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Architecture-based Approaches to International
Standardization and Evolution of Business Models

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1. Introduction

Standardization has a great impact on economic growth—it accelerates technology transfer and cost reduction. As technology progresses rapidly, the price of a product also quickly falls. Consequently, the efficiency of society as a whole is improved and the benefit to consumers is increased. This chain—standardization, technological progress, price fall, and expansion of consumer benefit—causes growth in global economy.

Especially after the 1990s, international standardization had a strong impact on the global

economy and accelerated collaboration with advanced countries and newly industrialized economies (NIEs). The background to this lies in the rapid development during the 1990s of semiconductors and digital technology. These technologies drove the modularization of product architecture forward. Modularization made it easy for countries with little technological knowledge to enter new industries such as DVD and mobile phone. It can be said that the economic growth of developing countries changed greatly because of product modularization and standardization.

The major companies that play a prominent role in developing core technologies and setting international standards have, however, also sought to maximize their profits. These companies ingeniously encapsulate their knowledge and intellectual property (IP) into a framework of technological standards. Their persistence to protect their IP apparently contradicts the goals of public standards organizations. The organizations promoting international standards, such as the International Electrotechnical Commission (IEC) and government institutions in each country, are more concerned with social welfare and especially consumer benefit.

The purpose of our paper is to provide a general framework for analyzing the economic impact of international standardization. Based on an analytical framework of product architecture, we seek an economic model that can harmonize the benefit of various entities such as the leading firms in advanced countries, the firms catching up technologically in NIEs, consumers in the global market, and public standards organizations.

In the following section, we analyze the impact of international standardization in the optical storage industry using the framework of product architecture. We then describe the modularization of products, international standardization, entrants from NIES, sudden fall in price, and rapid market expansion. Next, we suggest a new type of business model based on international standards. The division of labour between advanced companies and developing companies and their collaborative business model is described. Finally, we discuss economic growth based on the modularization and international standardization. A general model and some empirical data are provided.

2. Economic Impact of International Standardization

2.1. Product Architecture and International Standardization

Product architecture is a basic design concept for product functions and structures (Fujimoto, 2004). Basic requirement for product designer is how to realize a set of functions. Product is physically structured by some components. Product designer should determine how each function is allocated to some components. These concepts of allocation make the difference in the

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interdependency among components. Based on the concept of functional allocation and interdependency, product architecture can be classified into two types, modular and integral architecture:

- **integral architecture** has complex and strong interdependency among components. More than one function is allocated to each component. The design optimization of finished product depends on the mutual adjustment of component design itself (e.g., automobile).
- **modular architecture** has simple and very weak interdependency among components. Only one function is allocated to each component. The design optimization of finished product depends on each component that is independently developed (e.g., personal computers).

An architecture-based definition of standardization is summarized in Figure 1. International standardization, such as that provided by the IEC, is defined as a form of modular architecture. Because, in principle, it is open to every firm in many countries, and the design rules of the standardized layers are open to the public, the finished product has high potential to be extended not only to advanced countries but also to developing countries, and can thus increase benefits to

Figure 1 Architecture-based definition of standardization

Open international standardization = modular architecture

- 1) **Open technology & open design rule**
 - ⇒ accelerate diffusion and popularization of technology & product
- 2) **Remove interdependency between finished product & key components**
 - ⇒ accelerate international division of labor
 - ⇒ support rise of the industry in developing country
 - ⇒ popularize very low cost product worldwide
- 3) **World wide installed base**
 - ⇒ provides new value-added business opportunities

Closed local/de facto standard = closed architecture

- 1) **Closed technology & closed design rule**
 - ⇒ capsule technology & IP into product
- 2) **Keep strong interdependency between product & technologies**
 - ⇒ support vertical integration of product
 - ⇒ protect source of profit & revenue
- 3) **Need open standardized product as partner for market development**
 - ⇒ accelerate collaboration with advanced countries and NIEs

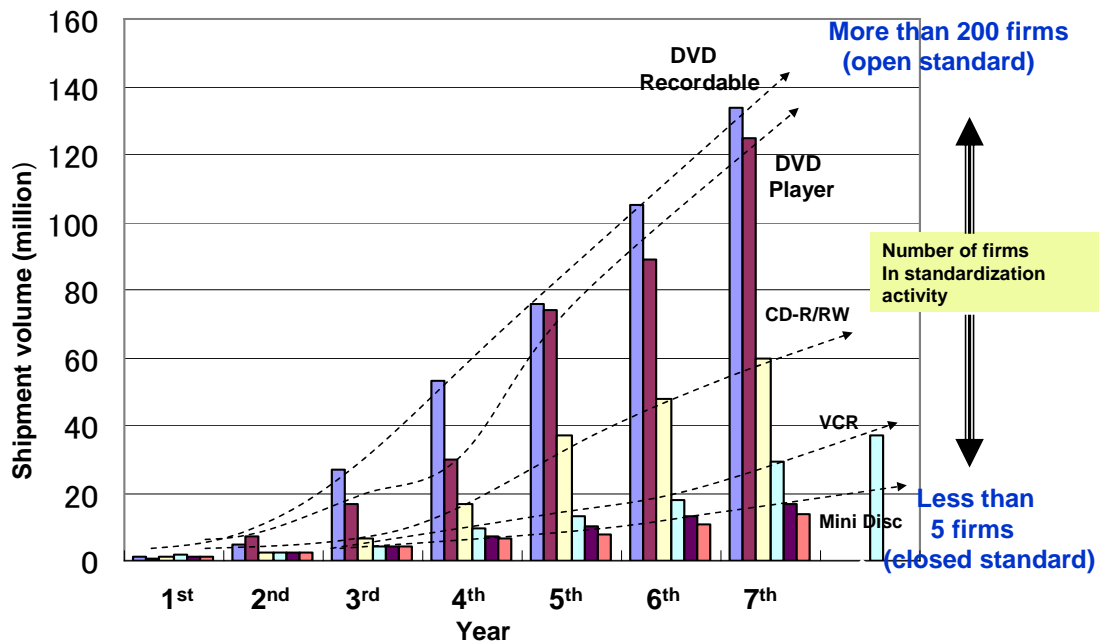
consumers worldwide. In addition, this worldwide installed knowledge base provides new business opportunities, such as the digital content business as seen in the DVD and mobile phone environment, with further contribution to economic growth.

The local and/or *de facto* standard can be defined as integral architecture. Because technology and design rules are largely closed or strictly controlled, firms that drive the standard forward have to promote the finished product themselves. However, history shows that huge marketing and promotion investment is needed; moreover, the product is restricted to a local and/or a niche market. A business strategy that has been successful for the integral product is collaboration with the open standard, which provides various business opportunities for partners. Without open standardization, the product with integral architecture, that is, a coordination-intensive product cannot enter the worldwide market. This shows that standardization plays a prominent role in the economic growth of the 21st century.

2.2. Development of Optical Storage Industry through Standardization and Modularization

The speed of market expansion depends strongly on the form of standardization, as shown in Figure 2. The technological standard of DVD families has been standardized in an international open forum called the *DVD forum*, of which more than 200 firms from 20 countries are members. Because it is open to firms from many countries, not only the technology-leading firms of advanced country but also many firms from NIEs that are catching up with their developed world counterparts (hereafter called catch-up firms) can join the DVD business. The accumulated volume of sales for the DVD family—writable DVD drive for PC, DVD player and DVD recorder for audio-visual—has reached over 300 million units within five years since the market opened up, and it is still growing. However, as seen in Figure 2, the sales volume of the Mini Disc, which is a small-sized music player that was very popular in the Japanese market of the 1990s, has been restricted to be less than 20 million. Because the Mini Disc was standardized in closed form by only a few Japanese and European firms, and because they did not open the key components and the technology, it has not been well accepted outside the Japanese market. In the case of DVD, which was standardized with many firms in the open international forum only one year after the first product was delivered in 1997, key components of the drive, such as optical pick-up, LSI chipset, control microcode, and electric motor, became available in the Asian-Pacific arena. Thus, the open standard quickly changed the product architecture to modular mode and then accelerated the division of labor. The distribution

Figure 2 Market expansion speed of standardized products



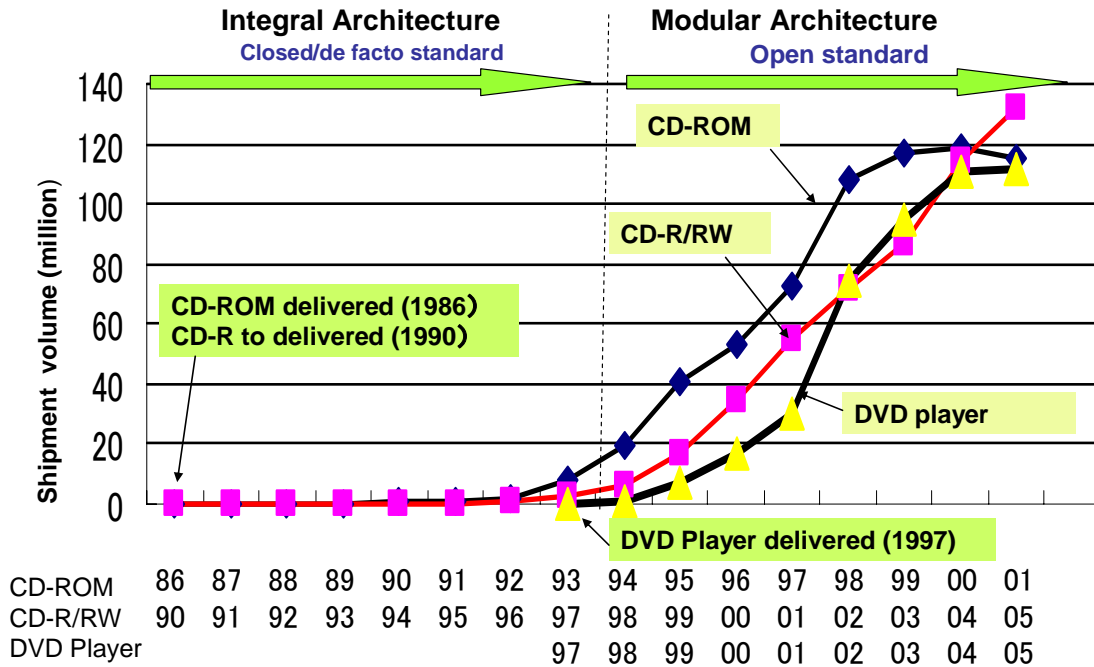
1st year shipment volume: 1 million per year
 DVD Recordable: 2001, DVD Player: 1998,
 CD-R/RW: 1996, VCR: 1978, Mini Disc: 1995

Source: Edited by authors using market information of TSR & GigaStream Japan

of these key components has provided the catch-up firms of NIEs with the opportunity to join the DVD business. In other words, the open standard has played a prominent role in creating new business opportunity for NIEs and encouraging their industry to flourish.

The product architecture of the CD-ROM and CD-R drive was initially in integral mode when these appeared in the market. Consequently, they could not develop volume market themselves, because there was no opportunity to change the division of labor. According to our investigation, the innovation of the microcontroller unit (MCU) and microcode technology (firmware) radically changed the architecture from integral to modular mode. The digital feedback servo technology of the CD-ROM since 1994 and microcode technology of CD-R's write strategy since 1998 are good examples of the innovation. The former has led the CD-ROM out of the integral mode to modular mode, because it has removed interdependency between optical pick-up and drive technology, while the latter has removed the interdependency between recordable media and drive technology. As is shown in Figure 3, the market for the two products has expanded explosively since 1994 and 1998,

Figure 3 Market expansion speed of standardized product after modularization

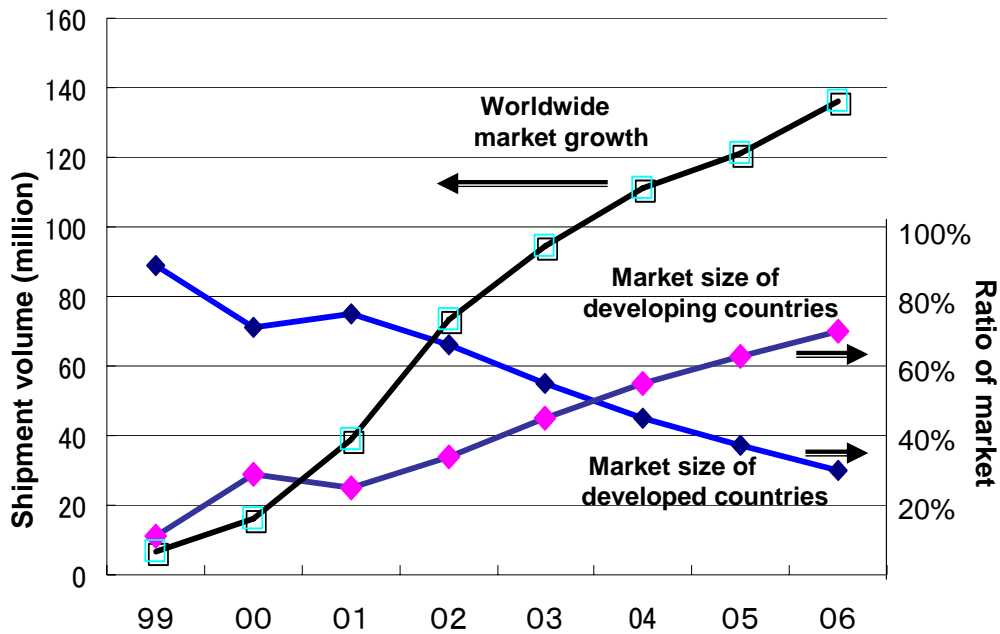


Source: Edited by authors using market information of TSR & GigaStream Japan

respectively, because key components of each drive have been available in the market of Asian-Pacific Arena and this has accelerated the division of labor. These cases in the DVD and CD family lead to the conclusion that the innovation of the digital technology since the 1990s has provided international standardization activity a prominent role in the history of industry—it contributes not only to increase consumer benefit but also to acceleration of economic collaboration between advanced countries and NIEs. It has been said that more than 50 firms joined the CD-ROM business in the mid-1990s and more than 300 joined the DVD business in the early 2000s from Korea, Taiwan, Hong Kong, China, India, Dubai, Turkey, and Singapore. Before the 1990s, when digital technology was not so powerful, international standardization could not have played such a prominent role.

As seen in Figure 4, the international standard has popularized the products in the newly developed markets of developing countries. The number of DVD players sold in the developing countries was less than 1 million in 1999; however, the number has drastically increased to account

Figure 4 Market development of DVD player in developing counties.



Source: Edited by authors using market information of TSR & GigaStream Japan

for up to 63% of worldwide shipments in 2005. This is the power of the open international standard in the environment of the digital technology. Both digital technology and standardization have accelerated modularization of product architecture enabling the division of labor, and popularization of products in the world.

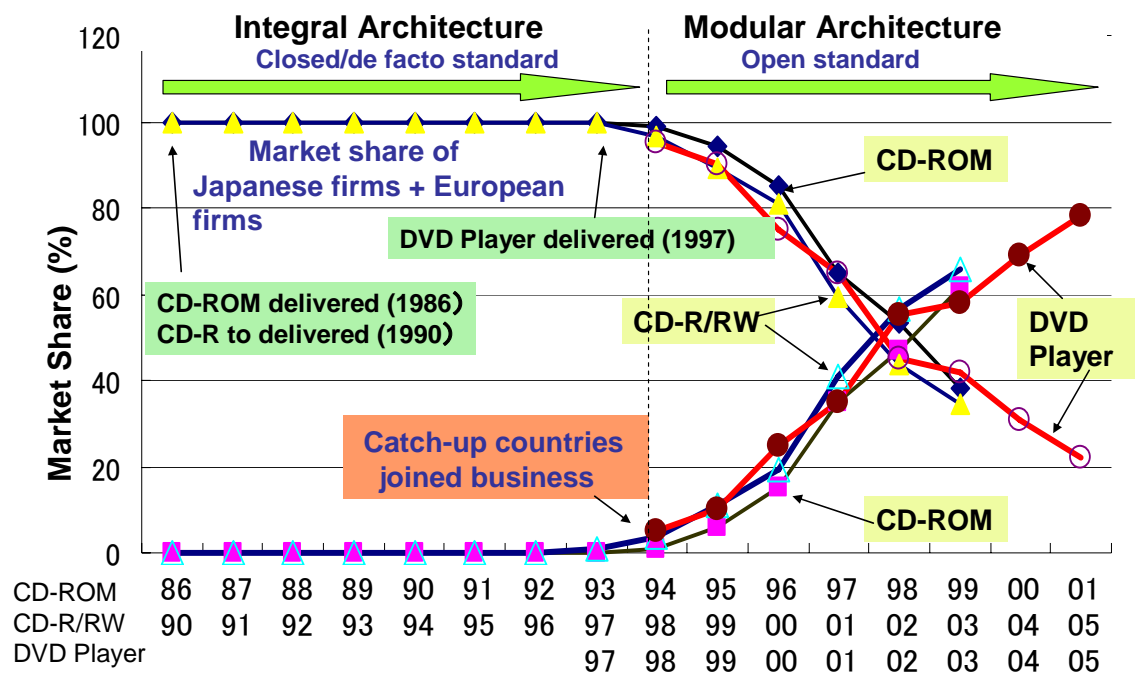
A similar contribution by the international standard has been observed in the mobile phone industry. The cumulative number of the subscribers in China was less than 4 million in 1995; however, the number has increased well over 400 million in 2005, which is almost the same as for the expanded European Union or more than twice the number for the USA. The volume of shipments of mobile phones by Chinese and Korean firms, for example, has been remarkable, rising to over 150 million in 2005. From the above analysis, it is clear that the international standard of the mobile phone has played a very prominent role in stimulating the economic growth not only of China but also of the advanced countries that have developed core technologies and set the standard.

2.3. Acceleration of Technology Transfer to NIEs

International standardization in open form has accelerated rapid technology transfer of finished products from technology-leading firms to catch-up firms of NIEs. Figure 5 shows sudden drop in the market share of Japanese and European firms with developed technology and have set the international standard. In the case of closed/*de facto* standards, such as CD-ROM and CD-R/RW, while product architecture was restricted to the integral mode, the market share of the finished product by Japanese and European firms was more than 90%. However, this share suddenly started to drop after the architecture changed into modular mode. On the other hand, in the case of DVD, the drop began even in early stages of the market's opening, because the architecture was already modularized—it was standardized in the late 1990s, when digital technology was in a phase of rapid innovation. It is very interesting to note that the trend of market share drop for the DVD has been almost the same as the drop for the modularized CD-ROM drive and the modularized CD-R/RW drive.

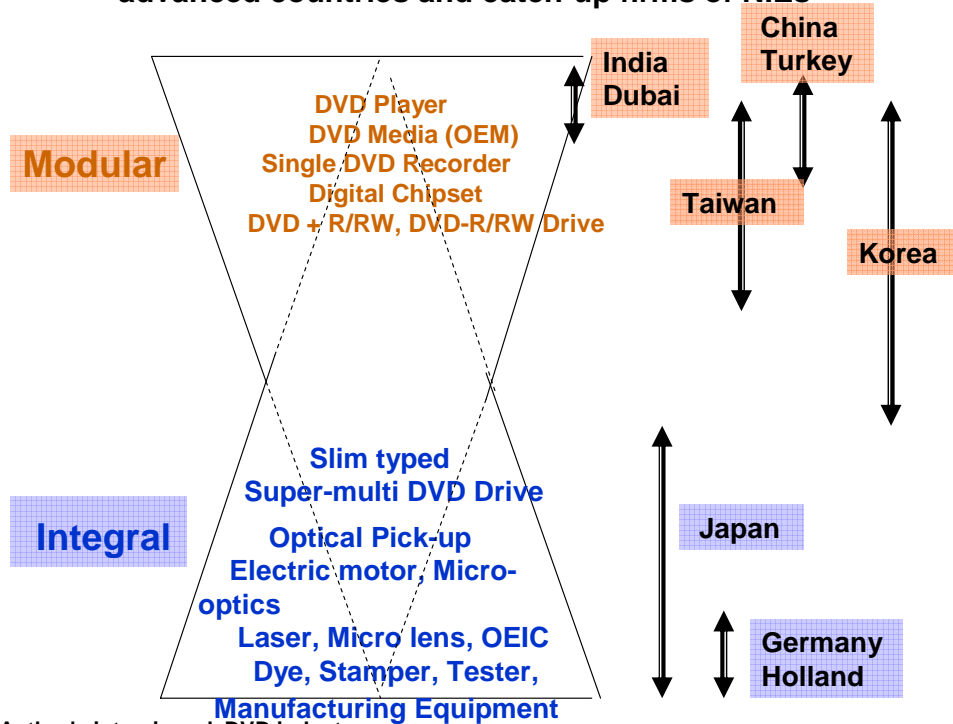
The product architecture of key components, such as the optical pick-up, first appeared in integral mode and remains in the same integral mode even today. The optical pick-up is a typical

Figure 5 Market share change of standardize product after modularization



Source: Edited by authors using market information of TSR & GigaStream Japan

Figure 6 Architecture-based positioning of standard leading firms of advanced countries and catch-up firms of NIEs



Source: Author's interviewed DVD industry

product with integral architecture or a coordination-intensive product in which there are strong interdependencies between the core technologies. Even though the optical pick-up has been manufactured by factories in NIEs, and has been available in the open market since 1985, the market share of Japanese and European firms has been over 90% in the innovation-intensive computer applications and over 80% even in less innovative audio-visual applications.

Figure 6 summarizes the architecture-based positioning of finished products and of key components in the DVD industry. All the key components developed by technology-leading firms in advanced countries are positioned in the integral architecture domain. The firms of NIEs cannot join the key component business, because it is a technology- and coordination-intensive product with integral architecture, which needs a long-term investment of education, long-term R&D, and a wide range of industry.

On the other hand, almost all the finished products manufactured by NIEs are positioned in the modular architecture domain. The technology-leading countries find it very hard to join the finished product business, because it is labor-intensive low cost. However, firms in NIEs can join it by taking advantage of their comparatively small overheads. It can be concluded that each domain needs

collaboration—firms in advanced countries cannot operate without the finished products from NIEs. The NIEs bring the value-added key components to the worldwide market by providing a finished product at very low cost. If the NIEs do not join the finished product business, then new markets in developing countries cannot be opened quickly, and the market size for the DVD player would be restricted to less than one third of current market or one fifth of the future potential market. This means that open international standards have provided the leading firms of advanced countries with 3–5 time bigger market for value-added key components, and this has encouraged the growth of their industry. This is due to the architecture-based division of labor created by international standardization.

Each country holds a unique and strong position in their product architecture, and this will not change in the short term because it originates from a country's comparative advantage based on culture and history. It must be emphasized that international standardization since the digital innovation era of the 1990s has created a new economic environment in which advanced countries and NIEs can be and will be in symbiotic co-prosperity. Because this co-prosperity has been created by international standardization, it can be said that the role of standardization in world economic growth will be much more prominent in the 21st century than in the 20th century.

3. New Alliance Business Model based on International Standardization

Although the catch-up firms in NIEs have a high presence in the optical storage industry, the international division of labor between Japanese and the catch-up firms has become very important for the continuation of their business. The firms in the advanced countries focus on the integral products and components such as the optical pick-up and LSI chipset. On the other hand, the firms in NIEs have competitive advantage only in the final modular product. These two parties have had the large transaction of key components in the market.

In the optical storage industry, for example, the market share of a typical integral product, such as the optical pick-up, is more than 80% for Japanese and European firms, while NIEs take more than 70% of the market share of such a finished product as the DVD player with modular architecture. A similar phenomenon has been observed in the mobile phone industry, where almost all key components with integral architecture, such as baseband chip and optical modules, have been supplied by advanced countries (for example, Nokia, Texas Instruments, etc.).

It is very difficult for NIEs to enter the market for technology-intensive key components, because these components require long-term investment in education and basic R&D, also require a

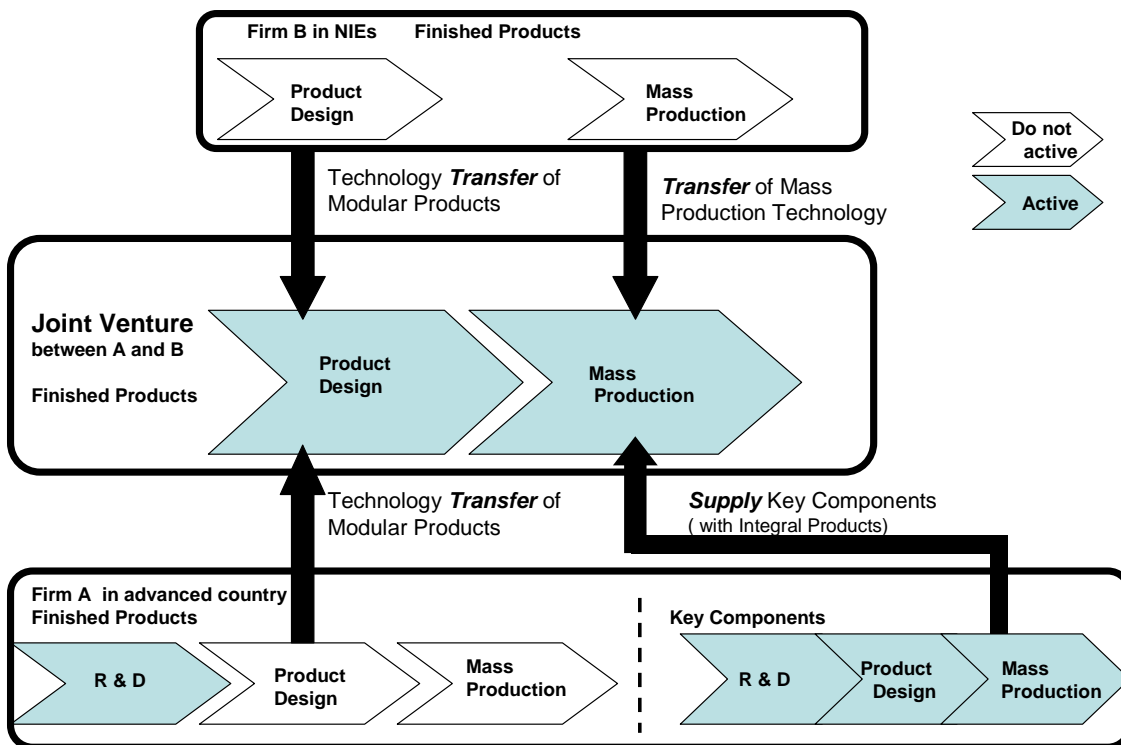
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wide range of industry infrastructure in the country. The firms in advanced countries invest in the technology development, product development, and market development of the technology-intensive integral products. On the other hand, it is very difficult for the firms in advanced countries to join the market of modularized low-cost products, such as the DVD player, because the gross profit margin of the low cost-product is very small and they cannot absorb the large overheads for investment. That is, the firm in advanced country is weak in the low cost operation of modularized products.

Recently, this international division of labor has evolved to the new alliance model. We can observe several successful alliances between technology-leading firms in advanced countries and catch-up firms in NIEs. These alliances are designed based on architecture—this may be defined as “architecture-based alliance model.”

A successful example of the alliance is a joint-venture company called HLDS where Hitachi of Japan takes a portion of integral architecture, while LG Electronics of Korea takes a portion of modular architecture. Hitachi is one of the firms that led the international standardization of the DVD and has provided IP to the technological standard. While Hitachi has transferred technologies of the

Figure 7. Architecture-based alliance model



modularized products, the DVD drives, to HLDS.

Table 1 Architecture based alliance in DVD industry

Establishment (year)	Name of Joint Venture	Investment	
2000	Hitachi LG Data Storage (HLDS)	Hitachi 51%	LG 49%
2001	JVC Light-on Manufacturing & Sales (JLMS)	JVC 51%	Light-on 49%
2003	Philips BenQ Digital Storage (PBDS)	Philips 51%	BenQ 49%
2004	Toshiba Samsung Storage Technology (TSST)	Toshiba 51%	Samsung 49%

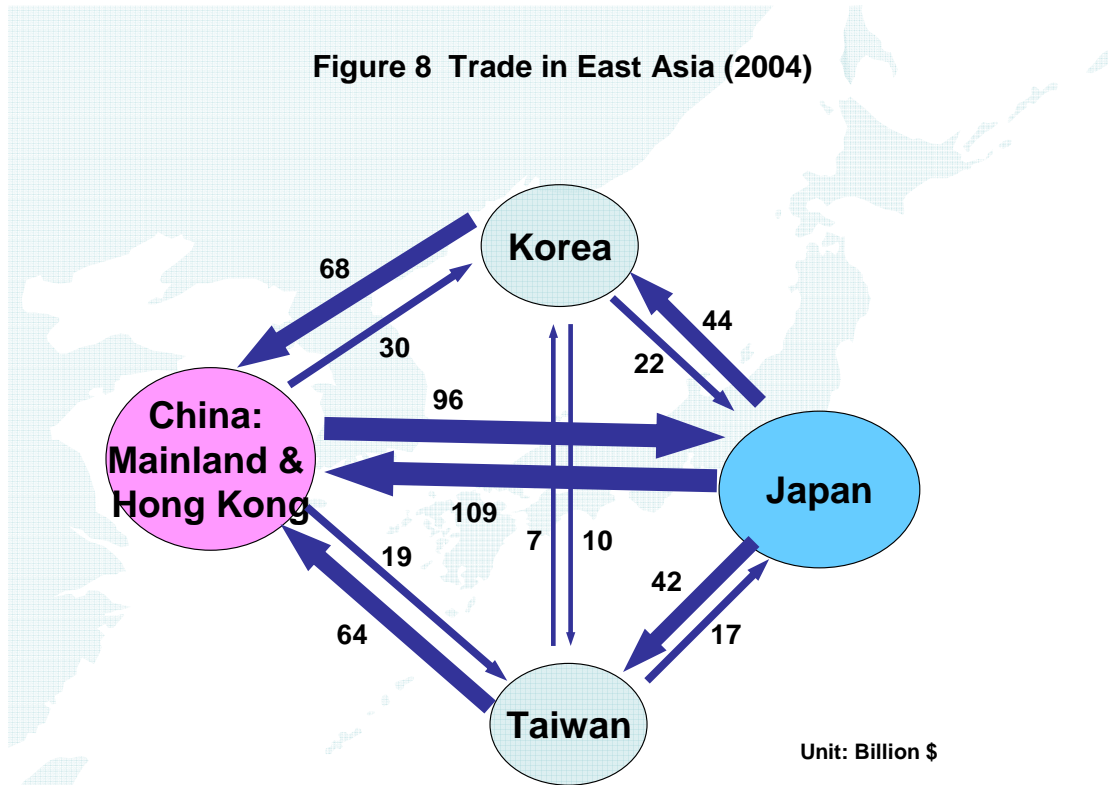
However, Hitachi does not transfer technologies of key components to HLDS. Key components with integral architecture, such as the optical pick-up and the LSI chipset with microcode, have been provided to HLDS from Hitachi of Japan. Figure 7 shows the concept of the architecture based alliance model. Since 2003, only three years after the collaboration started, HLDS has become the leading optical storage manufacturer in the world. Many similar alliances have been seen between not only Japan and NIEs but also between Europe and the NIEs (see Table 1).

4. Economic Growth through International Standardization

4.1. Trade structure in East Asia

The international standardization has accelerated the modularization of the product. Product modularization has promoted the international division of labor and the alliance model described in section 3. We can confirm the development of this new business model in macro by observing the current trade structure in East Asia.

Figure 8 illustrates the trade structure among Japan, Korea, Taiwan, and China. In Korea and Taiwan, there is an excess of exports from Japan, while in China, there is an excess of exports from



both Taiwan and Korea. There is a chain of manufacturing flow from Japan to Korea and Taiwan, and further to China. Korea and Taiwan import key components and manufacturing equipment from Japan, manufacture products using the imported materials, and export their products to China. Low-cost, final products such as the internationally standardized DVD players are assembled in China and exported to the US and European markets.

Although some Chinese manufacturing companies export to advanced countries, the foreign-affiliated firms in China export to the global market from China. Japanese, Korean, and Taiwanese companies have made a huge investment in China (see Figure 9). With the advance of China, the hollowing of the manufacturing industry has become a serious problem even in Korea and Taiwan. However, high-tech products such as LCD panels and semiconductors are still produced in Korea and Taiwan, and exported to China.

LCD and semiconductor companies in Korea and Taiwan depend on foreign companies, especially Japanese companies. For example, major equipment and materials for LCD panels, such as polarizer and color filters, are supplied to Korean and Taiwanese LCD manufacturer by Japanese firms (see Table 2).

Figure 9 Cumulative amount of direct investment in East Asia (2004)

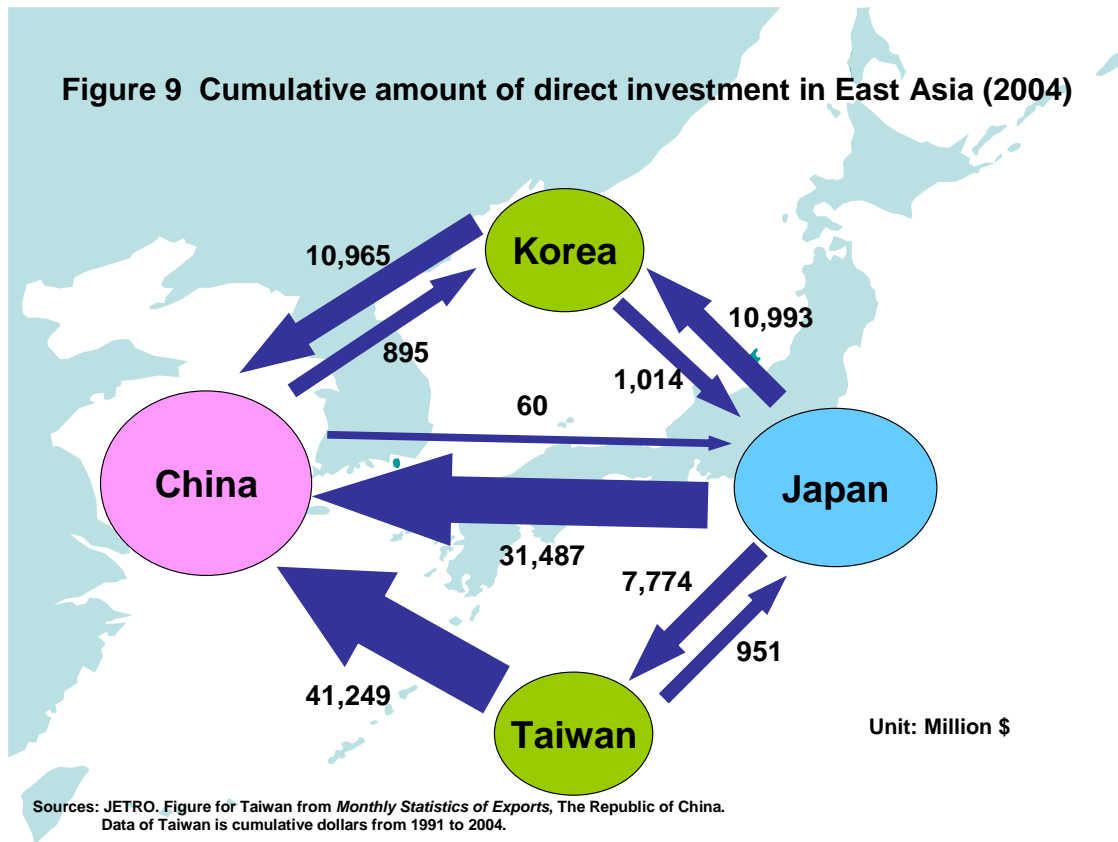


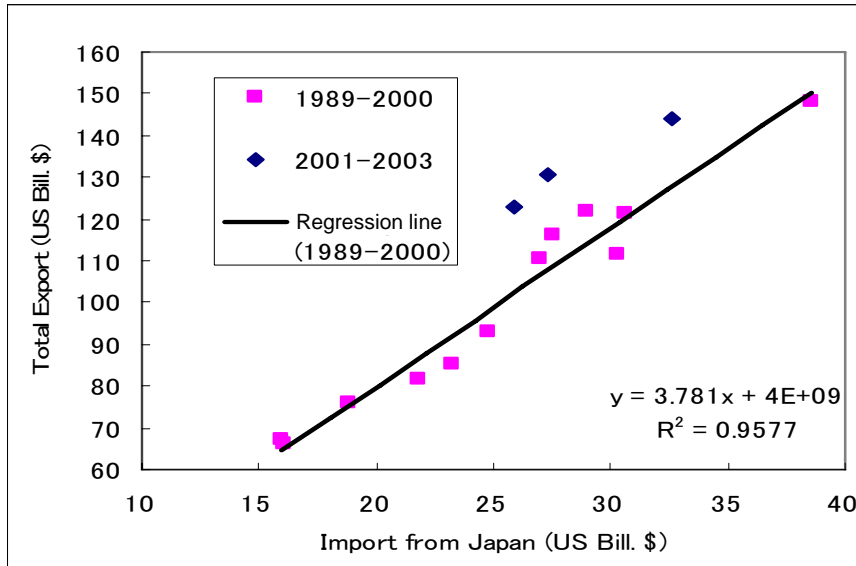
Table 2 Top 3 countries imported from Japan in 2004

Category	Item (6 digit HS code)	First	Second	Third	Top 3 share in total export
IC	Monolithic IC(Digital)	CHINA (18.3%)	HONG KONG (16.3%)	R KOREA (13.5%)	48.1%
	Other MIC	HONG KONG (17.2%)	R KOREA (14.4%)	CHINA (14.0%)	45.6%
	Photoelectric semiconductor and LED ¹⁾	HONG KONG (21.4%)	CHINA (18.1%)	GERMANY (11.7%)	51.2%
	Element doped for electronics industry (discotic and wafer) ²⁾	TAIWAN (28.5%)	U S A (28.1%)	R KOREA (19.8%)	76.4%
	Pattern etching machine for semiconductor material	TAIWAN (45.6%)	R KOREA (17.9%)	U S A (15.9%)	79.4%
	Stepper	TAIWAN (31.5%)	R KOREA (20.0%)	U S A (13.4%)	64.9%
LCD	Sheet and board made by polarized material	R KOREA (36.8%)	TAIWAN (26.7%)	CHINA (21.5%)	85.0%
	Glass (processed)	R KOREA (49.9%)	TAIWAN (25.0%)	CHINA (10.0%)	84.9%
	LCD	CHINA (43.0%)	HONG KONG (11.7%)	R KOREA (11.4%)	66.1%
Steel	Hot rolled and other sheet steel over 10 mm thickness	R KOREA (61.9%)	CHINA (20.3%)	INDONESIA (3.6%)	85.8%
	Hot rolled and other sheet steel between 3-4.75 mm thickness	R KOREA (62.3%)	THAILAND (24.4%)	INDIA (6.1%)	92.8%
	Hot rolled and other sheet steel less than 3 mm thickness	R KOREA (37.6%)	TAIWAN (20.6%)	THAILAND (19.5%)	77.7%
Others	Other machinery (aimed for specific usage)	TAIWAN (27.7%)	R KOREA (21.3%)	CHINA (20.4%)	69.4%
	Other electric quantity meter (no recording device)	R KOREA 27.6%	TAIWAN (26.9%)	CHINA (10.3%)	64.8%
	Printed circuit	CHINA (22.0%)	R KOREA (15.6%)	HONG KONG (10.8%)	48.4%
	Prisms and other optical devices (uninstalled and polished)	HONG KONG (23.3%)	CHINA (22.7%)	R KOREA (16.0%)	62.0%

Note: 1) CCD solar-electric generated element 2) semiconductor wafer, etc.

Source: Based on figures provided at JETRO web page.

Figure 10 Trade structure of Taiwan



Source: Based on figures provided at MOEA (Ministry of Economic Affairs, R.O.C.)web page.

Taiwan has had a consistent trade deficit with Japan even though it has enjoyed a trade surplus for years. The export industry in Taiwan depends on imports from Japan. Figure 10 shows the relation between the total amount of exports from Taiwan, and the amount of imports from Japan. There is a positive correlation between these two.

Similar dependence on Japan is also observed in Korean exports. Korea depends on Japan for the equipment and materials for LCD panels and semiconductors. Korea automakers import the outer steel panels from Japan. The leading export companies in Korea, such as Samsung Electronics, LG, and Hyundai, are also the top importing companies.

4.2. Market Growth and Change of Value Chain

As already mentioned in this paper, product architecture has a huge impact on the speed of catch-up of latecomers. Akamatsu (1962) and Vernon (1966) claimed that the production of new products started in advanced countries and later production was transferred to the low-cost developing countries, as the technology matured. However, they did not mention the effect of modularization or the effect of international standardization on production transfer. As is mentioned in section 2, modularization radically accelerates this transfer process to developing countries and

Figure 11 Change of catch-up process

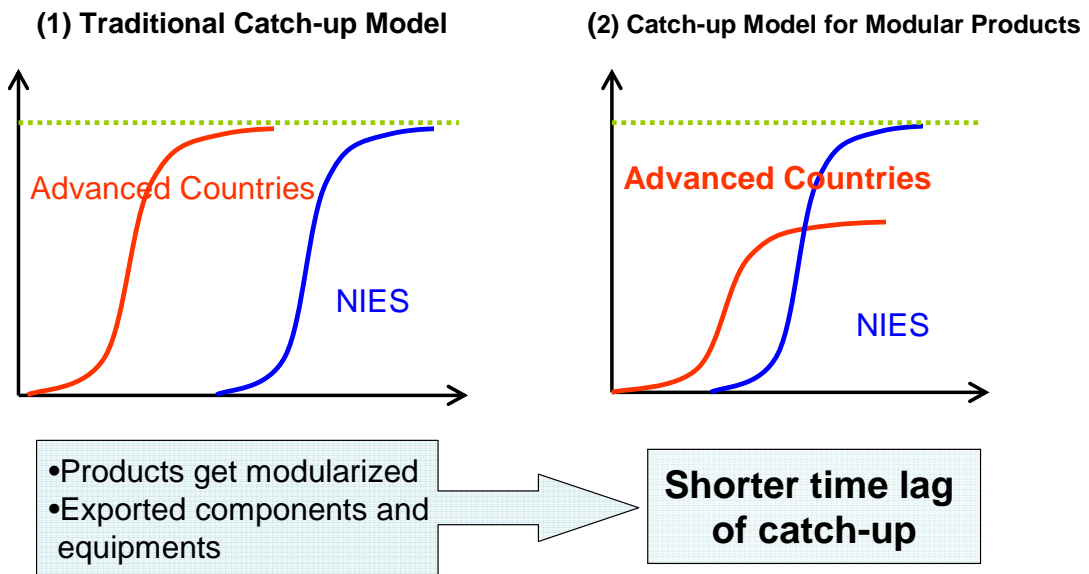


Figure 12 Change of vertical structure: price fall and market growth

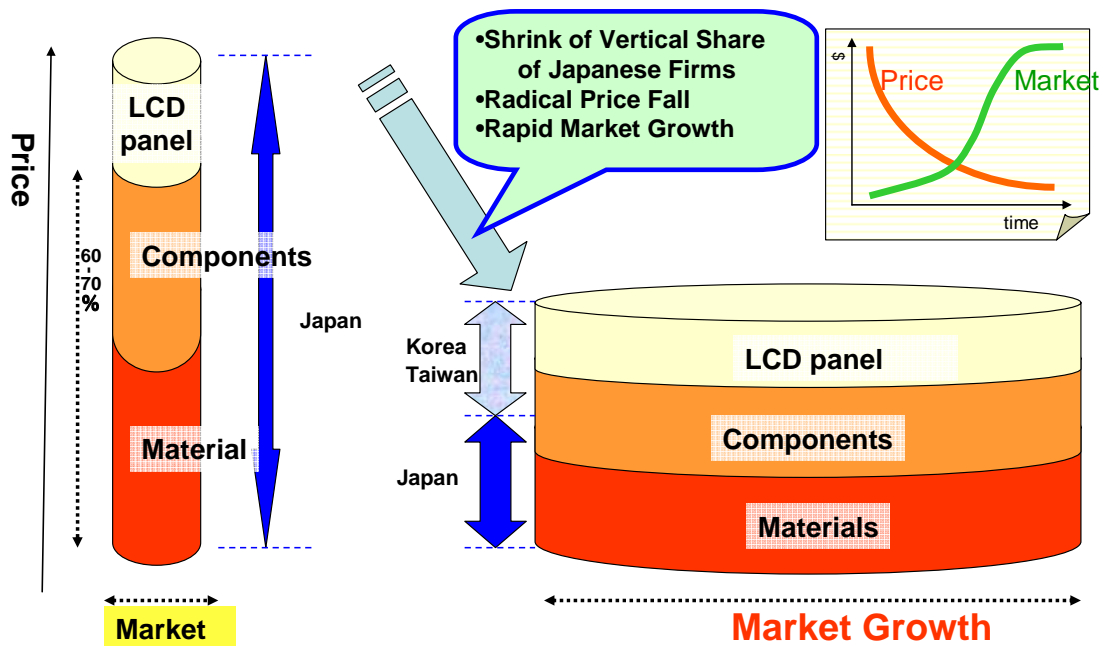
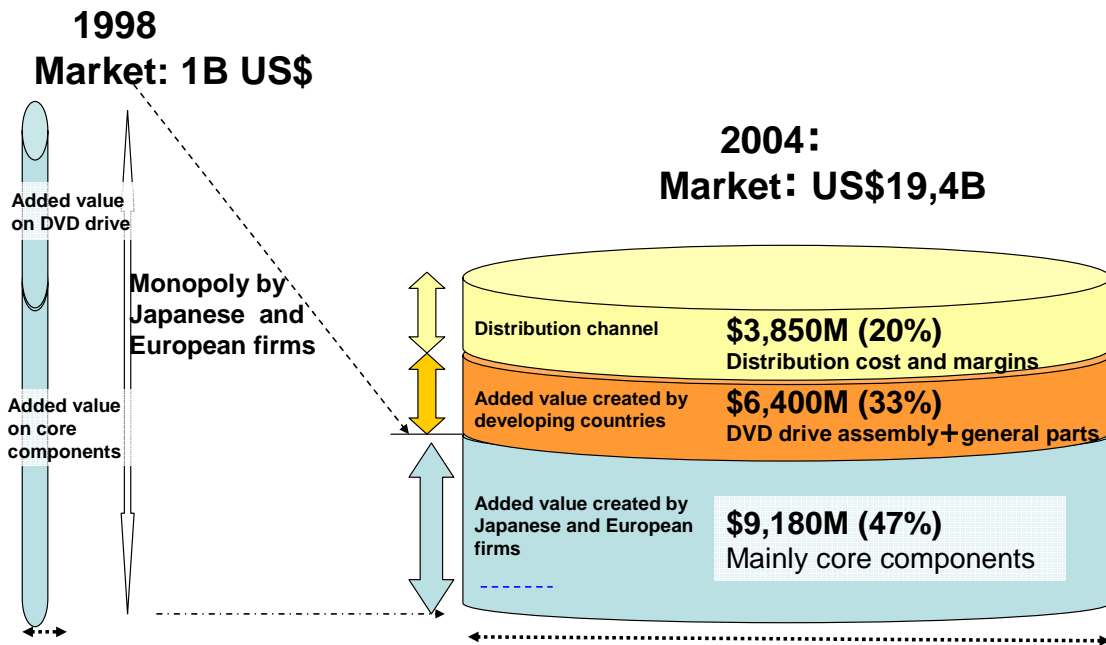


Figure 13 Shift of added value on DVD

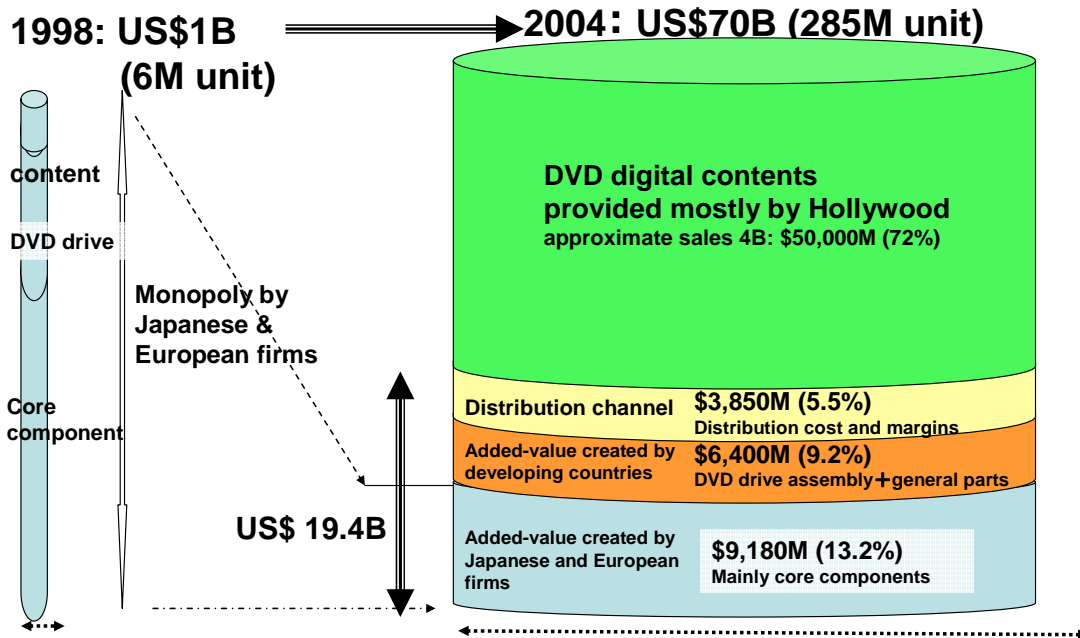


modularization is one of the key drivers for the recent remarkable growth of the Chinese manufacturing sector.

Figure 11 shows these changes in the catch-up process. The left side of the figure shows the catch-up model explained by Akamatsu (1962) and Vernon (1966). The right side of the figure shows that NIEs catch up and overtake the advanced countries. However, as we mentioned, their catch-up is supported by components and equipment from advanced countries in which IP and technical expertise are encapsulated.

However, these changes in the catch-up process do not mean that the economic gain of advanced countries decreases. Figure 12 illustrates the change in economic gain between advanced countries and NIEs in LCD panels. Japanese LCD companies such as Sharp commercialize LCD panels and dominate all business in a vertical chain in the early phase of industry. Technological progress drives the modularization of production and technical expertise is encapsulated production equipment. This modularization makes it easy for Korean and Taiwanese companies to enter the LCD panel industry. One of the most important factors for success in LCD industry is huge investment for large plants. Their entries caused fierce price competition. The price of LCD panels radically

Figure 14 Content market generated by DVD



decreased and a huge market emerged. Recently the share of Japanese firms in LCD panels has been decreasing, while the share in equipment and materials still quite large. The share of Japanese firms in the vertical chain has decreased. However, the total amount of Japanese economic gain is still increasing because of the total market growth.

These changes in economic distribution between the advanced countries and NIEs have been observed in various industries. Figure 13 gives a concrete example of the DVD. The DVD market was only 1 billion dollars in 1998, when Japanese and European firms dominated the market. After the entry of NIEs companies, the market grew rapidly to 19 billion US dollars in 2004. In the vertical value chain, the portion of components is estimated at 47%. The market for components (9 billion US dollars in 2004) is still dominated by Japanese and European firms and is almost nine times the total market in 1998.

Additionally, the large installed base of DVD players has generated an even larger content market, as illustrated in Figure 14. Around four billion pieces of DVD media containing content such as movies were officially sold in 2004. This content market, equal to about 50 billion US dollars, is more than double the DVD hardware market. The DVD content business was dominated by US movie companies. DVD sales are up to 47% of their total sales in 2004 and DVD division is the

biggest sales division for US movie companies. They are very interested in the international standard for the next generation of DVDs, although they have never manufactured DVD players. They are also a key player in the industry and enjoy the large economic gain.

5. Concluding Remarks

We have described the economic impact of international standardization using a framework of architecture. Focusing on the optical storage industry, we have described in detail the process by which the modularization of products and international standardization induce many entrants from NIEs and that entry causes fierce price competition and rapid market expansion. Next, we suggest a new type of business model based on international standards. The division of labor between advanced companies and developing companies and their collaborative business model is described. Finally, we have discussed the economic growth model based on the modularization and international standardization. Advanced countries and NIEs have been able to share the economic gain and collaboratively generate a larger market. International standardization could contribute to global economic growth. However, an adequate process of international standardization would be needed for this economic gain to be fully realized.

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