part will be prepared mostly by examining various second hand materials.

3. Information and communication technologies (ICT) industry development and infrastructure deployment has facilitated the process of improving technological capability.

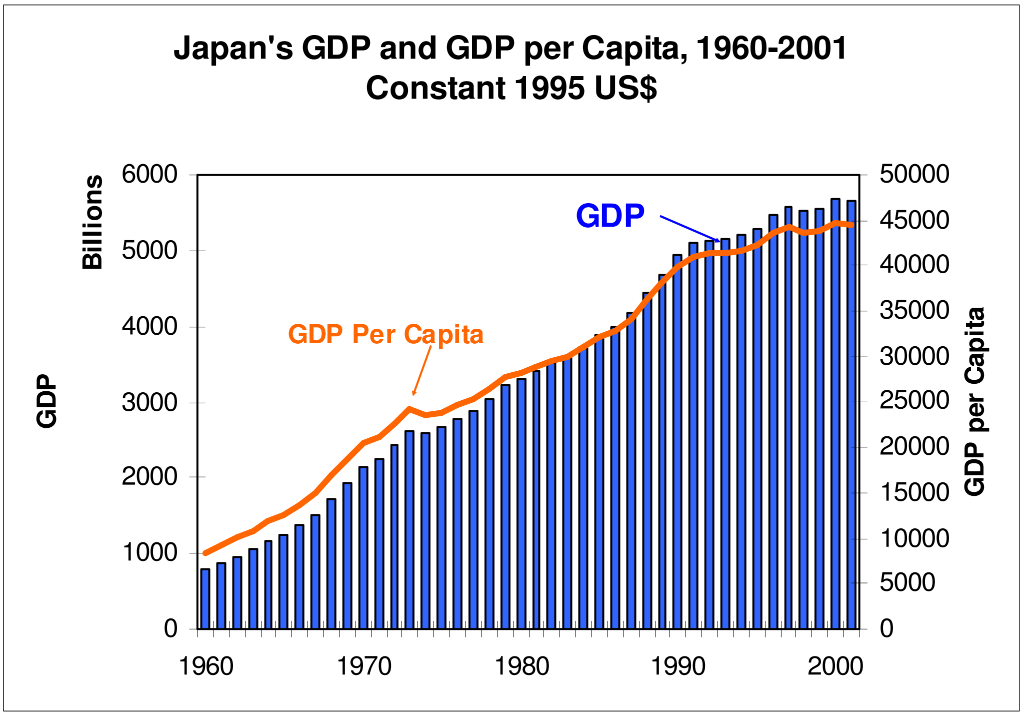
To prove this hypothesis, I will investigate the linkage between ICT development and technological capability improvement, and economic development. Related policy issues will also be addressed.

II. Contribution of Technology Progress to Economic Development

2.1 Economic Growth of Japan and China

In the Post-war Era, Japan created the "miracle" that astounded the world by quickly recovering from the ruin of the war and developed itself into the second largest economy in the world. This process is illustrated by Figure 2.2-1, which shows a rapidly increase of Japan's GDP and GDP per capita from 1960 to 1990. Japan's economy slowed down in 1990s after the burst of its bubble economy, as reflected by GDP and GDP per capita in the 1990s.

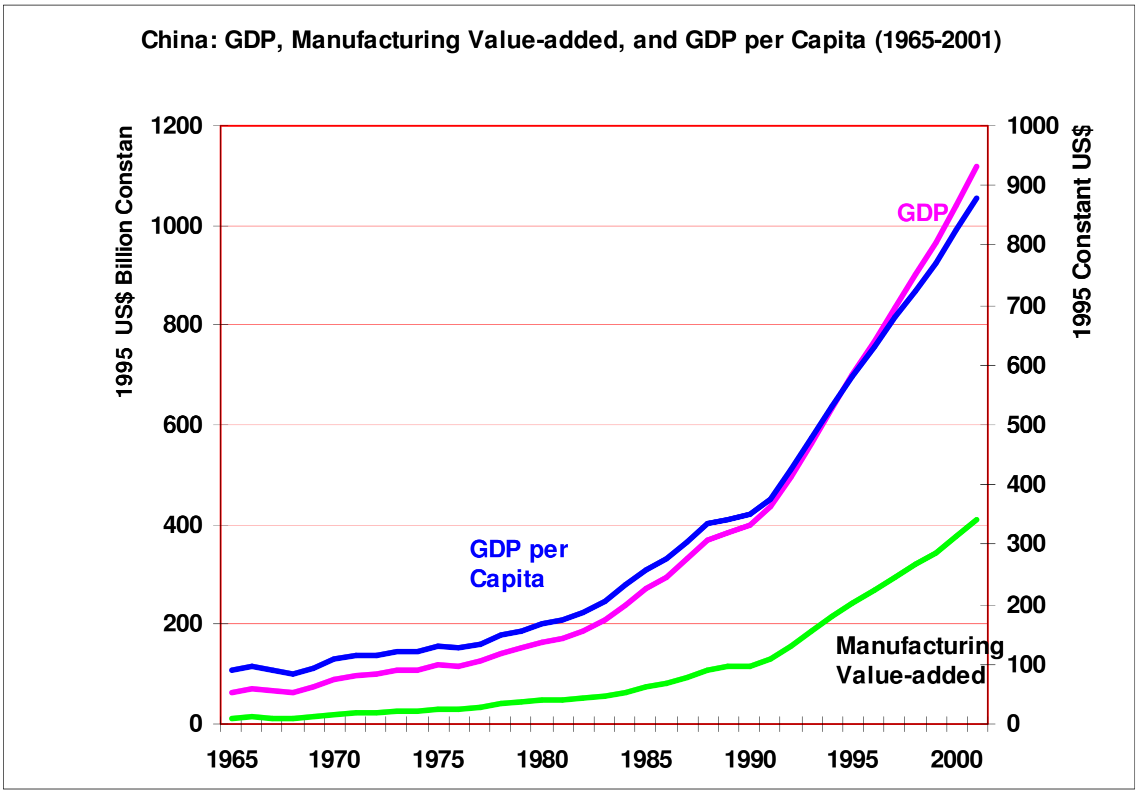
Figure 2.1-1: Japan's GDP and GDP per Capita



Source: Word Bank. 2003. World Development Indicator CD-Rom.

Figure 2.1-2 provides a sketch of China's economic development since 1965. As illustrated, the magnificent growth has started since1980s and the GDP growth rate has been kept around 9% (1981-2000). GDP per capita growth shares the similar trend.

Figure 2.1-2: China's GDP and Manufacturing Value-added (1965-2001)



Source: Word Bank. 2003. World Development Indicator CD-Rom.

Comparing to its glorious catching up era from 1960s to 1980s, Japan's overall competitiveness ranking has dropped sharply from as number one in the world in the 1980s (up till 1992). It was ranked as number 11th in 2003 and it is still maintain as one of the leaders. China increased its competitiveness to Number 12 in 2003. The US, at the same time, has increased its ranking from 7th to number one since 1993 and kept it till now. (IMD, annual issue)

2.2 Technology's Contribution to Economic Growth

Method

GDP has been used widely to indicate the level of economic development. Consequently, the growth of GDP has been used to indicate the growth economic activity of a country. We can adopt the production function that incorporates labor, capital, and technology as their production factors: Y = F (L, K, T); where Y stands for GDP; L stands for labor, K stands for capital, and T stands for technology stock. Thus, the increase of GDP can be written as following:

$$\frac{\Delta Y}{Y}=\frac{\partial Y}{\partial L}\bullet\frac{L}{Y}\bullet\frac{\Delta L}{L}+\frac{\partial Y}{\partial K}\bullet\frac{K}{Y}\bullet\frac{\Delta K}{K}+\frac{\partial Y}{\partial T}\bullet\frac{T}{Y}\bullet\frac{\Delta T}{T} \qquad (1)$$

The above equation explains that the growth of the GDP can be decomposed into three parts: the contribution of the capital, labor, and technology.

Equation (1) can be also rewritten as:

$$\frac{\Delta Y}{Y}=\frac{\partial Y}{\partial L}\bullet\frac{L}{Y}\bullet\frac{\Delta L}{L}+\frac{\partial Y}{\partial K}\bullet\frac{K}{Y}\bullet\frac{\Delta K}{K}+\frac{\partial Y}{\partial T}\bullet\frac{R}{Y} \qquad (2)$$

The contribution of technology progress, measured by total factor of productivity (TFP) growth rate, depends on two factors: marginal productivity of technology (MPT) $\frac{\partial Y}{\partial T}$ and R&D intensity $\frac{R}{Y}$.

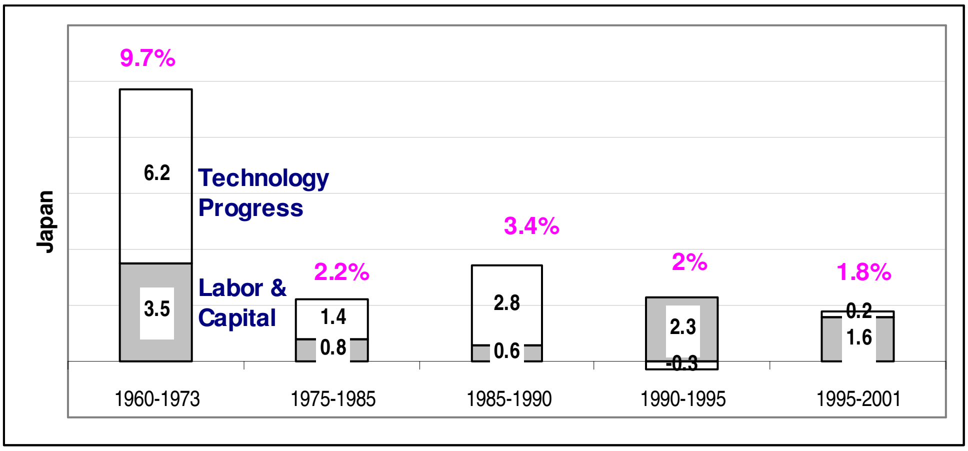
In this paper, I use the TFP growth rate to analyze the contribution of technology progress to Japan and China's economic growth.

Findings

How much has technology progress contributed to both countries' economic growth? Decomposing Japan and China's GDP growth into the three factors' contribution reveals that technology has contributed significantly to both countries' economic development, especially during their high growth periods.

Decomposing Japan's GDP growth (Figure 2.2-1) indicates that staring from 1960s, contribution by technology, measured by TFP growth rate, had conspicuously increased up until the 1980s, but then dramatically decreased in the 1990s. In the 1960s to the 1980s, Japan's growth was mainly due to technological progress. Especially in the 1960s, technological progress led the GDP to growth at 6.1%, while labor and capital led the GDP to grow at 3.5%, which made a total 9.7% GDP growth rate, similar to China's current economic growth rate. In the later decades (1970s and 1980s) technology progress continued to play an essential role for sustaining Japan's growth. However, in the 1990s, as Japan entered its post-bubble and economic recession period and its GDP growth rate dropped to around 2%, meanwhile, technology progress have marginal contribution to the economy, the TFP increase rate fell to -0.3% in the early 1990s.

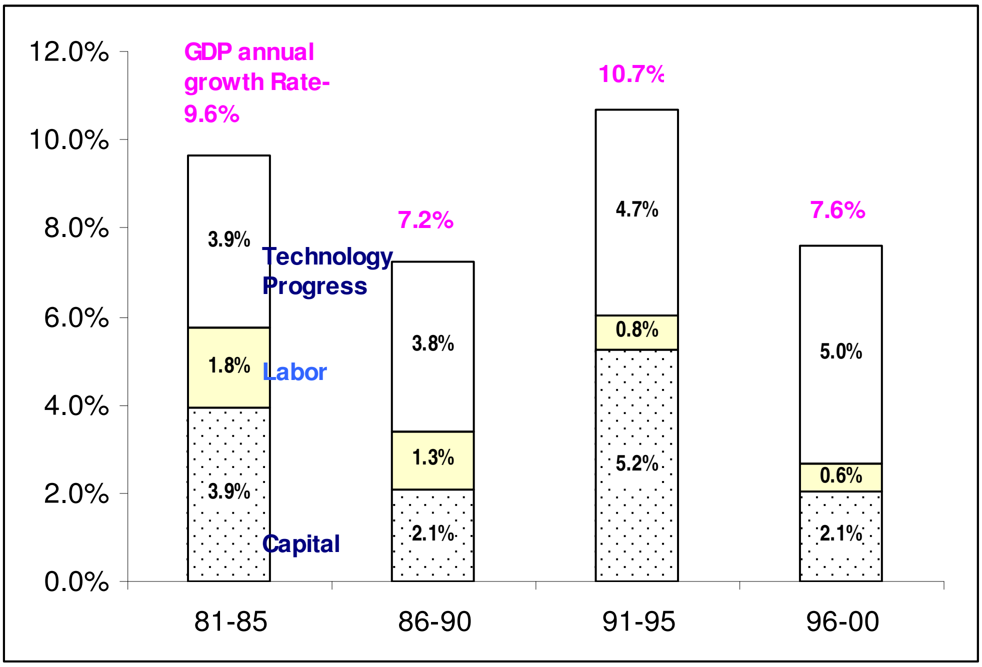
Figure 2.2-1: Comparison of the Contribution of Technological Progress to Economic Growth in Japan, the US, and Germany (1960-2001)



Source: 1960-1973: OECD Economic Studies (1988); 1975-2001: European Competitive Report (2001)

Similarly, it is evident that technology progress has contributed significantly to China's economic growth, especially in the 1990s (Figure 2-2.2). At the beginning of the reform era (1981-1985), capital and labor together caused the GDP to grow at 5.4% annually, while technology progress caused the GDP to grow at 3.9% annually. From 1986 to 1990, technology progress became the leading production factor that contributed to the GDP growth. During the period from 1991 to1995, the average annual GDP growth rate reached 10.7%. This high rate was mainly brought by the huge capital injection, which caused GDP to grow at 5.2%, while labor increment only contributed marginally (0.8%). They together made China's GDP to grow at 6% annually during the period. Nevertheless, technology progress caused GDP to grow at a 4.7% rate. The role of technology progress is more distinguished in recent years. From 1996 to 2000, China's GDP grew at 7.6% annually and technology progress caused the GDP grew at 5.0% annually.

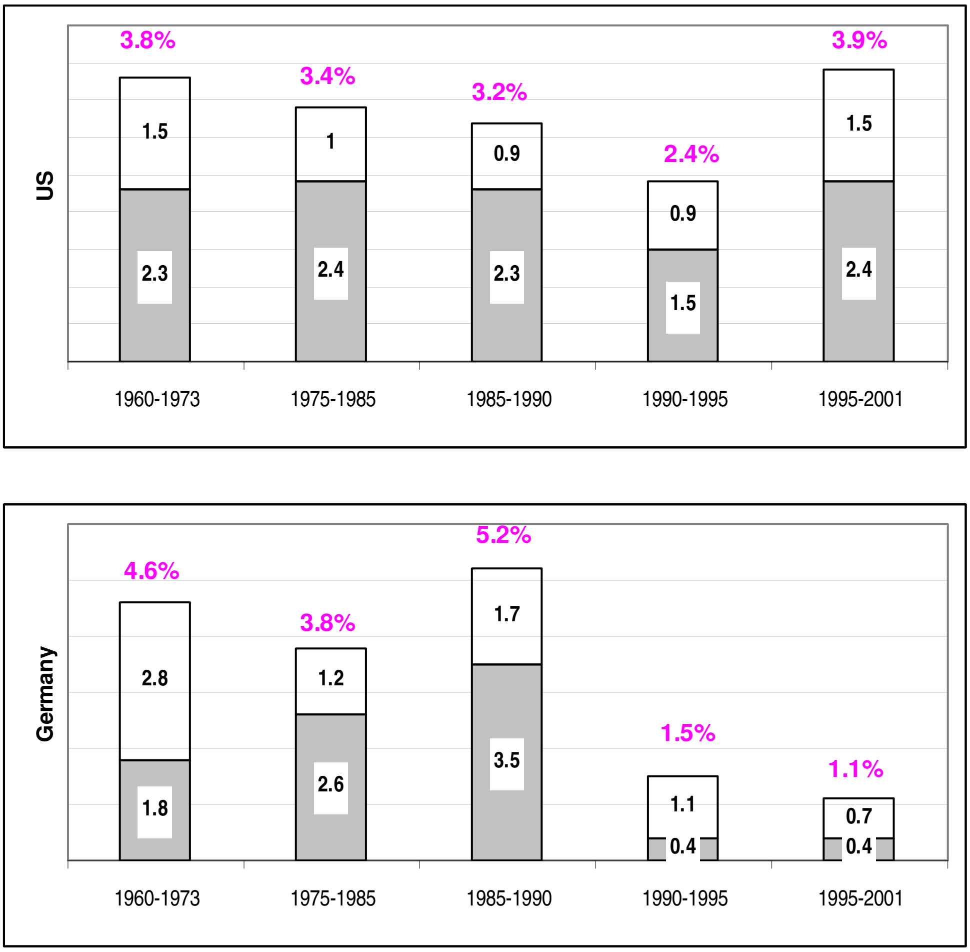
Figure 2.2-2: Contribution of Technology Progress to Economic Growth in China (1981-2000)



Source: the figures were calculated by the author based on the following data sources.
GDP: Word Bank. 2003. World Development Indicator CD-Rom.
Labor: Word Bank. 2003. World Development Indicator CD-Rom.
Growth Capital Formation Rate: China Statistical Yearbook. 2002.
R&D spending as % of GDP: China Statistics Yearbook on Science and Technology. 2003.

Comparing Japan and China's economic growth with other leading economies such as the US and Germany, we can see that the US has comparatively more stable TFP growth rate, i.e., technology progress has been continuously contributed to its economic growth, especially in the late 1990s, when the US led the world in the ICT sector. Germany's path seems somewhere in between the US and Japan. In the 1960s and 1990s, Germany's economic growth was stimulated mainly by technological progress, while from 1970s to 1980s, capital and labor has greater impact, though technological progress still played a significant role. (Figure 2.2-3)

Figure 2.2-3: Contribution of Technology Progress to Economic Growth in US and Germany

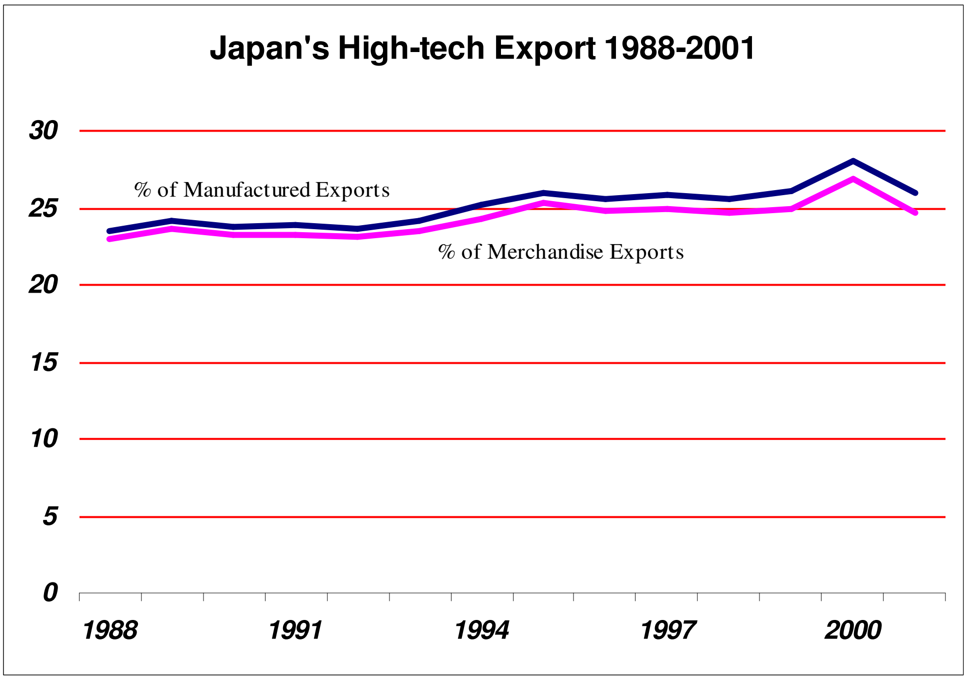


Source: 1960-1973: OECD Economic Studies (1988); 1975-2001: European Competitive Report (2001)

2.3 High-tech Export and Patent

Corresponding to its economic achievement, Japan's technological accomplishment impressed the whole world as well, especially before the burst of the bubble in the early 1990s. In the 1980s and 1990s, Japan's high-tech products exportation was kept as a stable 25% of its manufacturing export (Figure 2.3-1). Since the 1960s and 1970s, "made in Japan", has been a synonym for high-quality and high-tech for consumers all over the world, especially for the consumer electronic goods.

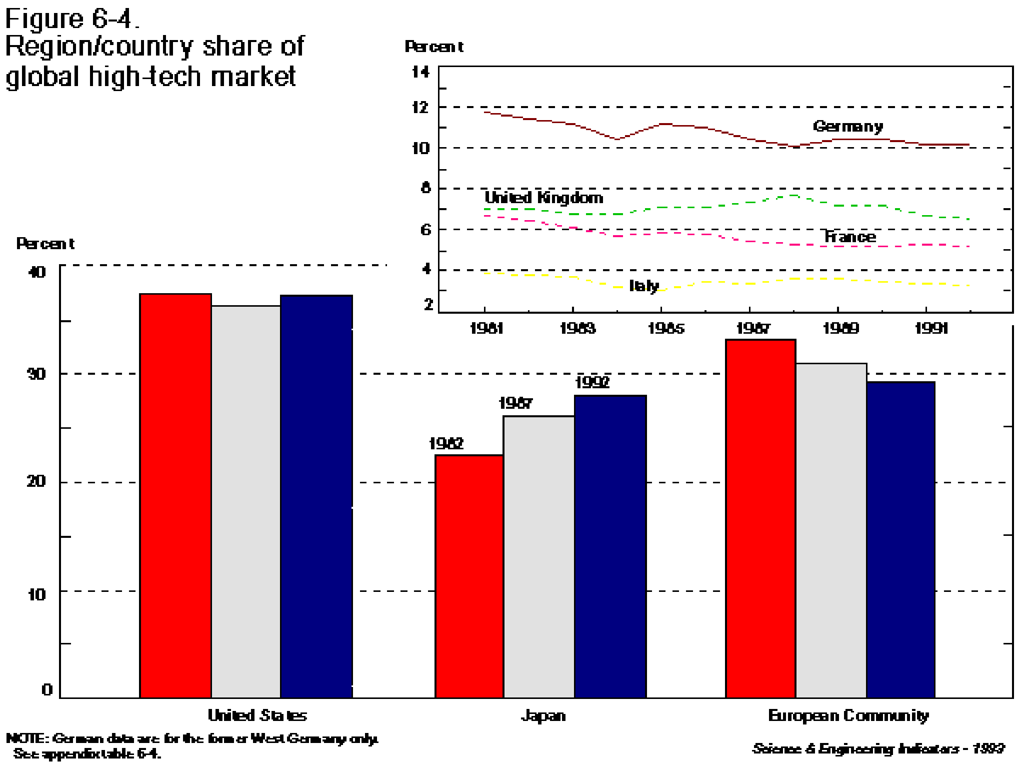
Figure 2.3-1: Japan's High-tech Export



Source: Word Bank. 2003. World Development Indicator CD-Rom.

During the 1981-92, while U.S. high-tech industry struggled to maintain market share, Japanese high-tech industries followed a path of steady gains in global market share. In 1992, Japan accounted for nearly 28 % of OECD member countries' production of high-tech products, moving up 6 % since 1981. (Figure 2.3-2)

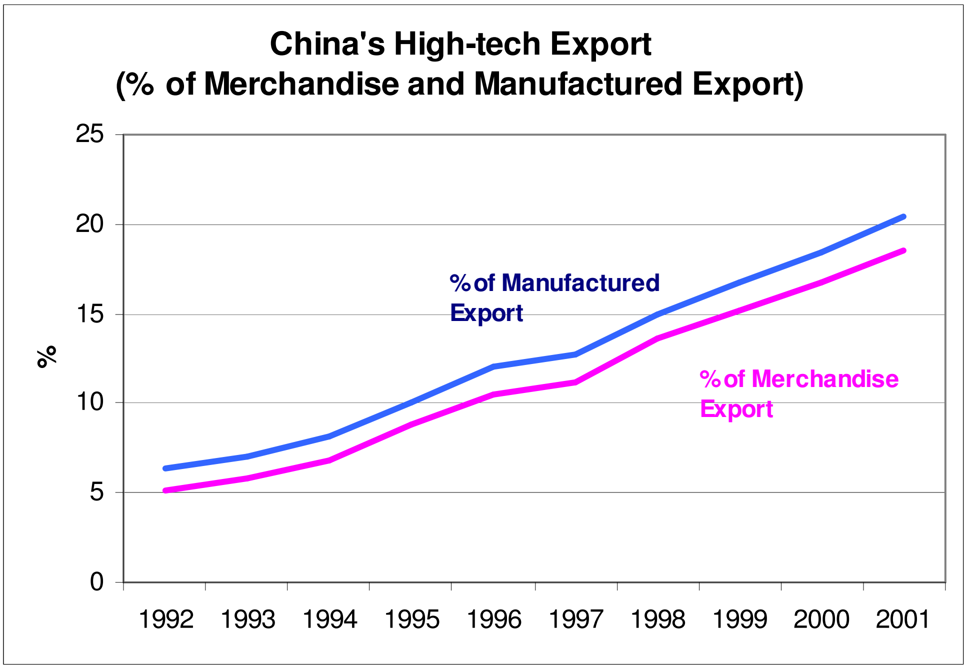
Figure 2.3-2: Region/Country Share of Global High-tech Market



Source: http://www.nsf.gov/sbe/srs/seind93/chap6/gif/06-0493.gif

High-tech export can be viewed as a direct indictor of economic benefit from technological progress. From 1992 to 2001, China's merchandise export increased three times and manufactured good export increased 3.5 times. However, the achievement in export is less impressive when compared with China's high-tech export, which increased from US $4.4 billion in 1992 to US $49 billion in 2001, i.e., more than 10 times within 10 years. Figure 2.3-3 illustrates the increasingly important portion of high-tech export vis-à-vis the merchandise and manufactured export.

Figure 2.3-3: China's High-tech Export



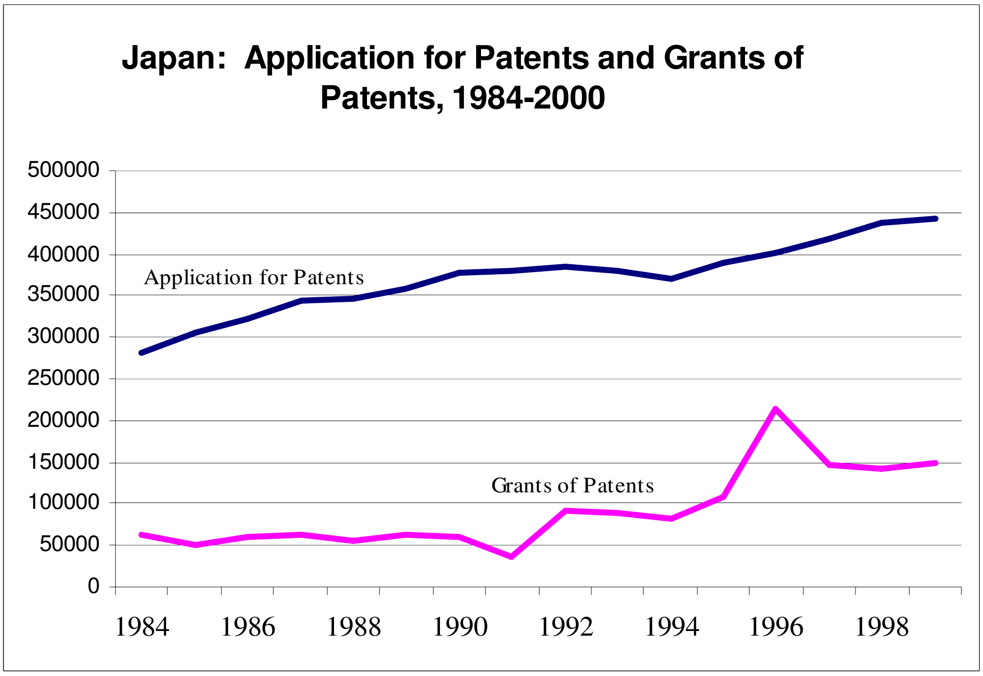
Source: the author calculated based on data from World Development Indicator (World Bank, 2003).

In 2003, China's high tech export has reached $110 billion, growing 5% from 2002, accounting for a quarter of the country's total exported goods; while in 1992 high-tech products only accounted for 5% China's overall exports. China's Vice Premier Wu Yi said that China's policy of "enhancing trade by relying on science and technology" has led to the rapid growth of exports.[1]

Innovation and invention created by the Japanese companies and institutes also reflect the technological progress of the country. Patent application and patent certification has kept growing (Figure 2.3-4). For instance, in 1999, Japan's patent application totaled 442,245, more than the US, which was around 294,706; while Japan's patent certification reached 150,059, only slightly lower than the US -153,487. (UNSYB, 46th)

[1] http://asia.news.yahoo.com/040106/afp/040106182907hightech.html

Figure 2.3-4: Japan: Application for Patents and Grants of Patents: 1984-2000

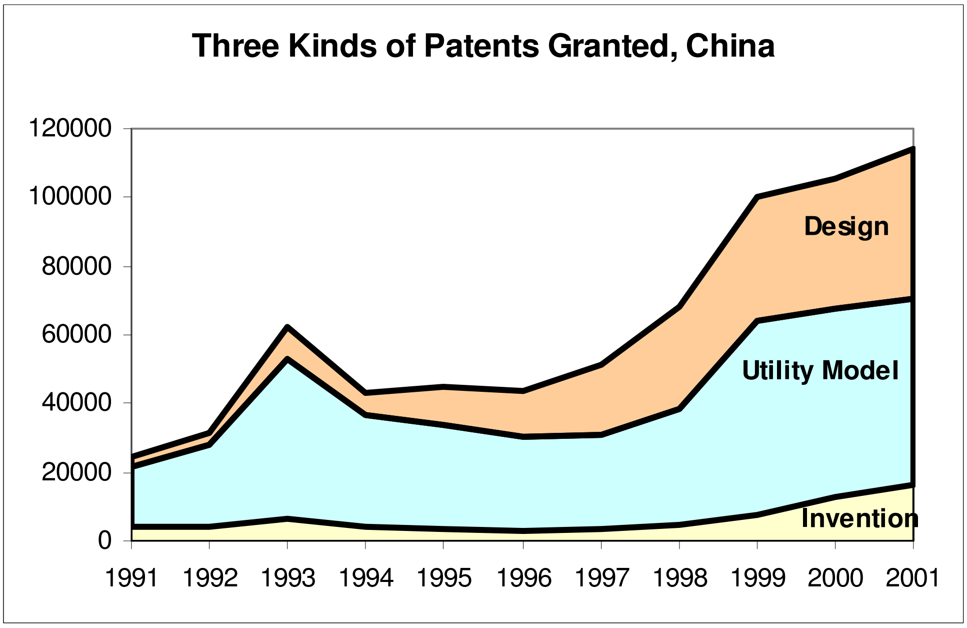


Source: United Nations Statistical Yearbook 46th Issue.

During the last decade, China's granted patents have grown rapidly, as illustrated in Figure 2.3-5. All three kinds of patents have growth proportionally. Invention patents managed to keep its proportion of the total patents granted, even though during the middle 1990s, its growth rate appeared to be very sluggish. The utility model patent was the major leader of the growth by its significant portion of the total patents. Nevertheless, design patents grew from about 13% in 1991 to 38% in 2001.

It is also interesting to point out that domestic residents are the absolute main owners of the utility model inventions – each year, 99% to 100% of the utility model inventions were granted to domestic residents. Similar situation happened to the design patents, about 80% to 90% were granted to domestic residents each year from 1991 to 2001. However, foreigners, especially multinational companies were the majority owner of the most innovative kind of patents – the invention patent. Each year, foreigners contribute to about 55% to 60% of the invention patents granted.

Figure 2.3-5: Three Kinds of Patents Granted, China



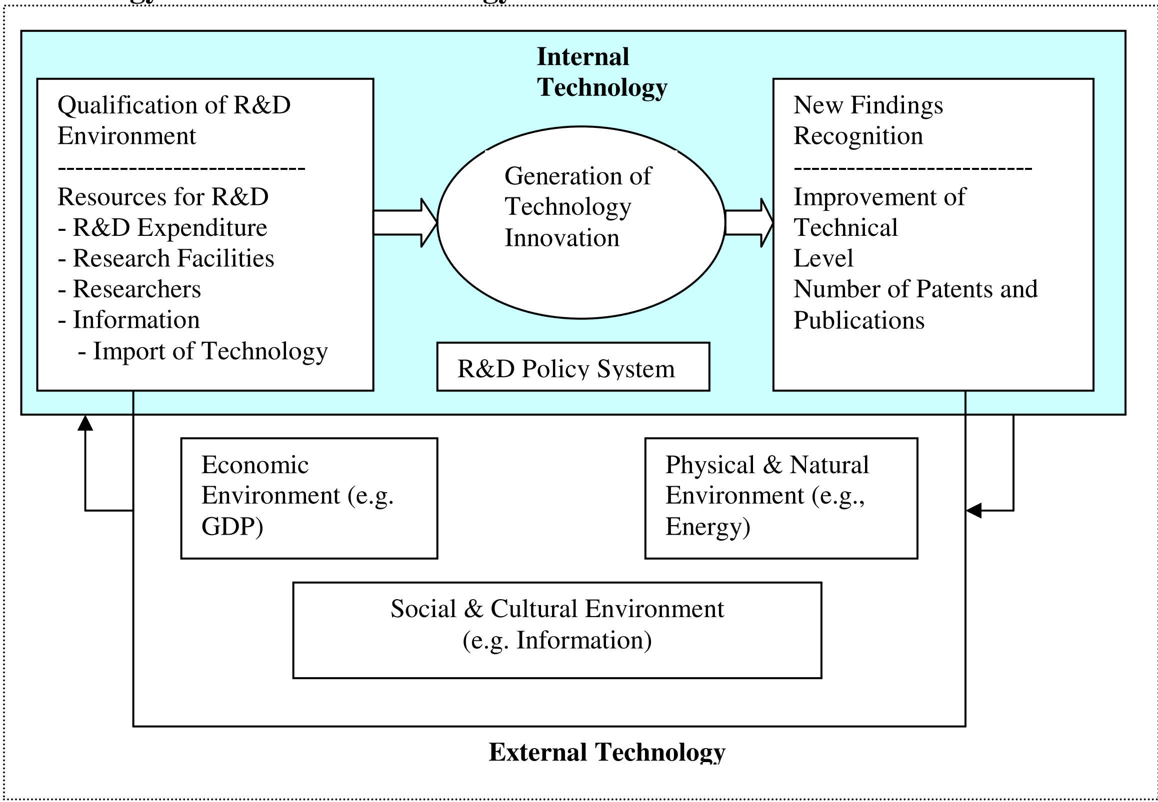
Among the non-individuals who were granted the three kinds of patents, industrial enterprises became the main force for utility model patents as well as the design patents. While universities and colleges were kept as the major owner for invention patents, with the industrial enterprises become more significant in its contribution.

2.4 Resources for R&D

Examing the mechanism of technology innovation in detail (Figure 2.4-1), there are many factors matters in creating technology innovation thus contributed to the output of the innovation system. Here I would like to focus on resources for R&D, especially financial expenditure and human resources.

The main indicators of China's innovation system confirmed that China has made impressive progress in technology innovation over the past 20 years, especially during the last decade.

Figure 2.4-1 Mechanism of Technological Innovation – Interaction between Internal Technology and External Technology

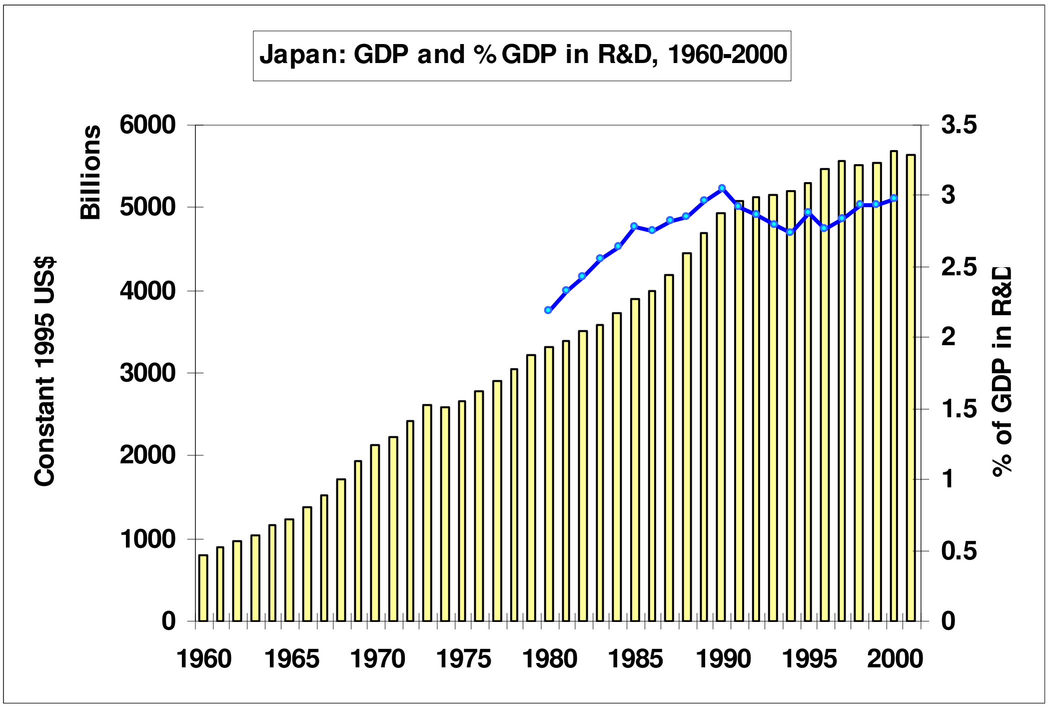


Source: Watanabe, 2003.

Financial Expenditure on R&D

Japan's achievement of technological capability was closely bounded with its effort in R&D input. For instance, in the 1990s, Japan spent an average of 3% of its GDP in R&D (Figure 2.4-2). The absolute amount of R&D expenditure (US$ 168 billion in 2001) was listed as the second, only behind the US. In terms of percentage of GDP in R&D, it was listed as the fourth, following Sweden, Israel, and Finland, who spent 3-3.5% of their GDP in R&D. In contrast, most other developed countries spent 1-2% of GDP in R&D and most developing countries spent less than 1% of GDP in R&D.

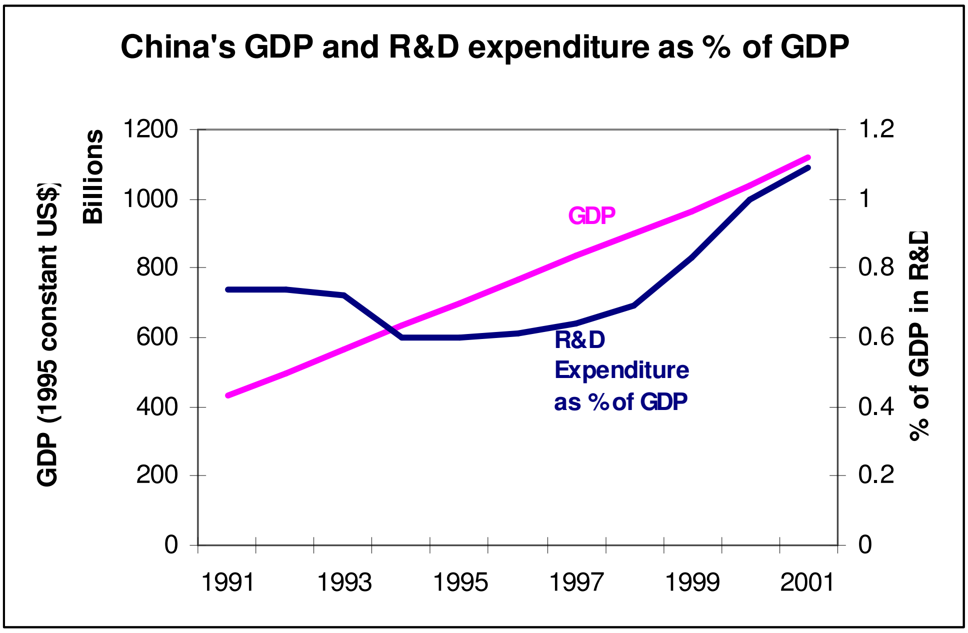
Figure 2.4-2: Japan: GDP and % of GDP in R&D, 1960-2000



Source: Word Bank. 2003. World Development Indicator CD-Rom.

Corresponding to China's average 9% GDP growth rate from 1991-2000, China's expenditure on S&T and R&D increased magnificently. R&D expenditure increased from around 0.7% in the early 1990s to about 1.1% in the new millennium (2001) (Figure 2.3-5). This figure is still far behind other developed countries that generally spend 2-3% of the GDP in R&D expenditure. However, China's progress is impressive, considering that R&D expenditure increased even faster than the astound GDP growth rate. Both the absolute amount and the relative proportion of R&D spending placed China ahead of most of other developing countries.

Figure 2.4-3: China's GDP and R&D Expenditure as % of GDP

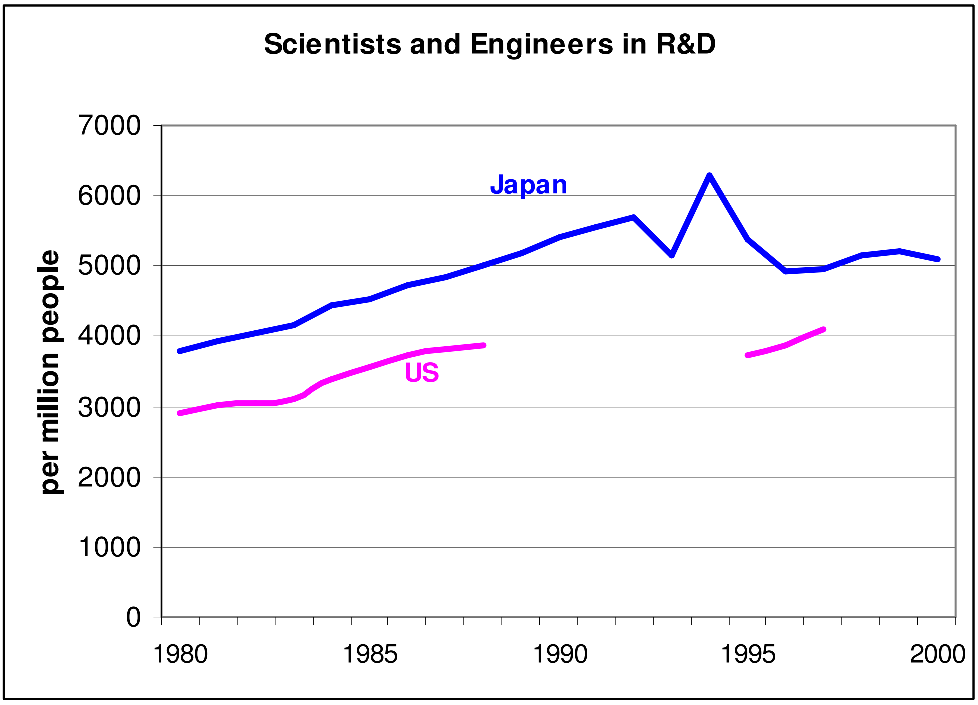


Source: Word Bank. 2003. World Development Indicator CD-Rom.

Human Resource

Figure 2.4-4 is a reflection of Japan's advanced human resource stock. Compared to the technology leader the US, Japan has a significant higher ratio of "scientists and engineers in R&D per million people." However, starting from 1995, similar to R&D expenditure, this ratio started to drop, which reflects Japan's overall sluggish performance in technological progress. The virtuous cycle which fast growing economy stimulates efforts in technology development which further pushes the economic growth, now becomes a vicious cycle which the sluggish economy leads to lethargic technology development that leads to more severe slow-down of the economy.

Figure 2.4-4: Scientists and Engineers in R&D in Japan and the US



Source: Word Bank. 2003. World Development Indicator CD-Rom.

China is one of the leading countries in R&D personnel resource. For instance, it had 0.6 million R&D personnel in 1991 and close to one million in 2001. Japan and Germany had 0.9 million and 0.5 million R&D personnel in 1999, respectively. However, in relative term, because of China's huge population base, R&D personnel per 10,000 economically active populations was only 10 to 13. Nevertheless, total full-time equivalent R&D personnel per 10,000 economically active population increased from 67 to 82 from 1991 to 2001(China Statistical Yearbook on Science and Technology, 2003, p.5).

Further, using World Development indicator (Table 2.3-2), China's scientists and engineers in R&D is 545 per million people in 2001, which is only one ninth of Japan, one seventh of the US, and one sixth of Germany. However, it led other developing countries such as Malaysia and India by three times. Investigation of the annual increasing rate revealed that China has a very distinguished growth rate of this human resource. From 1994 to 2000, China has a growth rate of 20.7% of its scientists and engineers in R&D. Meanwhile, Malaysia has 9.4% growth from 1993 to 1998, India has a marginal 0.7% growth from 1990 to 1996. Comparing to other developed countries, France led the annual growth by 16%, while the US maintained at 2.1%. Japan however, showed a decline of its scientist and engineers stock during the last decade and the growth rate is -1.0%.

Table 2.4-1. Scientists and Engineers in R&D (per million people)

	China	Malaysia	India	Japan	United States	France	Germany
Scientists and engineers in R&D (per million people)	545 (2000)	160 (1998)	157 (1996)	5095 (2000)	4099 (1997)	2718 (1999)	3161 (2000)
Annual increasing rate	20.7%	9.4%	0.7%	-1.0%	2.1%	16.0%	0.4%
calculated Period	1994-2000	1993-1998	1990-1996	1990-2000	1980-1996	1990-1999	1991-2000

Source: the author calculated and summarized based on data from World Development Indicator 2003.

III. Technology Policies for Industrial Development

Japan and China's development of technological capability was closely bounded with the governments' effort in upgrading their industrial infrastructure and economic reform. Therefore, in this section, I focus on the dynamic involvement of the state in improving technological capability. I will also highlight two other crucial aspects in the process: balancing import of technology and indigenous development and engaging the business sector in R&D development.

3.1 The Role of the State

Japan

It has been widely acknowledged that the Japanese government has played a very active role in Japan's economic development. Japan's government involvement offers another way that the capitalist state can be in addition to the laissez-faire liberal market model. The role of the government is quite unusual by the Western standard and "it gives Japan an unusual capacity to think strategically and at times to make deliberate changes of direction as a nation society" (Sheridan, 1993, p. 180).

Japan's policy cycles (Table 3.1) reveal two most distinguished periods of Japan's economic development, the early Meiji period (1868-1890) and the post-war period (1956-1986).

Table 3.1: Japan's Policy Cycles, 1868 – 1999

Date	Policy
1868-1890	The effort to industrialize
1881-1900	Reworking the effort along national(istic) lines
1901-1916	Expansion overseas and a concern for welfare at home
1917-1937	Taisho democracy, depression and militarization
1937-1945	The war economy and economic collapse
1946-1955	Occupation reforms and the basics of subsequent success
1956-1970	The years of rapid growth
1971-1985	Responses to crises, upgrading and decelerated success
1986-1991	Bubble economy
1991-present	Domestic recession and concern for global position

Source: Preston, 2001, p. 94.

From the very beginning of Japan's industrialization in the early Meiji period (1868-1890), it is the state that planned a top-town reform that pushed Japan towards its modernization in every aspect of social-economic life, especially in terms of creating an industrial-capital economy. In its post World War II recovery and later periods, it is also the state that identified national priority for industrial development, provides guidance and direction, and directly involved in the industrial development especially through its emphasis on industrial technological capability.

The Meiji government mobilized the whole population to achieve the economic development by the following activities: 1. setting up Ministry of Industrial Development to foster the development of coal, steel, railways and machinery industries, to establish public modern enterprises in key sectors, and to modernize agriculture and agricultural products; 2. developing domestic knowledge and skills through oversea education, use of temporary foreign experts, and reform of domestic schooling; 3. searching entrepreneur talents nation-wide; and 4. implementing the German model that stressed national needs and confirmed the role of the state within the developing economy.

"By 1900 the government had developed a coherent, public/private, Western/Japanese model of national economic planning and management and at some point around 1900 the State economy 'took off' from its previous infantile and formative experimental stage" (Sheridan, 1993, p. 33). Preston commented that Japan's early industrialization can be regarded as a political-cultural project, formulated by the elite (which powered the Meiji government) and disseminated through the population. (Preston, 2002, p. 38)

During the post World War II period, Japan's economy took off from the ruin of the war. The government intervention, again, played an essential role. The government has formed different sets of industrial policies at different stages of the country's development and mobilized all available resources to reach their policy goals. As Table 3.2 illustrates, in each decade, Japanese government identified the key sectors of the industrial development. The technological capability development was centered on those key sectors and the R&D projects initiated by the Ministry of International Trade and Industry (MITI) clearly shows the correspondence. The details will be discussed in next section.

Table 3.2: Trends in Japan's Industrial Structure Policy in the Post-War Era

Period	Industrial Focus
1950s	Priority Production System
1960s	Heavy And Chemical Industrial Structure
1970s	Knowledge-intensive Industrial Structure
1980s	Creative Knowledge-intensive Industrial Structure
1990s	Creation Of Human-values in the Global Age

Source: Watanabe, 2003.

Among all the government bodies, Japan's Ministry of International Trade and Industry (MITI) was the most distinguished one because of its close relationship with Japan's post-war industrial development.

MITI: Policy Formation and Implementation

MITI was formed in 1949 "in an effort to curb postwar inflation and provide government leadership and assistance for the restoration of industrial productivity and employment." It "provides industries with administrative guidance and other direction, both formal and informal, on modernization, technology, investments in new plants and equipment, and domestic and foreign competition" (FAS, 2003). MITI's vision can be summarized by several key words: penetration, identification, providing direction, instilling confidence, developing general consensus (Watanabe, 2003). MITI's action falls into the following main categories:

- Incentive: National Research Laboratory, R&D program, investment, conditional loans, financing, tax exemption
- Stimulation: R&D consortium, publication, open tender
- Regulation: IPR, monopoly, accounting
- Dissemination: Diffusion, transfer, demonstration, public procurement

The following is a brief review of Japan's industrial policy and MITI's effort in implementation (Table 3.3).

The 1960s' industrial policies emphasized shifting Japan towards a heavy (especially steel, car, and machinery) and chemical industrial structure. The steel industry during the 1960s was featured by increased size of investment in plant and equipment driven by technological innovation in using converters in steel making and the introduction of strip mills (continuous rolling machines) in the rolling process. At the beginning of the 1970s, the Japanese steel industry occupied the foremost position in the world in both quantity and quality of output.

Despite the restriction of car production by the Allied Occupation authorities in the 1950s, MITI made serious effort to foster it, because it considers automobile industry as a strategic industry which contributes to the supply industries such as machinery, steel, and many other industries. The total volume of automobile production increased by 12.6-fold from 1959 to 1970. The machinery industry similarly underwent the high-speed growth in the same period. Again, the primary driving force of both industries' expansion was the vigorous investment in plant and equipment. In addition, the machinery industry's growth was accelerated by the growing demand from the steel industry and from the shipbuilding industries.

Japan began to develop its petrochemical industry around 1955. The competitive import of foreign technology propel the technological development of the petrochemical and related industries that producing synthetic fibers and plastics. *The Petrochemical Industrialization Plan* led to establishment of four petrochemical complexes into operation in 1950s, and the establishment of eleven other complexes during 1962 and 1972 as MITI approved the import of foreign technology.

What role did technology policy play during this period, then?

The starting point is 1963, when *Industrial Technology Committee of the Industrial Structure Research Committee*, in their report, pointed out that "it was necessary to transform the economy from one that replied on imported technology to one driven by domestically developed technology, a pattern that prevailed in all industrially advanced countries" (Sumiya, 2000, p. 481). It suggested selecting core technologies (those that would play key roles in upgrading the industrial structure and increasing international competitiveness) and giving high priority to them in technology development process.

The report led to MITI's program in 1964 for research and development in mining and industrial technology which Japan was underdeveloped compared to other industrially advanced countries. The huge research expenditures would be born by the government and the government would commission R&D to researchers from the private sector to fully utilize their capabilities. Later in 1966, this system of R&D was dissolved into the system of large-scale industrial technology R&D and three large-scale projects were selected (1) magneto-hydrodynamic power generation, (2) super high-performance computers, and (3) desulphurization of flue gas from thermoelectric power plants. Three other projects were added in 1967 and 1969, research on a new manufacturing process for olefin, the desalination of sea water and utilization of by-products, and remote control offshore deep-sea oil-drilling rigs. The budget for these six projects totaled at 5.05 billion yen in 1970.

At the same time, the government has improved laws on industrial property rights. The Patent Law was completely revised in 1959. Patent Law, Utility Model Law, Design Law, and Trademark Law went into effect in 1960. The Patent Law and the Utility Law were amended again in 1970 and went into effect in 1971 to improve examination procedure and dealing with increasing applications.

The Sunshine Project in the early 1970s targeted to satisfying increasing demand of energy by developing and promoting new energy-related technology. The Sunshine Project challenged the research community with its three principle points of the new energy technology: having abundant quantity, being not more expensive than traditional forms, and being pollution-free. Consequently, technology development on solar energy, geothermal energy, synthetic natural gas, and hydrogen energy were supported by MITI. The first oil crisis in 1973 and the second oil crisis in 1979 both quickened the pace for development. MITI further implemented the law that targeted for alternative energy development, along with an organization as a type of special corporations supported by treasury investments, loans, and subsidies. The law contained an article stipulating that the government would introduce the financial, lending and tax measures needed to promote development and introduction of alternative energy.

From 1973 to 1985, Japan's economy has shifted from a high-growth path to a so called "stable-growth" phase. The international environment in the 1970s (New Economic Policy by the Nixon government, world food crisis, energy crises, global adoption of the floating exchange rate system, etc) caused the inflationary in many countries, including Japan, which resulted the slow-down of the Japanese economy and the increase of the unemployment rate. However, the Japanese government successfully utilized technology policies to encourage the development of energy-saving and less energy-intensive technologies to make Japan's economy less energy-intensive. Nevertheless, despite the success in certain technology policies, overall, the government has failed to institute the structural reforms that put Japan in long-term stable growth basis. Hirono (2001) analyzed that the Japanese government failed in (1) deregulation and decontrol to increase the competitiveness of domestic industries; (2) trade liberalization; (3) decontrol foreign exchange; and (4) decentralization of public administration and tax.

These failures in structure reform were only the prelude of the policy failures in the bubble and the post bubble period (1985-1999). During the period, the international environment was characterized by accelerated globalization through further trade liberalization, a rapid enlargement of highly liquid global capital market, and the sky-rocketing price of shares and real-estate, all these are accompanied by the rapid advanced development of information and communication technologies (ICT). The huge appreciation of Japanese yen caused an outflow of manufacturing investment to oversea. The government continued its effort in supporting technologies development in manufacturing sectors. However, heavy regulation and protectionist mindset has prevented restructuring in non-manufacturing sectors. The failure of government policies in those areas has constrained Japan's productivity improvement at national level despite the marvelous progress in manufacturing technology. (Hirono, 2001)

Comparing to the prosperity of the Japanese electronics industry, the software industry in Japan has been far behind. It took the Japanese government long time to realize the importance of the software industry. More importantly, there was strong resistance from part of the government bureaucracy that to deregulate the information industry to accelerate the development and application of the software industry. The government feared that the deregulation of the software industry would drive some existing media industries out of the market. Further, it also feared that inter-ministerial rivalry, particularly between the Ministry of Post and Telecommunications (MOPAT) and the MIT. It was only after strong foreign pressures for deregulation and liberalization for the information and telecommunication sectors, that Japan's software industry began to grow rapidly and started to shine in Japan's industrial stage.

Japan's experience reveals that institutional settings can facilitate or impede technology development. While appropriate institutional setting will stimulate innovation (in the 1960s and 1970s); inappropriate institutional setting will impede innovation (in the 1990s).

Table 3.3: Chronology of MITI Initiated R&D Programs

Period	Project	Technologies
1960s	**Heavy and Chemical Industrial Structure**	
1966-	The National R&D Program (Large-Scale Project)	Leading technology (big, risky)
1970s	**Knowledge-Intensive Industrial Structure**	
1974-	R&D on New Energy Technology (The Sun-Shine Project)`	Oil-substituting energy technology (renewable energy and energy conversion)
1976-1979	VLSI Project	Innovative computer technology
1976-	R&D on Medical & Welfare Equipment Technology	Medical and welfare technology
1978-	R&D on Energy Conservation Technology (The Moonlight Project)	Technologies for improving energy productivity
1980s	**Creative Knowledge-Intensive Industrial Structure**	
1981-	R&D Program on Basic Technologies for Future Industries	Basic and fundamental technology
1982-1991	Fifth Generation Computer Project	Innovative computer technology
1985-	Key Technology Center Project (Industrial R&D on Fundamental Technology)	Fundamental technology initiated by industry
1989	The Designated Research Frame in The Global Environment Field	Basic technology for global environment
1990s	**Creation Of Human-Values in the Global Age**	
1990-	R&D Program for Global Environmental Industrial Technology	Global Environment technology

Source: Watanabe, 2003

China

As the analysis (decomposing GDP's growth to contribution of different factors: capital, labor and technology progress) in Section II (Figure 2.3-2), technology progress has contributed significantly to China's economic growth, especially in the second half of 1990s -

from 1996 to 2000, China's GDP grew at 7.6% annually and technology progress caused the GDP grew at 5.0% annually. Main indicators of China's innovation system: from the more output oriented high-tech export and granted patents, to more import oriented R&D expenditure, human-resources, all have confirmed that China has made impressive progress in technology innovation over the past 20 years, especially during the last decade.

What has the Chinese government done in improving China's technological capability then? Here we reveal the policy dynamics behind those figures.

The significant contribution of technological progress to economic growth in the second half of the 1990s is closely related to the central government determination in improving S&T. On May 5, 1995, the State Council announced the "Decision on Accelerating S&T Development" (U. S. Embassy China, 1996). The decision outlined China's S&T development for the next several decades. It emphasized that S&T research should be closely tied to the market. Instead of designate all the researches at the state-owned research institutes, universities and private industry should do research as well. This is a dramatic change from the old Soviet-style institutes, which China was implementing since the 1950s. It called to create joint ventures with Chinese or foreign venture capitals (VCs) to accelerate transfer of technology to industry. The decision listed a goal of R&D spending: by year 2000, China should spend 1.5% of Gross National Product (GNP) on R&D. The decision also emphasized protecting the environment and achieving sustainable development and indigenization of S&T creation capability in key areas of manufacture technology and system design. (SCBC, 2003)

Before this decision, China actually already started its S&T system reform mainly through two distinguished national S&T development programs: the "863 Plan" and the "Torch Program."

863 Program

The National High-tech Development Plan or "863 Plan" aims to foster high-quality fundamental research in China. The history of the plan can be traced to March 3, 1986, when four respected scientists, Wang Dayan, Wang NieChang, Yang Jiaxi, and Chen Fangyong, wrote a letter to the State Council, advising on how to catch up with the developed countries and develop China's own technology in high-tech industries. This letter drew great attention from Deng Xiaoping, who later requested the State Council react quickly. In the following half year, the State Council organized about 200 scientists and researched strategies for developing high technology, which finally led to the National High-tech Development Plan Outline ("863" Plan Outline), approved by the State Council. Considering the prevailing situation in China, a developing country that has limited resources for developing all kinds of high technologies, the 863 Plan suggested that China should focus on 7 areas and 15 topics. The 7 areas are: biotechnology, astro-technology, information technology, laser technology, automation, and energy technology. The "863 Plan" will select experienced scientists and researchers for these projects. As a government organized national science and technology program, the "863 Plan" especially encourages participation from domestic enterprises.[2] (Fan, 2003)

Projects in "863 Plan", most of which are basic research[3] (or even pure science), are impractical to conduct at the individual company level because of their high cost/benefit ratio and long (or infinite) time horizon. Through participating in national S&T projects, companies can become familiar with the knowledge breakthroughs in the field, thus facilitating higher-level R&D at the company level, such as applied research, exploratory development, and advanced development.[4] The gathering of R&D staff from different companies and universities has helped to form virtual networks among participants, which has stimulated innovation and encouraged idea exchanges, and to some extent has brought effects similar to those of physical network clusters. (Fan, 2003)

Torch Program

Initiated in 1988, the Torch program[5] aims to make technological development more market-oriented and facilitate commercialization of technology. Sponsored by the State Science and Technology Commission, the main tasks of the Torch Program include:

1. Develop a favorable environment for high tech industry.
2. Set up high-tech zones and high-tech business start-up service centers.
3. Execute Torch projects in seven high-tech industries mainly geared towards the market need.

[2] Source: www.863.org. 2003. "History of 863".
[3] Basic research aims to search for new knowledge for radically new marketable products and pure science searches for intrinsic knowledge.
[4] For a detailed description of R&D categorization, please see the paper "New Classification of R&D for International Comparisons (With a Singapore Case Study)" by Amsden, Goto and Tschang (2000).
[5] Source: http://www.chinatorch.gov.cn/

4. Facilitate international cooperation of Chinese firms in high-tech industries.
5. Train high-quality human capital.

3.2 Balancing Import of Technology and Indigenous Development

Japan

Japan has extensively used imported technology for its industrial development. However, the Japanese government has also strived on promoting indigenous technology development. It is the effectiveness usage of both approaches that has enabled Japan quickly improving technological capabilities.

Japan has established socio-cultural systems which enabled Japan's smooth and effective assimilation of the imported technology. Before the World War II, the technology development in Japan was principally based on introduction, adoption, assimilation and development of western technology selectively into the Japanese social and cultural system without spoiling the indigenous culture, ever since the Meiji period (1868-1912). Post-war technological innovation in Japan relied heavily on imported technology and it was one of the factors that brought about high growth to the Japan's economy. For instance, a study conducted in 1961 reported that contribution made by imported technologies to sales were twice as great as the contribution made by domestic technologies. (Sumiya, 2000)

Why Importing Technologies?

Three major factors contributed to the prosperity of the technology imports of Japan. First, this is a long-held policy by the government since the Meiji Restoration to discourage foreign ownership of productive assets in Japan. The government fear that it would eventually lead to economic colonialism by Western countries. The government "assisted Japanese industrial corporations in locating advanced technology abroad and even in negotiating licensing agreements with foreign licensors. Foreign exchange allocations were also made available on a preferred basis to Japanese licensees importing advanced technology"(Hirono, 2001, p. 161). Second, Japanese companies generally view purchasing foreign technology and pay royalties under licensing agreements is much more economical than to develop new technology through their own research and development effort, especially for firms in the industries with very short product cycles. Third, the available well-educated and well-trained engineers and technicians of the Japanese corporations can quickly master imported technology, adapt to specific requirement to Japan and even develop new technology from these imports. (Hirono, 2001)

Policies in Indigenous Technology Development

Nevertheless, the policy makers (MITI) were fully aware Japan's excessive dependence on foreign imported technology. The Industrial Technology Agency published two papers in 1949 and 1950. The Technology White Paper in 1949 ("The Present Conditions of Industrial Technology in Japan") was published in 1949 and it stressed the importance of technological development. In 1950, the "Research White Paper in 1950" ("The Present Conditions of Experimental Research in Japan") was published. The 1950 white paper focus on promoting technological development and focused on private investment in research and development (R&D).

Four measures were listed as specific tasks of technology policy: (1) maintaining a balance in experimental research activities, (2) providing subsidies for experimental research in mining and manufacturing technology, (3) establishing a special corporation to supply needed funds for industrial applications of technology, and (4) developing special tax measures to support private experimental research. (Sumiya, 2000)

One of the powerful policy instruments that were exercised by the state is the control of import of technology. The import of technology (through technical licensing agreements) was screened and approved or disapproved based on whether it meets the three criteria (contributing to Japan's international balance of payments, being conducive to the development of key industrial or public utilizes, and being necessary for the continuation or renewal of technical licensing agreements relating to key industries or public utilities).

China

In the 1990s, to promote technology development within and outside, and engage in technology transfer with the outside world, China designed "Technology Contract Law," which later merged with two other laws and became "Economic Contract Law." This law became internationally acceptable and recognizable. Recognizing that import of foreign advanced technology is the key factor in its economic growth and technology exports, China initialized a series of reforms to adopt a fairly liberalized trade policy for importing highly sophisticated and advanced technology. China expanded technology imports in essential sectors such as energy, transportation, telecommunication, petroleum, chemicals, raw material, and some high-tech areas: switchboards, microelectronics, aircraft manufacturing, space technology, and nuclear energy. From 1978 to 1998: china signed 27,875 contracts ($104.97 billion) for technology imports. Just in 1998, 6000 contracts were signed ($6.5 billion). (Kanungo, 2001)

China's technology export, an indicator for successful indigenous development of technologies, was achieved only in the late 1990s. By the end of 1999, China had exported 9,198 technological items to more than 100 countries, with the contractual volume amounting to $28.22 billion. China's technology export started from mere transfer of software technology and now progressed to complete sets of equipment, high-tech products and technical services. In 1998, China signed 2,500 contracts for technology exports ($6.69 billion). (Kanungo, 2001)

As mentioned before, high-tech export can be viewed as a direct indictor as economic benefits for technological progress. China's high-tech export increased more than 10 times within 10 years from 1992 to 2001 (US $49 billion); in 2003, China's high tech export has reached 110 billion dollars, accounting for 25% of the country's total exported goods; while in 1992 high-tech products only accounted for 5% China's overall exports (WDI, 2003). It is worth mentioning that high tech products suffered very little during the Asian financial crisis (export generally was hit badly), rather maintained steady and rapid growth (Kanungo, 2001).

What has contributed to the rapid growth of the high-tech export, then? The rapid growth of export is due to China's policy of "enhancing trade by relying on science and technology" and efforts from government agencies, especially Ministry of Foreign Trade and Economic Cooperation (MOFTEC). MOFTEC used the strategy of revitalizing trade through S&T: importing foreign technology to develop a wide range of hi-tech products and enterprise matching the international standards and competitiveness. Two other ministries worked jointly with MOFTEC in creating a series of initiatives to promote foreign trade through S&T: Ministry of Science and Technology (MOST) and Ministry of Industry (MOI). They have placed an emphasis on developing high-tech products for export and upgrading tech level of traditional export, especially for sectors such as information technology, biomedicine, consumer electronics, and household electrical appliances. (Kanungo, 2001)

Various department and government agencies connected with foreign trade also extended full-support to hi-tech enterprises, from granting import and export powers, to holding exhibitions abroad, training human resources in foreign trade and marketing abroad, encouraging foreign funding for manufacturing capital, to providing information on high tech products and technologies through established information service centers. To promote China's hi-tech products, the government has also organized exhibition of Chinese high-tech products to the international market through fairs. For instance, from 1999, International Hi-tech Achievements Fair has been held in Shenzhen each autumn. Beijing International Hi-tech Industries week is held in May each year. (Kanungo, 2001)

Some author (Kanungo, 2001) emphasized the importance of foreign direct invest (FDI) in creating and promoting export-oriented production because FDI helped to prompt wealth to R&D and facilitate the intellectual property (IP) law. However, I argue that the indigenous technology development effort made by the domestic enterprise is essential to China's technological capability development and the growth of the technology export. All other players-the government, the concerned agencies, R&D, HR-only added the strength of the domestic enterprise to perform well in technology export.

My study on domestic firms of China's information industry (Fan, 2003) has proved that innovation capability and self-developed technologies have been the key to Chinese domestic firms' catching-up with the multinational companies (MNCs) and have determined who are the leading domestic firms in these industries. First, simple regression analysis confirms that strong innovation capability contributes to companies' leadership and heavy R&D spending accounts for leading companies' high revenue and profit in the telecom-equipment and PC manufacturing industries. Second, the cases confirm that innovation capability and self-developed technology are crucial for starting and growing a high-tech company in China. The leading telecom-equipment manufacturers all developed small-scale digital switches and used them as a main source of income initially. The leading PC manufacturers all started their companies with self-developed technology--Chinese language add-on cards (Legend Chinese add-on card and GW 0520 card for Legend and Great Wall, respectively) and the fourth-generation electronic publishing systems for Founder. During the later stages, telecom-equipment manufacturers entered into other sub-sectors through self-developed technologies, such as access equipment, transmission equipment, routers, and switches. Domestic PC producers have caught up with the MNCs by making PCs with the most technologically advanced components rather than just seeking a low-cost advantage. Legend initiated a market war in the middle 1990s by advertising the most advanced PC in China at the time. Founder's one-decade monopoly position in electronic publishing was maintained by its continuing innovation. In the domain of cell-phone production, TCL's jewelry phone (a totally innovative product concept), Haier's firewall phone, and Hisense's self-developed CDMA and color-screen phones all brought market success to these companies. Their successes only underscore the importance of self-developed technologies.

3.3 Engaging the Business Sector in R&D Development

Japan

Another characteristic of Japan's development of technological capability is to engage both the public and the private sectors. As mentioned above, the Japanese government played a crucial role in developing Japan's technological capability from various perspectives. For instance, MITI's action falls into four main categories and are to ensure private sector as well as public sector's participation. These actions range from providing incentives (R&D program, financing), to stimulating R&D activities (R&D consortium), to using regulation to encouraging and protect innovation, to facilitating dissemination of the innovation (diffusion, transfer, demonstration, public procurement).

For instance, during 1963-1970 (Sumiya, 2000), MITI developed programs to aid the development of technology in the private sector:

- Subsidies for R&D expenditure for important technology
- Tax incentives for R&D and facilities required for commercialization of new technology,
- Indigenous technology promotion financing (Japan Development Bank loans)
- Mining and manufacturing technology research association.

Table 3.4 listed stimulation of R&D activities initiated by the private sector. The activities have a wide range, from direct financing to indirect tax incentives, from R&D on fundamental technology to conditional loans for specific R&D. It also reflected the government's policy in terms of sector priority. For instance, the 1980s conditional loans focused on energy R&D for oil substitution and new power generation.

Table 3.4: Stimulation of R&D Initiated by the Private Sector

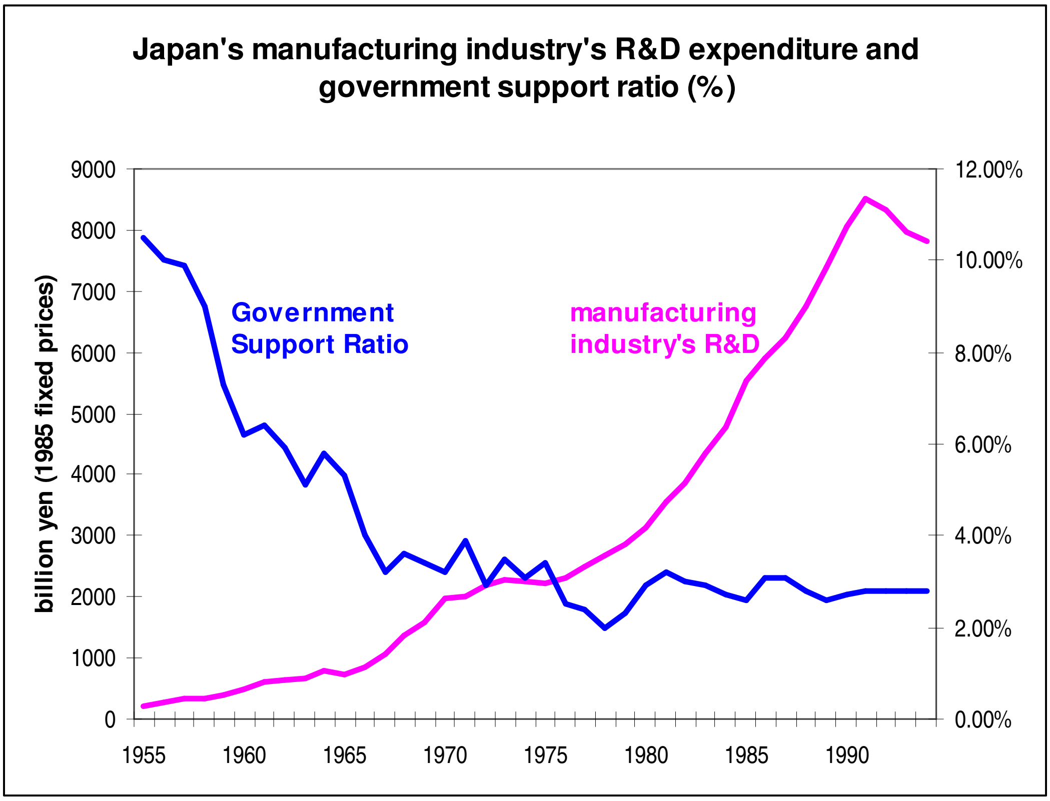
Period	Activities
1951-	Financing for Industry's New Technology
1967-	Tax Incentives for Technological Development
1980-	Conditional Loans for Energy R&D (oil substitution)
1981-	Conditional Loans for Energy R&D (new power generation)
1985-	R&D on Fundamental Technology (investment/financing)
1988-	International Joint Research Grant Program
1993-	Conditional Loans for Energy R&D (rational energy use)

Source: Watanabe, 2003.

These technology polices resulted research expenditure of private companies increased from 184 billion yen in fiscal year 1960 to 1.195 trillion yen in fiscal year 1970, i.e., 1.15% to 1.63% of GNP and the consequent narrowing gap between Japan and the advanced nations. Japan's technological capability is also closely related to private companies such as Sony, Mitsubishi, Toshiba, etc.

A closer look at Japan's manufacturing R&D expenditure further reveals that business sector has been the driving force for Japan's high R&D expenditure (Figure 3.1). Government support has dropped from 10% to less than 3% of the total funding.

Figure 3.1: Japan's Manufacturing R&D Expenditure and Government Support Ratio (%)



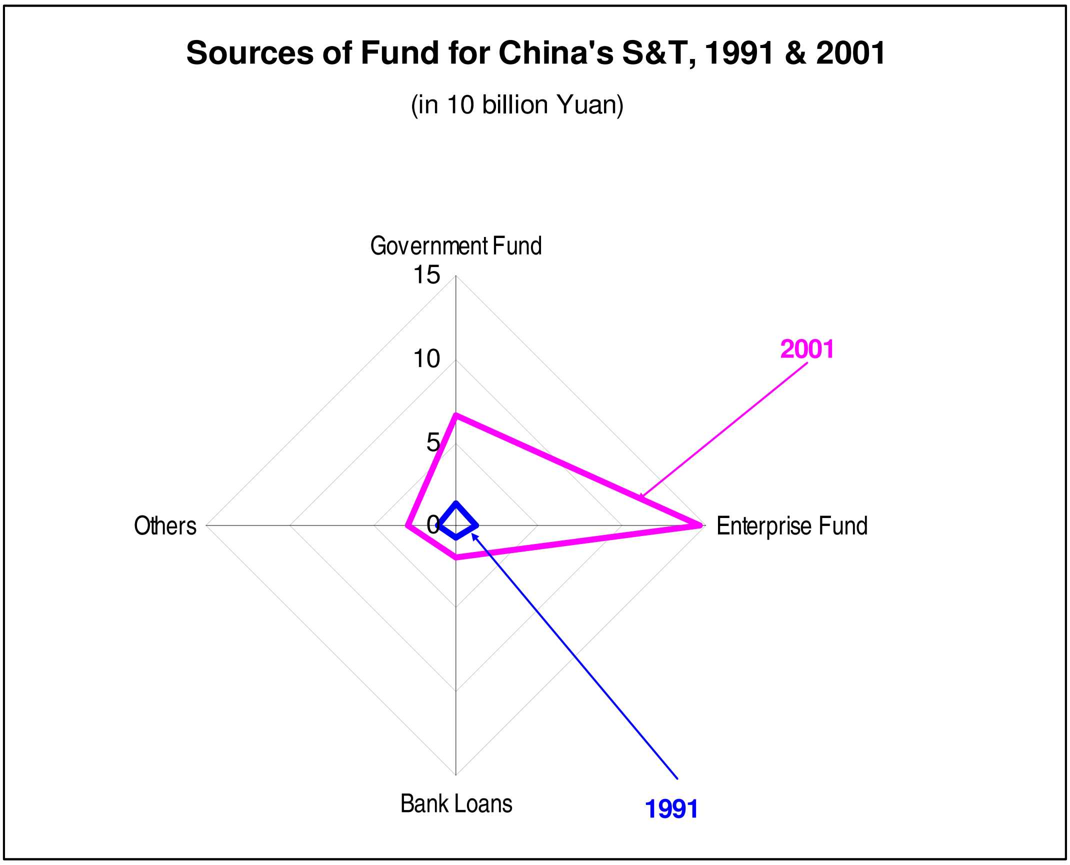
Source: Watanabe, 1999. (Table 4).

China

Enterprise fund of S&T and R&D expenditure both increased dramatically, which reflects that Chinese enterprises became much more involved in S&T activities and is the driving force for China's S&T activities.

For instance, China's S&T funds increased more than 6 times, from 42 billion Yuan in 1991 to 258 billion Yuan in 2001 (Figure 3.2). Among the major sources of the fund, enterprise fund increased more than 10 times and contributed to more than half of the total fund (56%), while both government fund and bank loans increased in absolute amount, they decreased relatively and contributed only 25% and 7% of the total fund.

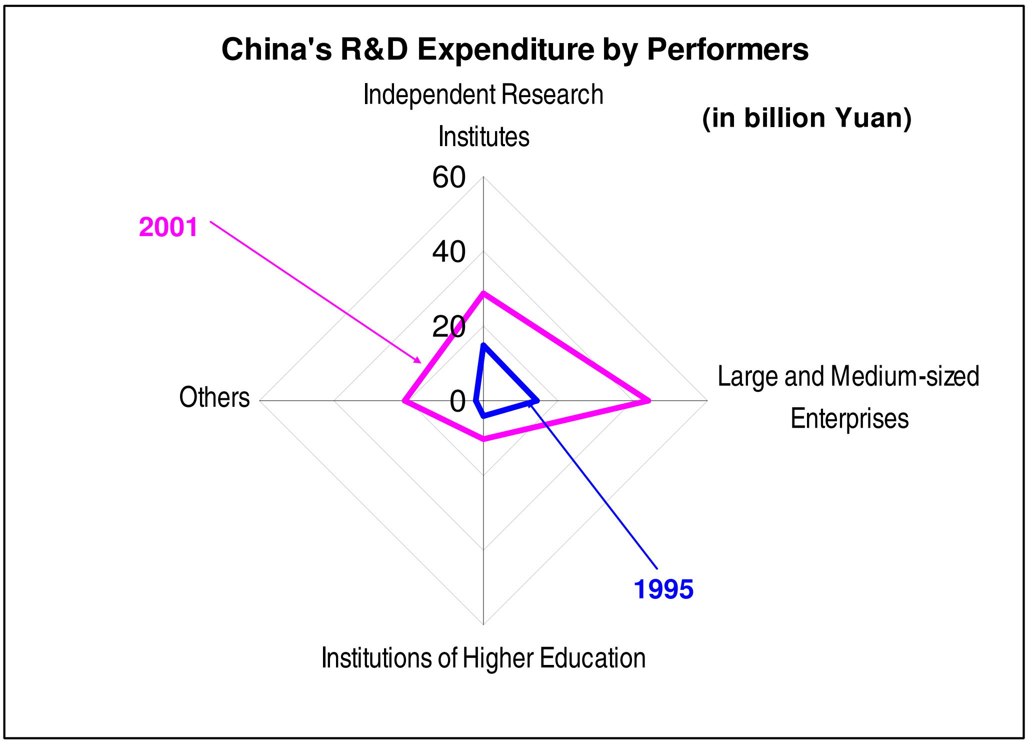
Figure 3.2: Source of Fund for China's S&T, 1991 & 2001



Source: the author summarized based on data from "China Statistical Yearbook on Science and Technology, 2003", p.6, Table 1-5.

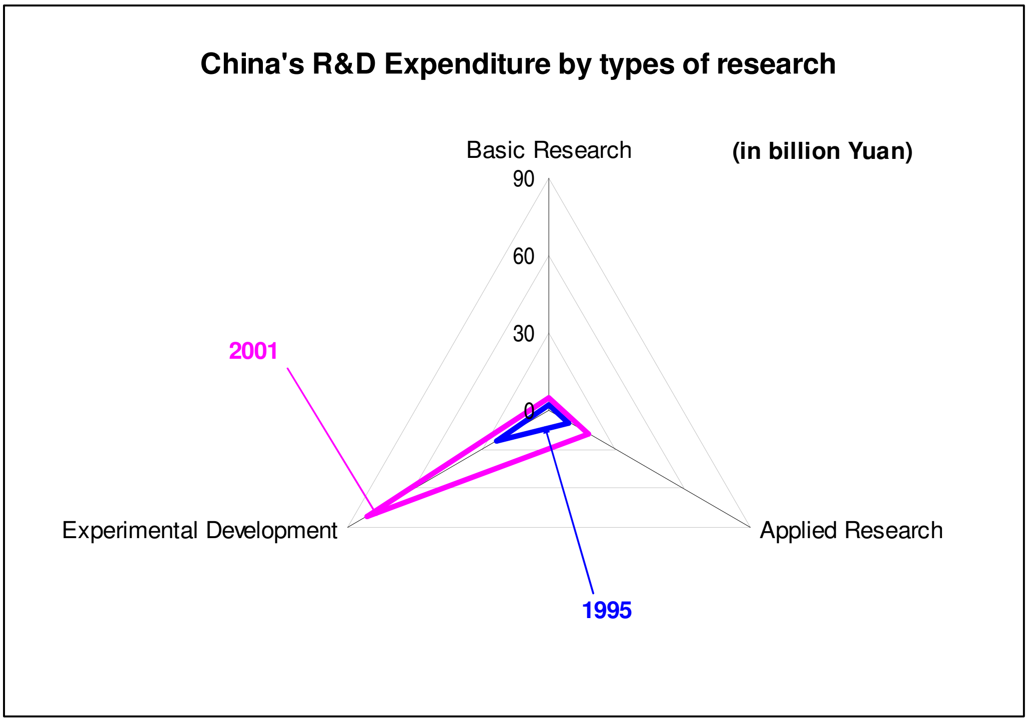
R&D denotes more specifically for innovation creation, R&D has a much narrow sense than S&T. China's R&D expenditure was slight less than half of the S&T expenditure in 2001. Corresponding to enterprises active involvement in S&T funds, they, especially large- and medium-enterprises, were the major spender of the R&D expenditure as Figure 3.3 illustrated. From 1995 to 2001, large- and medium-enterprises increased their R&D spending from 14 billion Yuan to 42 billion Yuan, which was 42% of the national R&D expenditure. Figure 3.4 illustrates the R&D expenditure by types of research. Not surprisingly, experimental development became the dominant research type in terms of expenditure (81 billion Yuan), applied research expenditure almost doubled (18 billion Yuan), while basic research expenditure was kept almost the same (5 billion) in 2001, compared with 1995. This matches the general trend which moves towards product/process level R&D that enterprises are mostly concerned about.

Figure 3.3: China’s R&D Expenditure by Performers



Source: the author summarized based on data from "China Statistical Yearbook on Science and Technology, 2003", p.7, Table 1-7.

Figure 3.4: China’s R&D Expenditure by Types of Research



Source: the author summarized based on data from "China Statistical Yearbook on Science and Technology, 2003", p.7, Table 1-8.

3.4 National Innovation System

How to improve one's national technological capability has been a concern by many policy makers. Among the discussion of the best practice, the concept of national innovation system (NIS) is the most widely adopted approach because of its systematic and dynamic perspective of actors in the systems and actions performed by them.

Since the 1980s, researchers start to realize that national production of new technology is not something only related to firms, but to a system of firms, government, and universities. They use the NIS to refer this complicated system. NIS is the interactive system of existing institutions, private and public firms, universities and government agencies, aiming at the production of science and technology (S&T) within the national boundary. (Freeman, 1982; Dosi et al., 1988; Lundvall, 1992; Nelson, 1993)

NIS performs five fundamental activities which extend beyond the R&D system and include important inputs for research activities as well as the use of research output. These activities are: (1) research (basic, developmental, and engineering), (2) implementation (manufacturing), (3) end-use (customers of the product or process outputs), (4) linkage (brining together complementary knowledge) and (5) education.

With the description of the elements in the NIS, it is obviously impossible to put every element in equal position. How should a country set its own national priorities so that its policies and projects targeted at improving technological capability will be most effective and most beneficial for its overall national development goals? The following paragraphs offers experience from Japan and China.

Japan's NIS

Japan's National Innovation System has four essential groups of actors that carry out the basic NIS functions: the central government, the firms, the social innovations (inter-firm organizations), and the educational innovations. Here I focus on how these groups' activities have contributed to the development of Japan's NIS.

The Japanese educational and training system

Japan has a high-skilled labor force, reflected by its high education of the population. Japan has about 100% school enrollment for its primary and secondary schools. The tertiary school enrollment was about 20% in 1970s, 30% in 1980s, and 40% in 1990s. In 2000, Japan reached 47% of tertiary school enrollment. (World Bank, 2003)

In addition to its highly developed educational system, it is well-known that Japan's employment system has contributed greatly to the training of the workers for specific skills required for their jobs. It may related to the well know long-term employment system of the large companies. This phenomenon also fits into the Japanese view of technology that "skills" fundamentally resides in people (National Research Council, 1990).

R&D and its implementation

Japan's R&D spending consists mostly from corporations' R&D spending. It is worthy mentioning that this is a gradual process, for instance, the business enterprises contributed 72% to R&D spending in 1980 and this figure was increased to 80% in 1988. Cooperation between firms is stronger in Japan than in most other nations, although the role of the universities should not be underestimated. Japanese Keiretsu (conglomerate or network firms) is situated at the center of the networks of firms, leading the frequent interaction between the firm and its suppliers and subcontractors, concerning about product development, processes, and various aspects of innovation. (Tremblay and Rolland, 1998)

In addition, R&D consortia organized by the Japanese government has played an essential for Japan's technology catching up in the 1970s and 1980s and the creation of new knowledge in the 1980s and 1990s. Japanese firms, research institutes, and universities interact with each other through the defined objective of the consortia. The consortium provides not only training for their young researchers, but also opportunities to communicate and exchange which is difficult under the long-term employment system of large companies. (National Research Council, 1990)

The State

The central government mainly involved infrastructure provision, public investment in R&D which facilitate diffusion, and informal consultations between the sate and companies via MITI (for example, the exchange personnel between MITI and various companies).

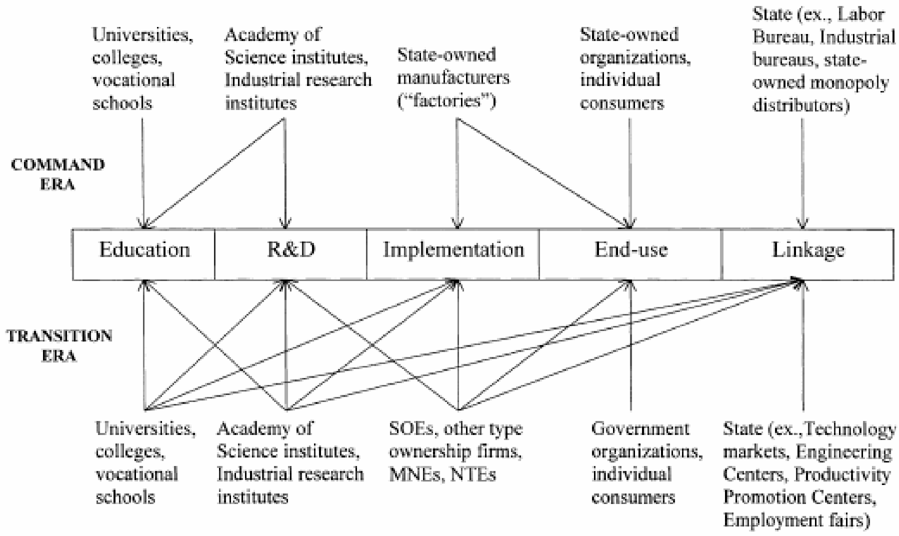
In the post-war era, the government formed different sets of industrial policies at different stages of the country's development and mobilized all available resources to reach their policy goals. In each decade, Japanese government identified the key sectors of the industrial development. The technological capability development was centered on those key sectors and the R&D projects initiated by The Ministry of International Trade, and Industry (MITI) clearly shows the correspondence. The R&D consortia mentioned above is fundamentally sets of government initiated R&D activities.

China's NIS

What caused the dramatic increment of these two indicators for the Chinese enterprises, then? A close look at the organization of China's national innovation system and its reform will provide some insights.

Corresponding to the improvement of the technological capability is the transitioning of China's national innovation system. China's innovation systems under central planning system and since the reform can be illustrated as Figure 3.5. The most conspicuous change of China's NIS is the expansion of the primary actors and the much horizontal involvement of the primary actors since the reform. For instance, in addition to State-owned manufacturers (SOEs), other ownership-types of firms, such as multinational enterprises (MNEs), national technology enterprises (NTEs), also joined as primary actors falls into the classification of firms. Before the reform, primary actors involves only one or at most two fundamental activities of the NIS. Now they have expanded to more activities. In the command era, universities were only involved in only education, but it has expanded activities in almost every perspective of the national innovation system. Academy of Science institutes and industrial research institutes have had the similar expansion.

Figure 3.5: Distribution of Activities and Primary Actors in China's Innovation System under Central Planning and since Reforms



Source: Liu and White, 2001.

China's NIS reform has focused on its R&D system. After the culture revolution, rehabilitation and expansion of R&D system were put into practice (1978-1980). From 1981 to 1985, R&D planning practice was further elaborated. Since 1985, there is consensus about market reform decision for R&D system and thus three steps were taken to into action in the following decade. First, R&D institutes were advocated to merge into existing enterprises (1987). Further, from 1988, spin-off enterprises from the research institutes have been encouraged and the Torch Program were started to offer incentive for commercialization of the R&D result (establishing new technology enterprises). In the 1990s, the government started to focus on the base of the R&D system, transforming the established R&D institutes.

The merging R&D institutes into the existing enterprises turned out to be a failure because of the inability of the enterprises both in terms of supporting R&D institute financially. Further, the R&D institutes were backward in technology comparing to other means that are available for the enterprises to get their technology. On the other hand, spin-off new technology enterprises have turned out to be very successful, especially in the field of computer technology. The direct transformation of the R&D institutes is much comprehensive package of system reform. In addition to the spin-off new technology enterprises, R&D institutes were also encouraged to establish production center and consultancy center that directly involved in the economic activities.

IV. Using ICT as A Tool to Develop Technological Capability

4.1 Why ICT?

The importance of information and communication technology (ICT) to a country's economic growth, especially to the development of its technological capability are mainly two folds: first, the ICT sector is one of the most important high-tech sectors where innovation constantly emerges; second, the degree of ICT infrastructure significantly influences the overall knowledge creation, codification and transmission of a nation.

Corresponding to its sector dynamics in innovation, the ICT sector is one of the leading sectors in terms of R&D effort.[6] A glance of major companies' R&D spending as a percentage of revenue from different sectors reveals that large ICT multinational corporations (MNCs) champion in R&D effort. For instance, large telecom-equipment MNCs had an average global R&D spending of 15% of sales revenue, with Cisco, Ericsson, and Nortel as leaders (21.4%, 20.1%, and 18.7%, respectively) and Siemens and Nokia as distant followers (7.8% and 9.6%, respectively). (Fan, 2003)

Further, the role of the ICT infrastructure has been recognized in knowledge creation, codification, and transmission (Mohnen, 2001). ICT constitutes the infrastructure for global innovation network. Evidence from Mohnen's study indicates that ICT is important in embodying new technology, as production and commerce more and more takes place electronically.

ICT has also been recognized by the United Nations that it "cut across all sectors and have enormous potential for accelerating progress towards achieving the MDGs (Millennium Development Goals" (CSTD, 2004, p. 9). It could be powerful tools in increasing productivity, generating economic growth, enhancing access to health care and health information, facilitating government operations and services, improving access to education and training, and improving the quality of life of all.[7]

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[6] The five high R&D sectors (electronic & electrical, health, IT hardware, pharmaceuticals & biotechnology, software & IT services) account for almost 60% of international 700 R&D (top 700 companies with 34 million pound as R&D in 2003)and all are dominated by the USA except for electronic & electrical where Japan leads and the US is third behind Germany. (http://www.innovation.gov.uk/projects/rd_scoreboard/introfr.html)

[7] Declaration of Principles, "Building the Information Society: a global challenge in the new Millennium" WSIS, http://www.itu.org/wsis

4.2 ICT Industrial Development

Japanese ICT Firms

Japan's ICT companies, such as Sony, Hitachi, Fujitsu, NEC, Matsushita, Mitsubishi Electronics, were perceived as posing a significant competitive threat to their western competitors. However, now they are perceived as being in a state of crisis and decline. What has caused the change? What are the opportunities and challenges facing the Japanese ICT companies?

The US has been the main location for dynamic improvement in the computer and communication industries. This reality pushed the Japanese firms to concentrate in the Japanese market, which brought two negative effects: (1) Japanese firms in general are very vulnerable to the economic performance of the Japanese economy; (2) Focusing on Japanese market tend to make them diverge from other global market in terms of standards, such as PCs and microprocessors, and some telecommunication equipment. Externally, Japanese ICT firms have been affected negatively by the three crises: the economic and financial crises that followed the "bursting of the bubble economy" in the early 1990s, the Asian financial crisis occurred in the mid-1997, and the collapse of semiconductor prices, particularly DRAM memories. (Fransman, 1999)

Despite the stagnant performance, Japan has kept a large percentage of global electronics production. For instance, in the 1990s, it kept around 20% of the global electronics production, while all Asia kept around 40%. (Wong, 2002)

As these three crises are resolved and growth is restored in Japan and Asia, profitability of Japanese companies is predicated to improve. Japanese ICT firms' future will be primarily determined by international competitiveness, which depends largely upon the R&D capabilities possessed by the firms. It is predicted that Japanese firms will be able to benefit from their largely unaffected R&D capability to regain their position. (Fransman, 1999)

China's ICT Industrial Development

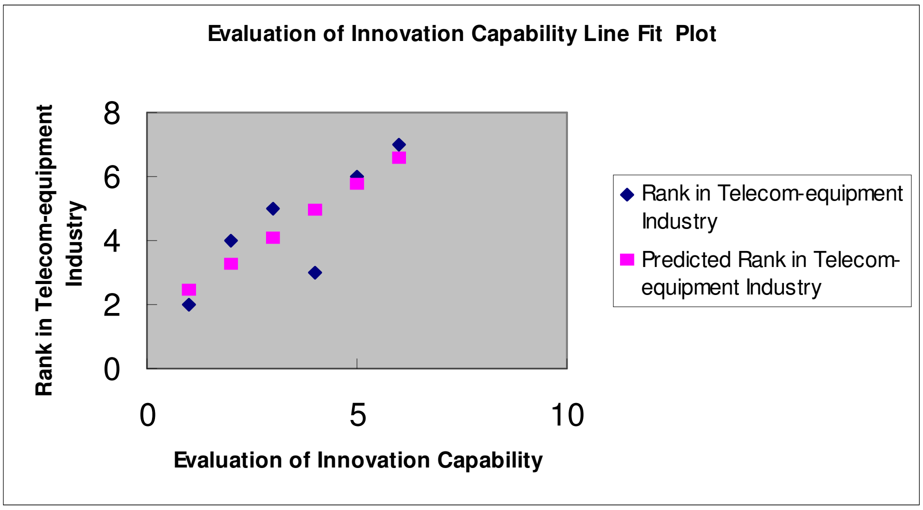
Overall, China's electronics production (including computer products, communication equipment, and electronic components) increased 4.4-fold from US$7.6 billion in 1987 to US $33.4 billion by 1996, achieving an annual growth rate of 17.9%. The world production increased 1.9-fold during the same period, with an annual growth rate of 7.6%. China's share of the world production rose from about 1.4% to 3.1%. (Meng and Li, 2002)

Even with a narrow definition of electronic industry, the contribution of the electronics industry to GDP has increased from 0.69% in 1993 to 1.66% in 1997, an increase of 140%. (China's Yearbook on Electronics Industry) (Meng and Li, 2002)

From the production side, the ICT industry can provide a country good chance to catch up because of its dynamic nature. East Asia's emerging economies such as Taiwan, Singapore, South Korea's catching up in the ICT industry, as well as India's Software industry's development all provides useful experiences for developing countries.

My recent study (Fan, 2003) on Chinese domestic firms in the ICT industry further provides insights how one can catch up by indigenous development of the technological capability. The study proves that innovation capability and self-developed technologies were the ultimate driving force that has enabled leading domestic firms to catch up with the MNCs in the telecom-equipment and PC manufacturing industries.

Figure 4.2: Rank in Telecom-equipment Industry vs. Evaluation of Innovation Capability Line Fit Plot



Source: Fan, 2003.

I adopted the liner regression model to investigate the relationship between "Leadership in the Telecom Equipment Industry" (dependent variable, Y) and "Rank in Innovation Capability" (independent variable, X) (Figure 4.2) (Fan, 2003). The regression analysis results of the six leading domestic telecom-equipment producers shows an R^2 value at 0.69, indicating that innovation capability has a strong explanatory power to leadership position of domestic firms in the industry. "Evaluation of Innovation Capability Line Fit Plot" of Figure 4.3 shows the strong correlation between "Evaluation of Innovation Capability" and "Rank in Telecom-equipment Industry."

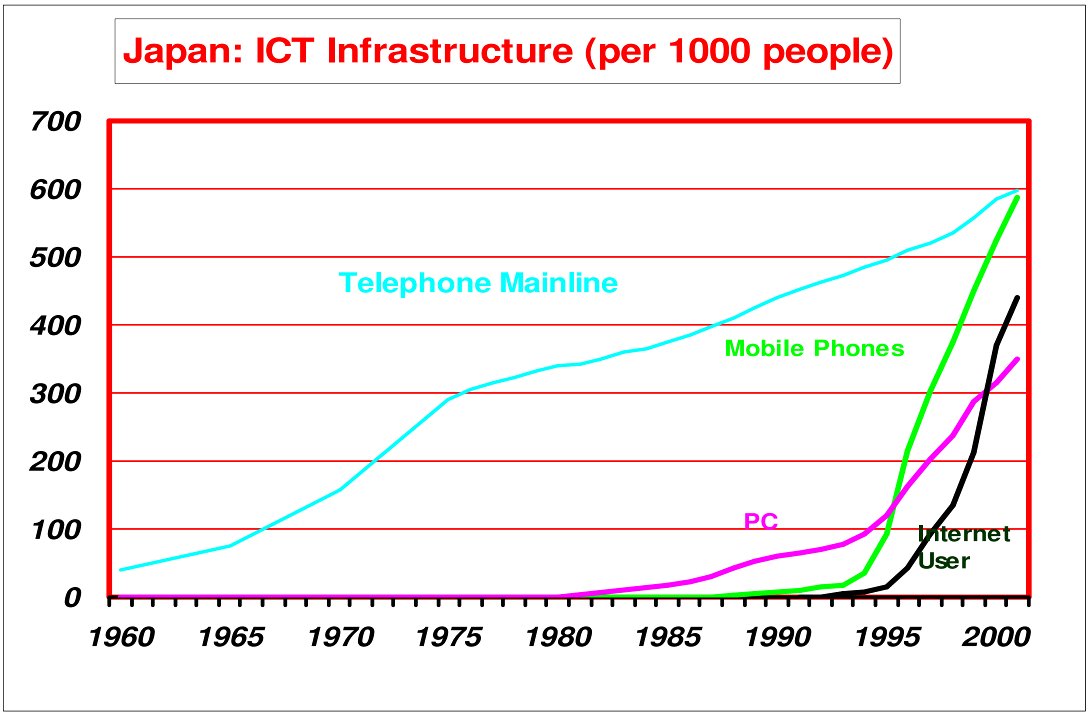
4.3 ICT's Contribution to Economic Growth

A country's ICT infrastructure is generally measured by the following indicators:

- Telephone mainline (per 1000 people)
- Mobile phone (per 1000 people)
- Internet host or internet users (per 1,000 people)
- Personal computers (per 1000 people)

Japan has a very well-developed ICT infrastructure, which leads the world now days. For instance, 60% of its population owns mobile phones, and 45% and 35% of its population are internet users and have personal computer, respectively. As we can see from the above figure, Japan's ICT infrastructure has a tremendous growth from 1995 to 2000 in terms of mobile phone subscriber, PC, and internet user per 1000 people. (Figure 4.1)

Figure 4.1: Japan's ICT Infrastructure (Per 1,000 People)



China's ICT infrastructure has experienced explosion over the past decade, as Figure 4.3 indicates, PC and internet users have grown from 0% to 2%, while mobile phone and telephone mainlines have significantly grown from 0% to 11% and less then 2% to 14%.

Figure 4.3: China's ICT Infrastructure (Per 1,000 People)

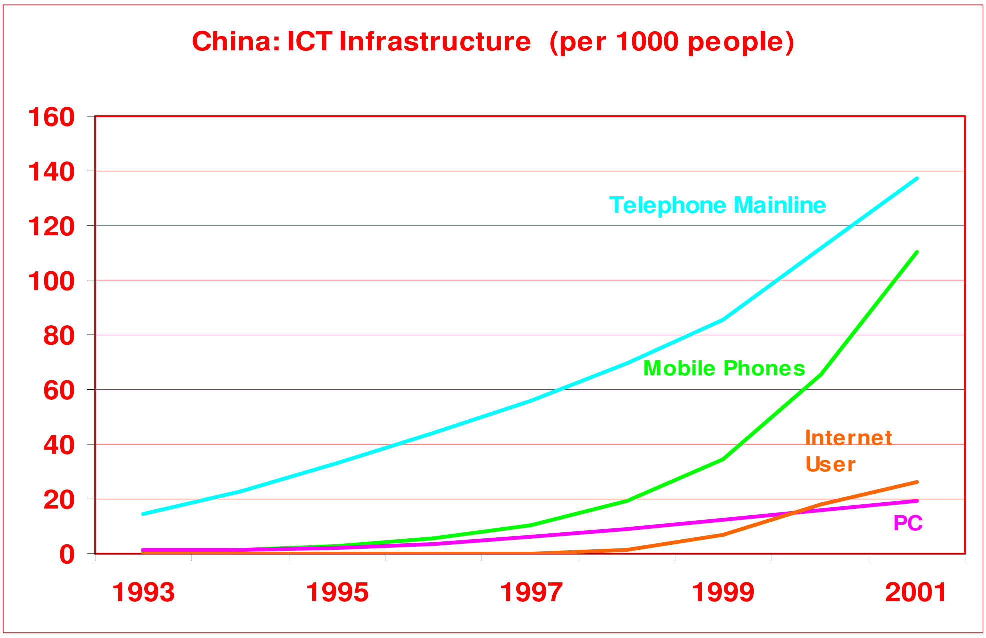


Table 4.1: ICT Infrastructure of Selected Countries, 2001 (Per 1,000 People)

Country Name	Telephone mainlines	Mobile phones	Internet users	Personal computers
China	137	110	26	19
France	573	605	264	337
Germany	634	682	374	382
India	38	6	7	6
Japan	597	588	440	349
Kenya	10	19	16	6
Korea, Rep.	486	621	515	256
United Kingdom	588	770	408	366
United States	667	451	501	625

Source: World Bank. 2003. World Development Indicator CD-Rom.

Table 4.1 provides a quick comparison of ICT infrastructure of countries at different development state. Overall, US and Japan lead in ICT infrastructure. China's ICT infrastructure is much more developed than other developing countries. India, surprisingly has a very low penetration level of ICT infrastructure, except telephone mainlines, it falls behind Kenya in terms of mobile phone users, internet users and personal computers per thousand people.

Decomposing economic growth to several inputs (one of which is the ICT capital input), we can examine how much ICT capital actually contribute to the output growth. Over the past two decades, ICT has contributed between 0.2 to 0.5% per year to economic growth of nine OECD countries (Australia, Canada, Finland, France, Germany, Italy, Japan, the United

Kingdom, and the United States). During the second half of 1990s, this contribution rose to 0.3 to 0.9% per year. (Colecchia and Schreyer, 2002)

Table 4.2 Percentage Point Contribution of ICT to Output Growth (Business Sector)

Japan			
Period	Growth of Output	Total Capital Service	Total ICT
1980-1985	3.31	1.1	0.18
1985-1990	5.14	1.5	0.3
1990-1995	1.33	1.49	0.31
1995-1999	1.1	1.07	0.38
US			
Period	Growth of Output	Total Capital Service	Total ICT
1980-1985	3.35	1.25	0.44
1985-1990	3.31	1.1	0.43
1990-1995	2.64	0.97	0.43
1995-1999	4.43	1.69	0.86
Germany			
Period	Growth of Output	Total Capital Service	Total ICT
1980-1985	1.13	0.69	0.2
1985-1990	3.59	0.91	0.27
1990-1995	2.22	1.08	0.3
1995-1999	1.73	0.95	0.35

Source: Colecchia and Schreyer, 2002.

Table 4.2 demonstrated percentage point contribution of ICT to output growth of the last two decades of Japan, the US, and Germany. Not surprisingly, the US economy has benefited most from the ICT deployment. At the second half of 1990s, ICT capital accounted for 50% of the overall contribution of capital services to output growth. Japan's ICT, in comparison, has a lower contribution (about 35% of the overall contribution of capital services) to output growth. However, during the past two decades, its ICT contribution has been increased, from around 16% (1980-1985) to 35% (1995-1999).

The ICT infrastructure has brought tremendous benefits for China's economic growth, as well as China's knowledge creation, codification, and diffusion, which is much harder to evaluate in the short term, but it will affect a country's technological capability in the long term.

I would like to offer another example to demonstrate the benefits brought by the development of ICT infrastructure. China leads other countries (except the US) in number of hits of the MIT Open Course Ware website, a famous on-line website that publishes MIT's courses free for all. (Table 4.3)

Table 4.3: Top 15 User Countries (Outside of the US) of MIT Open Course Ware

Geographic Region		# of Hits
1	China	13,048,000
2	Canada	10,651,000
3	United Kingdom	7,965,000
4	Germany	6,774,000
5	Brazil	5,834,000
6	India	6,448,000
7	Japan	5,445,000
8	France	5,224,000
9	South Korea	5,119,000
10	Spain	4,231,000
11	Taiwan	3,847,000
12	Italy	3,702,000
13	Australia	3,074,000
14	Singapore	2,351,000
15	Greece	2,216,000

Source: MIT Open Course Ware. Website: http://ocw.mit.edu/index.html.
Note: Web hits as of December 31, 2003.

V. Main Findings and Policy Implications

(1) Developing countries must be aware that the government plays an essential role in developing technological capability of the country. The government provides long-term vision, coordinates different partners, and ensures the healthy domestic environment for creation of knowledge and the usage of knowledge for socio-economic development.

Both the Japanese and Chinese governments have made serious effort in fostering the improvement of Japan and China's industrial technological capability, which contributed considerably to their economic growth. The Japanese government started much earlier than the Chinese government-since the early Meiji period (1868-1890). Its Post World War II involvement through Ministry of International Trade and Industry (MITI) covers a much larger range of activities, with specific focus of key sectors during various decades.

The Chinese government started its national innovation system reform in the 1980s. It took the government several tries to find the relative successful approach for reforming the R&D system. The government has also implemented two large-scale distinguished national S&T programs-the "863 Plan" and the Torch Program-that aim to foster high-quality fundamental research and to facilitate the commercialization of technology. The State Council's "Decision on Accelerating S&T Development" in 1995 has boosted the country's R&D spending, and consequently, the technology progress has contributed significantly to the nation's economic growth in the second half of the 1990s.

(2) Policy makers need to be aware that tools, options, and opportunities existed for their country to improve the technological capability and strive for the localized option that fits the country's development stage.

As Japan and China's experience illustrated, the process of improving technological capability is a complicated matter. Developing countries government should consider policy options within the country's socio-economic context. Japan's creative R&D institutions such as R&D consortia t are unique and were catered to Japanese culture to forge linkages between various R&D partners. Similarly, the reform of China's national innovation system attempted to change China's Soviet style R&D system.

Just as what China has experienced, it is almost guaranteed that the first step of the reform will not lead to the success, yet the failure of the earlier stage leads to success at the later stages and one has to continue trying.

(3) To facilitate the development of technological capability, developing countries should utilize both import of foreign technology and indigenous development.

Import of foreign technology can be a short cut for short-term technological capability improvement, however, a more long-term approach should be focusing on developing capability through building up its own stock of human resources, which reflect by its ability to absorb, and redevelop imported foreign technology as well as indigenous development of technology. Japan benefited greatly from both imported technology and indigenous development. It is well known that the Japanese workers are probably the best educated workers in the world. They not only absorb the imported foreign technology, but also improve and redevelop them. However, since the 1960s, MITI focused on promoting indigenous technology development through policy tools such as the control of import of technology. In China, technology import and indigenous development go hand in hand. The rise of the domestic firms in the ICT industry proves the importance of self-developed technology.

(4) To make the best use of the technological capability and effectively promote the improvement of technological capability, developing countries' government should engage the business sector in R&D development.

Many developing countries have a weak market mechanism and have an underdeveloped business or private sector. This poses challenge to the government, developing market mechanism and technological capability should be hand in hand. Both Japan and China's experience indicate that business sector should be a major source of innovation. For instance, Japan's MITI developed programs to aid the development of technology in the private sectors and China's reform in the 1980s focuses on pushing the enterprises being the driving force of China's S&T and R&D activities.

(5) Unleashing the power of ICT: Developing countries should utilize the unique opportunity provided by ICT industrial development and ICT infrastructure deployment to catch up economic development.

ICT is the main driving force of the so-called knowledge economy. There are clear evidences that the ICT industry has contributed tremendously to the economic growth of the developed countries (Kraemer and Derick, 2001; Jalava and Pohjola, 2002). However, it is not clear the role of ICT industry development for economic development in developing countries. Some developing countries are reluctant to encourage the development of the ICT industry concerning issue such as ICT's displacement effect of the low-skilled workers. Tough questions facing policy makers in developing countries include: (1) Can a developing country find competitive advantage in building its ICT industry? (2) Will ICT adoption and diffusion increase the pressure of unemployment? (Meng and Li, 2002)

Evidence from China's ICT industry development indicates that the industry is the most dynamic sector of the economy and there is fast improvement of domestic firms' technological capability. The rapid diffusion of the ICT infrastructure (telephone mainline, mobile phone, PC, and internet) has contributed to the knowledge creation, codification, and diffusion in general and forged the linkage of the China's knowledge network with the global knowledge network.

Since the ICT revolution is unavoidable, developing countries need to strategically think how it can best cope with it and take advantage of it rather than finding ways to escape. Some policy recommendations that use ICT to increase its technological capability include:

- In addition to increase its equipment stock of ICT, developing countries should also focus on building its own stock of ICT talents (knowledge in people)
- Finding alternative ways of financing ICT diffusion and adoption and ICT industry's deregulation
- Use ICT as a tool to achieve the millennium development goals (MDGs), including health, education, and poverty reeducation

VI. Conclusion

In this paper, I compared Japan and China's experience and analyzed how their technology policies have contributed to the industrial development and what developing countries can learn from their experience.

Numerical analysis proves that technological capability has contributed to Japan and China's economic growth, especially during the peak growth periods (from 1960s to the early 1990s for Japan and from the1980s for China, especially in the second half of the 1990s). A review of technology policies of both countries (from Meiji Period for Japan and from the 1980s for China) highlights the role of the government in promoting technological capability, the importance of balancing import of foreign technology and indigenous development, and the engagement of business/private sector as a major force for improving technological capabilities. The examination of the ICT production, adoption, and diffusion of both countries implies that ICT industry development and infrastructure deployment can greatly facilitate the development of technological capability.

The paper provides several policy recommendations to the developing countries. Developing countries should be aware of the important role of the government and the existing policy tools. They should strive for the localized option that fits the country's specific social-economic reality. Balancing import of foreign technology and indigenous development, as well as developing market mechanism that encourage private sector's engagement are two other important dimensions. Finally, ICT can be used as a powerful tool for increasing a country's technological capability.

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