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The Evolving Process of Color TV Mass Production Technology in China

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Introduction

Currently, there are two polarized views on Asia's economic growth. One is a positive view arguing that the 21st century will be "the Century of Asia", and that Asia will be the center of the world's economic growth, which is the mainstream. The other is a rather negative view which argues that "Asia's miracle", as P. Krugman[1] has put it, is a myth and Asia's economy will soon stop growing.

Taking up Singapore's economic growth as an example, Krugman discusses that Asian countries' economic growth has been created by the increased input of labor and capital, and there is little improvement in productivity by technical innovation. He concludes that Asia's economic growth will soon or later stagnate, because there is a limit to those inputs.

It is known that the growth rate ($\Delta Y/Y$: Δ is delta) of GDP (Gross Domestic Production: Y) can be obtained from capital stock (K), labor input (L) and total factor productivity (A) representing technical advance rate, in the following formula:

$$\Delta Y/Y = \alpha\Delta K/K + \beta\Delta L/L + \Delta A/A$$

Here, α and β vary from country to country. $\Delta K/K$ and $\Delta L/L$ are increases in labor input and in capital input, respectively. $\Delta A/A$ is an increase in total factor productivity (TFP), or technical advance rate. For the succeeding discussion, it should be noted that improvement in productivity due to the use of capital goods, such as sophisticated machinery, is also included in the increase in TFP. How TFP can affect GDP in developed countries can be seen in the examples of Japan and the U.S.. Japan's average annual growth rate of GDP from 1970 to 1989 was 4.8%, and contribution ratios of capital, labor and technical innovation to the growth were 2.9%, 0.3% and 1.5%, respectively. In the U.S., the average annual growth rate of GDP during the same period was 2.7%, and the contributions of capital, labor and technical innovation were 1.1%, 1.0% and 0.7%, respectively[2]. Technical innovation accounts for 30% of all factors contributing to the growth of GDP.

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This fact reminds us of A. Gerschenkron's theory of "advantages of least developed countries"[3]. He discussed that the least developed countries could achieve the most rapid economic growth because they could import state-of-the-art technology from developed countries. I. Nakatani[4] has extended this theory and contradicted Krugman's view, maintaining that it was "layered follow-up" and "a chain of information" that brought Asia's growth. He argues that first Japan imported advanced technology from the West and succeeded in ranking among developed countries. Then, NIEs (newly industrialized economies) imported production and management technology from Japan and succeeded in industrialization. Now, ASEAN countries, China and Vietnam are following them and developing most rapidly in the world.

Determination of which of these two contradicting views is relevant depends on how one assesses technical advances in Asian countries. That is, how technology, especially mass production technology, imported from developed countries has been assimilated by a country according to its social resources, and whether it continues developing to serve as a core of future technical innovation in the country.

This paper tries to elucidate the question through historical and exemplary analysis, using the formation process of Chinese color TV mass production technology as an example. China started color TV production with technology imported from Japan after the reform and opening policy in 1978, and grew into the world's production base within less than a decade. The method employed in the present study is different from the above-mentioned national economic viewpoint which evaluates technical innovation from TFP's contribution to economic growth. An argument without diagnostic analysis of how developing countries actually adopt foreign technology and how it stimulates technical innovation would be a house of cards. Moreover, as Gerschenkron has pointed out, developing countries become advantageous solely in large-scale production, and the government's initiative and guidance through institutional means play an important role in technical innovation. R. Minami[5] investigated the contributions of labor input, labor productivity and technical innovation to the increase in national income from 1952 to 1984 in China, and pointed out that the contribution rate of technical innovation was low because of the lack of human resources, low standards of engineering technology, irrational industrial organization, and immature machinery industry. H. Hoshino[6] pointed out that, in the case of China, the problem Krugman suggested would correspond to an inadequate management system.

Based on those arguments, Chapter I of this study discusses the relations between the result of correlational analysis of labor productivity and capital labor ratio, and changes occurred in imported production technology in a Chinese TV maker. Thereby, it attempts to determine the level of technical advance. Chapter II discusses how management technology, including production management and quality control techniques, has been absorbed, assimilated and developed. Chapter III evaluates the government's role in the evolving process of Chinese color TV mass production technology. Lastly, the possibility for China to cope with technical innovation is predicted as a conclusion.

In his previous report, the author[7] made cost analyses of the Chinese color TV industry and concluded that in order to be more competitive in the world market it would be essential for China to achieve economies of scale. For this purpose, China has to expand the scale of assembly makers, reduce costs of components by redistributing profits among assembly makers and component suppliers, and increase investment in new equipment by accelerating accumulation of capital within enterprises. The present study also aims to suggest a technical path for China to follow in order to cope with these challenges.

I. Technological Changes and Labor Productivity

In this Chapter, investigation results of Beijing Peony Electronic Group Co. (BPEG: former Beijing TV Factory, which was renamed after grouping of enterprises in 1991) are analyzed to see (A) what kind of technologies have been selected when importing production technology from developed countries, and to what extent home-made technologies have been substituted for them, (B) how product design technology has been developed and changed, (C) how those changes have affected the relationship between labor productivity and capital labor ratio.

First, how has the Chinese color TV industry evolved? Figure 1 shows the changes in the production and export of color TVs, together with the changes of the export ratio.

In 1981, imported color TV production lines were put in operation and mass production started. The number of products amounted to 1,340,000 sets in 1984, which sharply increased to 4,350,000 sets in 1985 and 10,370,000 sets in 1988. Thus, the production system in the order of 10 million sets was quickly established in only 7 years from start of the operation, and now China is producing 14,000,000 sets a year, being one of the world's leading producers. Moreover, the export-production ratio has been staying around 20 to 30% since 1987, ranking among the world's top exporters of color TVs.

Table 1 shows the change in the top 10 sales ranking of color TV assembly makers. It reveals the nature of the current Chinese color TV industry. First of all, the Chinese government's initiative has played an important role in establishing the industry. Among the top 10, Shanghai No.1 TV Factory (later, it was integrated into Shanghai Guangdian Gufen Co.), Tianjin Communications & Broadcasting Co., and Beijing TV Factory (later, it was integrated into Beijing Peony Electronic Group Co.) were all designated by the government as three production bases, where assem-

Figure 1 Changes in the Number of Color TV Products and Exports, and the Exports/Products ratio

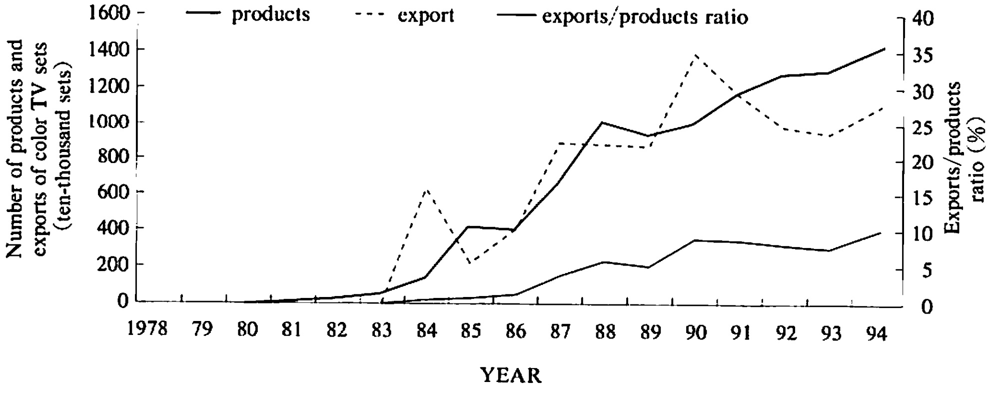


Table 1 The top 10 Chinese TV Enterprises (1993)

Name of Enterprises	Sales (ten-thousand yuan)		
	1993	1990	1986
Shanghai Guangdian Gufen Co. (* 1)	364,453 ①	116,136 ①	57,594 ①
Chenghong Machinery Factory	289,337 ②	115,089 ②	27,500 ⑤
Nanjing Radio Factory	288,066 ③	95,234 ③	40,388 ②
Kangjia Electronic Group Co.	222,178 ④	83,843 ⑤	—
Shenzhen Huaqiang Electronics Industry Co.	156,076 ⑤	81,828 ⑥	11,825 ⑧
Tianjin Communication & Broadcasting Co.	153,962 ⑥	93,594 ④	34,000 ④
Fujian Hitachi TV Co., Ltd.	144,133 ⑦	51,391 ⑨	14,550 ⑦
Zhuhai Dongda Group Co., Ltd. (* 2)	133,789 ⑧	17,915 ⑩	—
Beijing Peony Electronic Group Co. (* 3)	121,352 ⑨	65,748 ⑧	37,273 ③
Xiamen Overseas Chinese Electronic Co., Ltd.	104,594 ⑩	78,723 ⑦	18,356 ⑥

Source: "Electronic Industry Year Book of China"
Notes: The sales include products other than color TV.
* 1: The sales in 1993 are the sum of sales of Shanghai No.1 TV Factory, Shanghai No.4 Radio Factory and Shanghai No.18 Radio Factory. The sales before 1990 are the sales of Shanghai No.1 TV Factory.
* 2: An enterprise group established in 1991.
* 3: An enterprise group established in 1991. The sales before 1990 are the sales of Beijing TV Factory.

bly lines were installed for the first time in China. Even today, these state-owned enterprises continue to be the core of the Chinese color TV industry. Secondly, based on the government's "economies of scale" policy, restructuring of the industry has been progressing, and enterprise groups, which were formed by merger of middle and small enterprises, are becoming the center of color TV industry. Thirdly, joint investment with foreign capital, including Kangjia Electronic Group Co. and Huaqiang Electronics Industry Co., are emerging as prospective production bases.

(A) Changes in Production Technology

Changes in production technology of the Chinese color TV industry are clearly shown in the example of BPEG. Table 2 shows the kind of assembly lines installed in BPEG, together with their characteristics.

There are three ways for developing countries to acquire information on advanced production technology in developed countries and accumulate know-how. The first is to acquire it through actual production consigned by developed countries. For example, the E Line shown in Table 2 was made by technical tie-up for semi-knocked-down (SKD) production for Japan Victor Co., Ltd. (JVC) before 1979, when the first assembly line was imported from Matsushita Electric Industrial Co., Ltd. BPEG acquired advanced mass production know-how including manufacturing and product design technologies through the SKD production.

The second way is to use reverse engineering of imported technology. Developing countries can disassemble conveyor systems and products, study designs and features of machinery and components, and learn to reproduce copied products. The third way is to acquire a huge amount of technical information from suppliers when buying advanced equipment. For example, BPEG could obtain all necessary information during the business negotiations[8] for selecting a technology supplier, because bidders had presented all information necessary for designing a factory, including information on product design and materials technology, manufacturing process,

Table 2 The Types and Characteristics of the Assembly Lines in BPEG

Characteristics \ Type	Line "A"	Line "B"	Line "C"	Line "D"	Line "E"
Time of operation or installation	1981	1985	1993	1989	1979
Production capacity (sets/day)	500→667	750	400	1000	400
(ten-thousand sets/year)	15→20	22.5	12	30	12
Source of imported technology	Matsushita	Matsushita	Matsushita	GE	JVC
Main products (inch size)	14, 22, 20	14, 20, 21	10～29	20～25	
Number of components	800	800	2400(29″)		
Line length (meter)	1000	1200	1100		
Takt-time (second)	45→30	30			
Automated insertion ratio (%)	0→30	60→30	80		
Purchasing cost of foreign-made equipment (ten-thousand dollar)	400	260	1000	lower 30	
Ratio of foreign-made equipment	100	50	40		
Number of workers	direct 250 indirect 50	direct 250 indirect 50	direct 300		

Notes: The data were collected by the author based on hearing results and materials provided by BPEG.

equipment, factory area, and necessary amount of electricity, water and air, along with suggested prices.

The characteristics of installed assembly lines, as shown in Table 2, suggest the changes in production technology. The A Line is one of the first three color TV assembly lines imported by the national government. It was a mass production plant with a capacity of 150,000 sets a year, imported from Matsushita Electric Industrial Co., Ltd. At that time, exactly the same line used in Matsushita's factories was transferred, except for automatic component inserters, and therefore the state-of-the-art technology was introduced. Above all, the latest free flow line (FFL) was imported, which had been introduced into Japan only a year before. (FFL is a line in which operators can stop and move conveyors freely according to their own work speed. In Japan, it had replaced the earlier Takt system to improve the quality of working conditions.) Secondly, the same standard work method and time as used in Matsushita were adopted. Thirdly, in the area of product design technology, the compact M11 chassis[9] with components densely mounted on was introduced, shortly after it was developed by Matsushita.

Their attitude to go after the latest technology is often criticized, but of course the state-owned enterprises, as China's critical production base, have responsibility to take in the most advanced technology they can afford. On the other hand, joint enterprises with foreign investment are free from such constraints. For example, Fujian Hitachi TV Co., Ltd. established in 1980 could reduce investment in production lines to $ 1,080,000[10] by lowering the automation ratio, and it was as late as in 1990 that it introduced FFL and automatic component inserters[11].

The B Line is an assembly line with a production capacity of 225,000 sets a year, designed in collaboration with Matsushita in 1985. When compared to the A Line, it has shorter Takt time of 30 seconds. It is equipped with automatic component inserters. (They can automatically insert 60% of all components. They are used for both A and B Lines, feeding 30% of all components to each line.) Moreover, the installation cost was half that of the A Line, because 88% of conveyor equipments, 70.5% inspection devices and 80.7% jigs and tools were homemade products[12].

The increasing use of homemade equipments can be seen in the example of conveyors. Its junction part between motors and controllers was designed in collaboration with Matsushita. The know-how achieved at this time was successfully utilized to generate its own conveyor manufacturing technology. The C Line purchased from GE in the U.S. in 1990 (see Table 2) and the D Line (a line for assembling 29-inch large TV models) purchased from Matsushita in 1993 use entirely homemade conveyors.

This way, China has established its own production system of conveyor lines during the learning process of machinery design in the effort of adopting assembly line systems. One major factor that enabled this is that their technical source was the same company in Japan. The conveyor used in the line with a production capacity of 6,000,000 units a year, installed with technology transferred from Matsushita and JVC[13], was originally made by Hirata Machine Co., Ltd.[14]. The C Line purchased from GE was also originally made by Hirata. This monopolization of assembly line makers, together with monopoly of component producers in developed countries which will be discussed later, facilitated technical transfer from industrialized countries to developing countries.

The C Line, a 25-inch large color TV assembly line installed in 1989, was a former GE line. They bought it for less than $ 300,000 and then re-assembled and adjusted it by themselves.

The D Line is a 29-inch color TV assembly line operated in 1993, using Matsushita's technology. It boasts of a high automatic component insertion rate of 80%, by which it is capable of coping with the increase in the number of components and the mounting density. The D Line, just like the A line, uses the same technology as that used in Matsushita's factories in Japan. However, Chinese factory chose the insertion rate of 80% and left the job of inserting irregular parts to human hands, while Matsushita's automatic component insertion rate is 95%. It also uses more homemade equipment than previous lines, by which they could reduce the equipment's purchasing cost down to 40% of the cost necessary for importing everything from abroad.

(B) Changes in Product Design Technology

The change in product design technology is revealed in the example of the chassis. Table 3 shows the types of chassis applicable to color TVs produced by BPEG. As mentioned before, the first imported design technology was Matsushita's M11 chassis in 1981. Originally it was imported for making 14-inch and 21-inch chassis, but only 14-inch models were actually produced. Then, in order to meet the market demand, 18-inch chassis were developed in 1986 and 20-inch ones in 1987. As larger screen sizes required higher voltages, designs of only fly back transformers (FBT) and power transformers were changed, and the M11 14-inch chassis continued to be used. FBT and power transformers were designed by Matsushita and fabricated in China. In 1988, 22-inch TVs were developed and the production started. In this model, the deflection of CRT (cathode-ray tube) is 110 degrees instead of 90 degrees in the previous models, and therefore it cannot use the conventional 14-inch chassis. (Matsushita is using the same type of chassis for models from 14 inches to 21 inches.) This should have required a new development, but BPEG decided to reform the M11

Table 3 Type of chassis produced by BPEG

Model \ Type of chassis	Matsushita M11	Sanyo Mμ	Sanyo 83PG	Philips TDA	South Korea	Matsushita M16
14 inches	○		○	○		
18 inches	○					
19 inches			○			
20 inches	○	○	○			
21 inches	○	○	○	○		
22 inches	○					
25 inches					○	
29 inches						○

Note: (1) The data were collected by the author based on materials provided by BPEG.
(2) The circle shows the type of chassis of each TV model.

14-inch chassis into a 22-inch chassis by making full use of computer-aided design, because production of 22-inch models was small. Now, China has become capable of modifying design also in the area of product design technology.

Later, standardization of chassis was attempted. When color TV production technologies were transferred from various Japanese electric companies, different types of chassis were introduced along with them. Not only that, about 1,000 components were mounted on one chassis, and they too varied from maker to maker in design of circuits and characteristics of components. This problem has been alleviated, as key component production is increasingly monopolized by a few suppliers[15] and standardization of components progresses in Japan. Yet, there are still some variations, and if they are to follow each maker's specifications, an enormous variety of components will have to be made domestically. This will make it hard for Chinese enterprises to expand their production scale. Therefore, standardization of chassis and components is essential for increasing home production ratio.

In 1987, the Chinese government set about standardizing chassis. Basically, a chassis is designed according to the performance of the main IC. For this reason, in order to design an original chassis, it is essential to design, develop and fabricate main ICs domestically. While developed countries have already implemented one-chip main ICs, the mainstream in China is still 2-chip and 4-chip ICs. In 1993, 100% of 4-chip ICs and 30 to 60% of 2-chip ICs used in China were homemade products. One-chip ICs and other chips for multi-functional TV (with a surround-sound system, BB tuner, remote control, etc) were all imported[16].

In the area of color TVs' IC production, China started manufacturing 4-chip ICs in a semiconductor factory in Wuxi, using technology transferred from Toshiba Corporation in 1980. Then, 2-chip ICs' production technology was transferred from Toshiba in 1987. Beijing Electronic Tube Factory also started manufacturing 2-chip ICs for Mμ chassis of Sanyo Electrics Co., Ltd. This gave the national government an impetus to consider standardization of chassis, and the government selected three standard models: Toshiba's TA chassis, Sanyo's Mμ chassis (later replaced by 83PG chassis) and Philips's TDA chassis.

Beijing Dongfeng TV Factory (BDTF) succeeded in using 98% homemade components except for CRT, aided by optimum design of Mμ chassis. In 1989, Qiughua University developed CAD technology for TA chassis and Mμ chassis, and completed a standard chassis of optimum design through it. 98% of its components can be homemade, and it was approved as a superior model by the government[17]. Thus, China entered the stage of developing its own product design technology, to some extent freed from the constraint that forces the use of imported production technology and components of designs specified by foreign makers, though they could not design, develop and fabricate main ICs domestically.

BPEG, which had been continuing production of M11 chassis, also started producing 83PG chassis developed by BDTF when it was merged in 1993, and eventually stopped production of M11 chassis[18]. Thus, the product design technology imported in 1980, M11 chassis, was replaced by a domestically-developed standardized chassis, and it marked the end of an era.

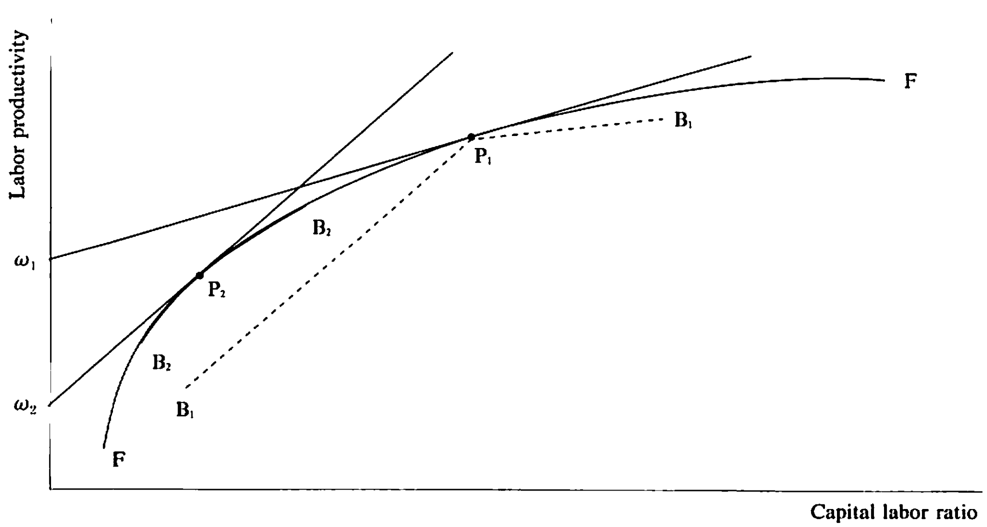
However, as a new era of 29-inch or larger color TVs arrived, China imported again a new chassis from Matsushita (M16 shown in Table 3) and increased reliance on imported ICs again. Other Chinese color TV makers also started actively developing large-screen color TVs, and there has been a growing demand for renewed technical co-operation with Japanese makers. For example, Shanghai No. 1 Factory invested $ 1,500,000 in the development of new large-screen models in 1995, and now it is planning to establish a development center for large-screen color TVs in collaboration with a Japanese maker[19].

(C) Correlational Analysis Between Labor Productivity and Capital Labor Ratio

A. Ono et al.[20] classified imported technology, based on empirical analysis of changes in technology adopted by Japanese textile industry emerging in the beginning of 20th century. Referring to the classified patterns of imported technology as shown in Figure 2, this Section examines the relationship between changes in production and product design technologies and labor productivity in BPEG.

The Japanese textile industry imported steam-powered iron machines from the West, and transformed them into water-powered wood reeling machines suitable for its technical standard of the time. Ono et al. argue that this enabled the Japanese to use cheap homemade elements and brought in high profits. Then, based on the pro-

Figure 2 Classified patterns of imported technology



Source: H. Okawa et. al., "Choki Keizai Tokei: Suitei to Buseki", Toyokeizai Shinbunsha, vol.11, p.181

duction function (relationship between labor productivity and capital labor ratio) as shown in Figure 2, they classified imported technology. The curve F in the figure represents the production function in developed countries. It is a conglomerate of potential production technologies that can be implemented under certain technical know-how. When the wage in developed countries is represented by $\omega 1$, profit ratio reaches a peak at the point P1 (profit ratio is equal to the gradient of Curve F's tangent). Therefore, production methods to be actually implemented in developed countries are determined at this point.

The first classified type of technology introduction is importing machines and designs perfected by developed countries. B1 in Figure 2 shows the production function of a recipient country. It is a limited production function refracting at P1, because the possibility of substituting elements are limited.

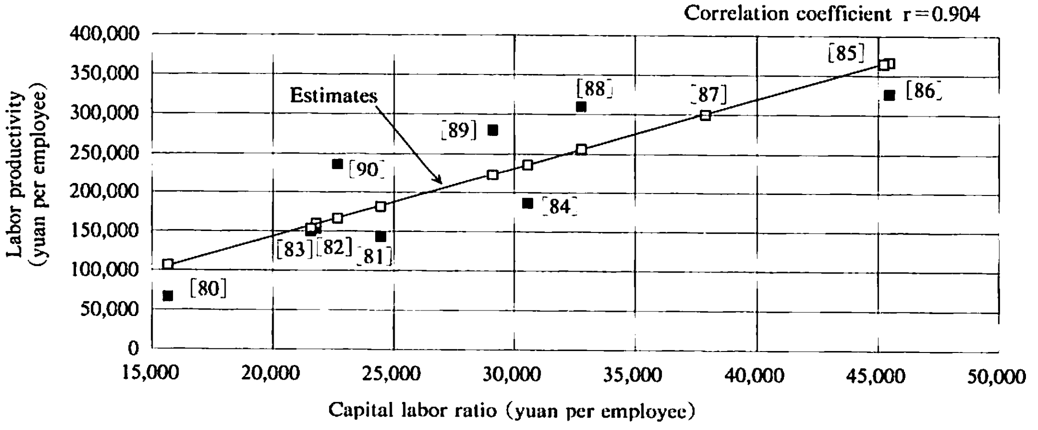
The second type is importing technology from developed countries and transforming it into a production system with lower capital labor ratio, taking advantage of cheap labor in developing countries. That means developing other areas on the potential production function F in Figure 2. This corresponds to the line B2 in the figure. When the wage is $\omega 2$, the profit ratio reaches the maximum at P2. The technology B2 has a lower labor productivity than the technology P1, but a higher profit ratio.

Figure 3 shows the correlational relationship between labor productivity and capital labor ratio after being corrected by the deflator based on BPEG's index[21]. Here, figures within brackets show the year, and the line represents estimates figured out by correlational analysis. From this figure, the following observations can be drawn:

(1) There is a strong correlation with a correlation factor of 0.904 between labor productivity and capital labor ratio. This suggests that increase in capital labor ratio brought high labor productivity. In terms of change by time, there are some distance between the actual values and estimates in some years because of the factors described below.

(2) The A Line operation in 1981 used exactly the same technology as that used in developed countries, except for expensive component inserters. BPEG decided to manually insert components into a printed board, and thereby reduced capital labor

Figure 3 Relationship between the Capital Labor Ratio and the Labor Productivity after Corrected by the Deflator



ratio. Naturally, labor productivity remained low. This corresponds to the left part of B1 in Figure 2.

(3) In the B Line operation in 1985, some inserters were foreign-made products, but conveyor systems, inspection devices, jigs and tools were all homemade substitutes. For this reason, labor-capital ratio remained low and labor productivity was high. This corresponds to the production function B2 in Figure 2, and falls into Ono's second type, where technical modification by employing as many homemade elements as possible accelerates technical innovation and increases labor productivity.

(4) From 1987 to 1990, high labor productivity was achieved by investing in modification of A and B Lines, together with adopting and reforming production and quality control technologies. It can be concluded that technical innovation helped labor productivity increase.

II. Changes in Managerial Technology

In this Chapter, how imported technology have changed and on what level it is today are discussed from the viewpoints of (A) production management and (B) quality control, using the BPEG's case as an example.

(A) Production management

What should be noted about production management in China is, above all, how management of the standard work time has been changing as enterprises acquire greater autonomy. In the past, the governments decided all production plans, and enterprises' biggest responsibility was to carry them out within a specified period of time. They didn't have to manage standard work time which would determine labor productivity. However, with the shift from planned economy to market economy, it has become a very important managerial task for them to effectively manage standard work time while keeping productivity and cost in mind. Moreover, the synchronization of work through management of standard work time is an essential technique in mass production relying on line work. Chinese enterprises were experiencing this for the first time.

When the A Line was imported from Matsushita, the same standard work method and time was introduced. The configuration of a station (a work domain of one operator), staffing and Takt time (45 seconds) were set same as Matsushita's. Before the A Line was imported, the concept of standardized work was not acceptable because it was regarded as Taylorism and considered that such sort of work was cruel. Taylorism was eschewed during the cultural revolution. Therefore, Japanese engineers involved in the technical transfer to BPEG estimated that it would take at least three months for Chinese operators to learn to repeat the same job in 45-second Takt time. However, only one month after the start of operation, they achieved the designed production capacity of 500 sets a day. Indeed, they have proved that they can do the same job as efficiently as Japanese workers once managerial technology is employed.

Later, A Line was modified so as to reduce Takt time from 45 seconds to 30 seconds and improve labor productivity. Then, when a new product was developed, new standard work time was set. Usually, a newly developed product consists of a different number of components from the previous one, and this requires a determination of new operation procedures and standard work time. In the earlier period, this determination was made based on the actual operation results. In other words, the number of the previous product's components were compared to that of a new product, and a necessary number of new processes was calculated from the ratio. However, with the adoption of scientific management in 1989, this determination method was changed. Now, the number of processes of one line is figured out by statistical method and finally determined through test operation.

This way, when mass production technology was first imported from developed countries, their production management technology was also imported along with it, but eventually they were replaced by standardized work manuals developed by Chinese enterprises themselves. This can be regarded as one index of advancement of imported technology.

(B) Quality Control

Quality improvement was an important motive for importing mass production technology, because the quality of the early home products was extremely low. Improvement of quality was essential for the Chinese color TV industry to become totally independent.

The biggest change occurred following the operation of A Line in 1981 was the intensification of quality control in the factory. Dual control points, a quality control point and a quality monitoring point, were placed in one production line. The quality control point is where workers of the production line inspect products' quality, and for that purpose, an inspector was chosen from workers at each workplace. The inspector finds faulty products, if any, and corrects them. If wrong components have been inserted into printed boards, the inspector returns them to the operator in charge of the component insertion. The quality monitoring point is where a representative of the quality control department inspects products. This inspector can stop the line if there are faulty products by lot.

A change in the character of their quality control was brought about by the adoption of Matsushita's component approval/quality guarantee system in 1985.

There are three types of quality control: (1) quality control for delivered components, (2) quality control for preventing errors in component insertion and mounting in assembly lines, and (3) quality control for reviewing designs based on fault information collected from lifetime testing and the market. The system for the type (2) quality control was established by setting quality control points and quality monitoring points. The component approval system is a measure to meet the requirement for (1) and (3). Matsushita provided them with manuals specifying standards, procedures and equipment necessary for giving approval to delivered components and for conducting tests on the operation life of products and components.

One of the leading color TV manufacturers, Shanghai No. 1 TV Factory, imported a component approval/quality guarantee system from Hitachi, simultaneously when they imported Hitachi's assembly line in 1981. It has been greatly helping them maintain their status as a top maker.

One of the changes brought by the introduction of the component approval system was the extension of life of products and improvement of their reliability. This made them more competitive in the market. In the market environment after

1989 when price competition began, quality was an important factor for product discrimination. Another change was the establishment of technical foundation for conducting quality approval tests of delivered components and selecting good suppliers based on the results. This contributed a great deal not only to improve the existing component manufacturers' quality but also to develop new component suppliers of high quality. The third change was the establishment of national standards. Before that, there was no national industrial standards, and one enterprise's quality approval system was functioning as alternative standards. This situation made it easier for the government to implement the national standards. The forth change was that they could establish technical basis for replacing imported components with homemade ones and for developing original production technology through quality tests of imported components. The fifth was that they achieved capability to feed back from the market to quality management in the factory through the study of causes of faults. The final change was the reduction of lead time from development of new products to their shipping to the market. Since 1989, quick response to the market situation has been increasingly demanded, which prompted the national government to change its inspection system for approval of new models. As a result, time required for inspection was shortened. One reason for this achievement was certainly that enterprises had already established quality control systems for themselves.

Then, in 1990, the government established national standards(Guo Biao: GB) for color TVs . Today, it is essential for Chinese color TV makers to comply with the standards in order to be granted with the government's approval. They have organized seminars in each factory to study GB. The government established GB with an objective of making Chinese products more competitive in the world market. Therefore, the standards for development and design, quality control and guarantee of production, and final inspection and testing are all in accordance with the international standards[22)].

Thus, a shift from total dependence on imported technology in the 1980s to development of its own technology has been observed also in the area of production management and quality control. In the market economy, China is now strengthening its capability to cope with the demand of the international market.

III. The Role of the Governments

This chapter discusses historical changes of the roles of the national and local governments in industrial development.

The process of the development of color TV mass production technology is divided into two periods: the domestic technology development period from 1973 to 1978 when the reform and open policy started; and the technology import and its nationalization period after 1978 when the open diplomatic policy opened the door to technology introduction. The latter period is subdivided into five periods. The first is the founding period from 1978 to 79. In this period, the introduction of mass production technology was started according to the national government's plan. The second is the adjustment period from 1980 to 82. China canceled orders for new plants due to the shortage of foreign currency, and called the world's attention. The third is the assembly line proliferation period from 1983 to 85, when the local governments imported a huge number of assembly lines. The fourth is the technology nationalization period from 1986 to 90. Based on the 7th 5-Year Plan, the national government took a strong initiative. And the fifth is the breakthrough period after 1990. While enterprises have achieved greater autonomy, merger of enterprises have been promoted by the national government's "Economies of Scale" policy, and joint business has been increasing to facilitate the introduction of large-screen TV, VTR and other new technologies.

The details of the government's role in each period is discussed below.

(A) The Domestic Technology Development Period (1973-77)

The most remarkable development in this period is that enterprise groups were formed in the north and in the south under the guidance of the national government to jointly develop color TV. At that time, there were 10 TV factories in the country, and these assembly makers had to do everything from the development of key components to their production, because component makers were not mature enough to meet their demand. They developed technology on their own for product design of color TVs and their key components, such as a CRTs, FBTs (fly back transformer), DYs (deflection yoke) and tuners.

The characteristics of the technology in this period were: (1) Production was done by the conveyor system, but the flow was not consistent[23]. (2) As it was the era of the vacuum tube, home producers could supply it, and TV makers were able to design products based on its actual performance. (3) The quality of products was very low. In those days, TVs were very expensive, and if they failed, considerable indignation was expressed by consumers. The improvement of quality was an urgent task for TV makers. For example, the mean time interval between failures(MTBF) of black/white TVs made by Shanghai Broadcasting & TV Factory was less than 500 hours in 1978, the percentage of flawless products when taken out of the box at a retail store was 20.8%, and the mean ratio of repair within one year was 86.9%[24]. It means that most products broke down within one year from the purchase.

Although there was a big problem in quality, they could manage to produce all the key components and design circuits on their own, and this became a solid basis for the striking breakthrough of color TVs in 1980s, in terms of human and technical resources. However, the mass production system in this period was not suitable for an assembly line. Modernization of mass production and product design technology was a big challenge.

(B) The Founding Period (1978-79)

Based on the reform and open policy in 1978, emphasis was transferred from heavy industry to light industry (consumer goods, including household appliances, are included in light industry in China), and it became a nation's important political issue to produce homemade color TVs. The number of imported TVs and the payment sharply increased with the start of the reform and open policy. Establishing an effective production system became an urgent issue in order to meet the exploding demand.

The characteristics of technology introduction in this period were: (1) The construction of plants were funded by the national budget. (2) Basically, government funding meant color TV assembly lines and key component manufacturing plants were closely related and systematically introduced. (3) What was sought for was the introduction of both the flow-system mass production technology and the latest product design technology.

In 1978, the national government worked out a plan to produce 1 million 14-inch and 21-inch color CRTs a year, and systematically introduced plants for manufacturing phosphor materials and other components such as glass bulbs, as well as plants for assembling CRTs. Then, in 1979, the government introduced three color TV assembly lines described earlier and production lines for manufacturing FBTs, tuners and printed boards according to the plan.

(C) The Assembly Line Proliferation Period (1983–85)

In this period, local governments throughout the country started to introduce color TV assembly lines, and the number increased sharply. 83 factories started color TV production and 119 production lines were newly installed in the country, realizing a production capacity of 17 million sets a year[25)]. Indeed, the production quadrupled from 4,350,000 sets in 1985. The author confirmed that at least 12,800,000 sets had been produced annually from the assembly lines transferred from major Japanese electric companies: 17 factories with a production capacity of 3,300,000 sets from JVC, 8 factories with 2,750,000 sets from Toshiba, 8 factories with 2,640,000 sets from Matsushita, 3 factories with 1,740,000 sets from Hitachi, 3 factories with 1,000,000 sets from Sony, 3 factories with 750,000 sets from Sanyo[26)]. Thus, a great number of product technologies of different design (as typically seen in chassis) were introduced from different makers to enterprises throughout China. Clearly, this situation made it difficult to expand the scale of component production, and prompted the national government to standardize chassis as explained earlier.

As such a huge number of assembly lines were introduced in a short period of time when a component self-supply system was not fully established, import of components sharply increased. This caused a serious shortage of foreign currency, which was even more aggravated by increased import of final color TV products in 1985. The national government ordered a stop in the importation of color TV assembly lines and their components in 1985, when shortage of foreign currency and over investment became evident.

Why did this proliferation occur? From the financial viewpoint, it is because local governments became the investors instead of the national government. There are two reasons for this. Firstly, during the founding period from 1978 to 79, the national government made a huge investment into large-scale steel and oil plants. This aggravated the shortage of foreign currency and created a budget deficit, which forced the national government to reduce investment. Secondly, as Guangdong Province and Fujian Province were designated as Special Economic Zones in 1979, decentralization of power progressed. Management of many state-owned enterprises were transferred to local governments, which enriched the local governments' budgets.

Another factor that prompted local governments to actively introduce technology was the appeasement of requirements for technical import in 1981. While over $ 100 million technical import still had to undergo the national planning committee's scrutiny and the national government's approval, it was decided that technical imports of less than $ 100 million should be examined by a local government and approved by the export and import control committee. The cost of importing a color

TV assembly line was under \$ 100 million, and so local governments could introduce technology within their discretion.

The market control by the national government was another factor that accelerated the introduction of assembly lines. In 1980, color TV broadcasting started. The import of color and black/white TVs skyrocketed, and the TV market was heated. Yet, the national government prohibited import of electric appliances in 1981, and the consequent shortage of supply drove local governments to seek for domestic color-TV production. In addition, the color TV industry was chosen as a target of the national government's high tech industry development policy, and planned prices were favorably set so that all enterprises including small establishments could make profits. This further encouraged local governments to introduce color TV assembly plants as a highly lucrative business.

(D) Technology Nationalization Period (1986–90)

Intensified autonomy of local governments caused the proliferation of assembly lines, and at the same promoted domestic production of components.

As discussed before, in the founding period technology was imported according to the plan aiming to perform both assembly and component production domestically. However, far from the intended objective, it caused a lot of confusion. For example, BPEG had first planned to be supplied with CRT by a factory established with the technology transferred from Hitachi, IC by a factory in Wusi with Toshiba's technology, and FBT by Beijing 3rd TV Parts Factory with JVC's technology. However, once assembly lines went into operation, all key components were imported from Matsushita. It was mainly because there were considerable differences in those makers' technologies and this obstructed the implementation of the original component procurement plan.

This problem were solved in local government-owned enterprises through the governments' administrative guidance. For example, the production technology of FBT was imported from JVC to Beijing 3rd TV Parts Factory on condition that the factory would make it applicable also to Matsushita's models.

As seen in the above instance of local governments' administrative guidance, autonomy of local economies played an important role in promoting domestic production of components. Table 4 shows the changes in the number of TVs produced in major provinces and cities, together with the key component self-supply ratios within each region. As clearly seen here, some regions show very high self-supply ratios of key components. Those who show several-hundred-percent ratios are the supply bases that were systematically located throughout the country by the national government. On the other hand, the Special Economic Zones, Guangdong Province and Fujian Province, show poor ratios, suggesting that they were highly dependent on imported components. Jiangsu Province, Shanghai City, Tianjin City, Beijing City and Shanxi Province show high self-supply ratios, primarily because they have national production bases within each region. Even the regions of small production scales show high self-supply ratios. With all these factors together, the use of home-made components increased considerably.

On the other hand, as it requires huge capital investment to produce color CRT at home, the national government adopted an industrial policy to encourage joint management with foreign companies.

Table 4 Changes in TV Production and the Ratios of Homemade Key Components in 1986 in Major Districts

Unit: Ten-thousand, %

Size*1	Districts	1985		1988		1992		Growth rate of CTV		Homemade ratio in '86(%)*2				
		TV	CTV	TV	CTV	TV	CTV	85-88	88-92	CCT	BCT	ﾁｭｰﾅ	DY	FBT*3
Big (I)	Guangdong Province	134	101	279	203	432	367	26.3	15.9	0	0	11	4	30
	Fujian Province	59	41	114	96	143	132	33.2	8.4	0	364	4	11	0
Big (II)	Jiangsu Province	276	26	435	91	603	170	52.1	16.8	0	43	281	124	87
	Shanghai City	334	72	473	109	435	112	14.8	0.8	0	122	205	46	62
	Tianjin City	92	36	135	62	141	68	20.3	2.4	0	135	210	46	53
	Beijing City	75	38	93	58	64	64	14.6	2.6	0	91	64	74	209
	Shanxi Province	48	22	94	71	81	54	47.8	−6.6	483	0	0	0	46
Medium	Zhejiang Province	118	4	104	16	216	39	56.5	24.5	0	0	0	0	0
	Shandong Province	42	7	59	27	54	38	60.2	8.5	0	0	118	23	62
	Liaoning Province	81	14	126	41	73	26	41.7	−11.0	0	38	666	42	67
Small	Hubei Province	34	2	38	15	23	12	96.5	−4.6	0	0	131	106	48
	Gansu Province	20	2	28	16	14	9	94.1	−13.5	0	0	480	457	59
	Hebei Province	29	5	47	22	21	6	66.6	−28.4	0	133	27	183	422
	Guizhou Province	20	2	23	8	42	1	60.6	−36.5	0	0	138	0	0
	Total	1,668	435	2,505	1,038	2,868	1,333	33.6	6.5	29	69	153	57	69

Source: The data on the number of TV/CTV products are taken form "The Chinese Stastics Yearbook" and homemade ratios are based on "The Chinese Electronic Industry Yearbook".

Note: * 1: Size means the type classified by production scale. Big(I) includes those who conduct large-scale production with purchased key components. Big(II) includes those who conduct large-scale production with self-made components.

* 2: The homemade ratio in each district was calculated by dividing the number of key component products by the number of TV products in the district.

* 3: CTV, CCT, BCT, DY and FBT represent color TV, CRT for black/white TV, defledtion yoke, flyback transformer, respectively.

In 1984, the national government made a plan to produce 9 million color TVs in1990, and accordingly decided to increase the production of color CRT. In November, 1986, Beijing city and Matsushita jointly invested and established Beijing Matsushita Color CRT Co., Ltd. (with a production capacity of 1,800,000 units a year). Then, Toshiba made a contract to construct an additional factory in Xianyang (1,600,000 units), and one in Shanghai (900,000 units). Philips made a contract to establish a joint corporation in Nanjing (1,600,000 units). In addition, Hitachi established a joint enterprise in Shenzhen (1,600,000 units), and GE in U.S. established a 100% foreign capital firm (500,000 units) in Shanghai.

(E) Breakthrough Period (1991～)

In the approval process of establishment of new color CRT plants, it was clearly shown that the national government's policy was to use foreign capital in the form of joint investment when large capital investment is needed. Since then, joint management with foreign key component makers and TV assembly makers has become the mainstream. The most remarkable instance is the joint corporation established by Sony and a factory in Shanghai. It is a big company with a plan to invest 41 billion yen by the year 2000 and produce 3 million units a year from key components including color CRTs to large-screen color TVs. It aims to export 70% of all products to Japan and other Asian countries.

In 1995, the national government decided not to approve further joint investment with foreign enterprises to prevent overproduction, and announced a plan for the development of color TV industry toward the year 2000[27]. The plan aims to: (1) group color TV makers throughout the country into about 20 corporations, including one or two 5,000,000 unit-class corporations and two or three 3,000,000 unit-class corporations, and expand the scale of enterprises in the color TV industry, (2) promote export with a target of 10 million sets a year, and (3) reduce technical gaps between China and developed countries.

When this plan and the current situation of the color TV industry are taken into consideration, it is clear that enterprises jointly established with foreign capital will be dominant in the Chinese color TV industry, supported by their technical and financial fortes.

Conclusions —To Cope With Technical Innovation—

In this prospect, how can those state-owned corporations throughout China compete with joint enterprises? Basically, their strategy should be to increase domestic production of key components including IC and to reinforce their ability to cope with the consequent innovation of product design, making full use of their accumulated technical resources.

For this, they have first to update equipment and technology to make them suitable for new component technology. With the emergence of new-generation color TVs with larger screens and multi-functions, the component technology has been changing rapidly. Yet, China's import of component mass production technology reached a peak in 1986, and the facilities have not been fully updated since then. One remarkable technical innovation is the emergence of surface mounting technology. For example, the surface mounting technology using chip components is essential for the micro-tuner developed in 1990. A tuner factory in Tianjin imported technology from Matsushita Electronic Parts Co., Ltd. in 1985, and again in 1990. A tuner factory in Chongqing, as well, imported production technology for different-generation tuners in 1985 and 1990 from Sanyo. On the other hand, Nanjing Tuner Factory imported technology from Sharp in 1985, and has not updated it since then[28]. Tandong Tuner Factory, which had 25% share of the national tuner production in 1988, has not updated the technology imported in 1985, and are losing its share rapidly.

Another challenge for state-owned enterprises is to innovate product design technology and accordingly to improve products' quality. Although China's color TV export ratio has been increasing, most of the exported products depend on imported components: in the export of color TVs, general trade was 4.6% in 1989 and 2.1% in 1990, and processing deal/reciprocal trade was 95.3% in 1989 and 96.4% in 1990[29]. Clearly, in order to produce components at home and meet the demand of international market for the latest color TV models, it is critical for them to establish a high tech component production system within the country and improve product quality. Though the products' quality has been improving as well, there were still some problems in the 1980s. Good-quality TV products approved by the national government decreased from 47.2% in 1989 to 37.65% in 1990[30].

The Chinese color TV industry, which was established in the early 1980s with the aid of imported technologies, has been striving to increase home production ratio through strengthened local economies and joint investment. Thereby, it has been rapidly developing mass production and product design technologies and improving labor productivity, while being disturbed by the low scale of economies due to excessive introduction of assembly lines. However, technical innovation in the area of color TV and its components is progressing very rapidly. In order to cope with this change, China will have to develop the home production system for main ICs and other new key components, by adopting an industrial policy to reinforce its capabilities for further technical development and investment.

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