

## **[JP] Mayumi TABATA**

### **Contact Information**

Address: 5F-2, No.6, Lane 35, Fuyang ST., Sinyi District, Taipei City 110, Taiwan.

Telephone:

Fax:

Mobile:

Email Address: mayumi@mail.ndhu.edu.tw

d89325002@ntu.edu.tw

Homepage:

Mayumi Tabata is a Assistant Professor in Department of Social Development, National Dong Hwa University (Taiwan)

Highest Degree: Ph.D. in Sociology, National Taiwan University (2008)

Specialty: Economic Sociology, Industrial Sociology, Social Network, Organizational

His recent Published works include:

(1) Mayumi,Tabata, 2008, “Social Networks and Culture Gaps in IC Industry Collaboration between Taiwan and Japan” Asia-Pacific Forum, No.39, pp. 230-262, Center for Asia-Pacific Area Studies, RCHSS, Academia Sinica, Taipei,Taiwan.

(2) Mayumi, Tabata, 2006. “Network Structure and Cross-National Knowledge Diffusion: Comparative Analyses between Taiwanese IC and TFT-LCD Industry” Soochow Journal of Sociology, No. 20, PP. 109-148, Soochow University, Taipei, Taiwan.

## **“Competition and Cooperation between Taiwanese High-tech firms and Japanese Counterparts: Technological Knowledge Introduction Mechanism of Taiwanese TFT-LCD industry”**

**[JP] Mayumi TABATA**

**Abstract:** The purpose of this paper is to explore the knowledge introduction strategy of Taiwanese TFT-LCD (Thin Film Transistor Liquid Crystal Display) manufactures in the international competitive and cooperative relationships of the LCD (Liquid Crystal Display) industry in order to reveal the transformation process of dependency between Taiwanese TFT-LCD industry and Japanese counterparts. This study asks how Taiwanese firms were able to develop a strong competitive power in TFT-LCD market despite their inferiority relative to Japanese firms in technologies. The logic of world system and dependency theory is a suitable theoretical basis to argue the transformation of power relationships between core firms and peripheral latecomer firms in competitive international high-tech industry. This research intends to demonstrate catch up process of Taiwanese TFT-LCD firms that the logic of world system and dependency theory was not able to predict. Specifically, in order to grasp the dynamic transformation process of the power relationships among international LCD industry, I attempted to shed light on the knowledge introduction strategy so as to investigate how Taiwanese firm overcome technological dependency and improve efficiency of learning in their flexible cross-firm boundary mobility of technical personnel.

**Keywords:** catch-up strategy, world system, dependency theory, TFT-LCD industry, technological knowledge introduction, mobility of technical personnel

### **Introduction**

Introduction of foreign key technologies is the most efficient strategy of catching up with the global technological trend and the developed economies for underdeveloped country. At first, Taiwanese TFT-LCD industry did not have its own independent research and development, however, in the past almost 10 years, Taiwanese related firms introduced key technologies from Japan smoothly, and absorbed new technology within a short period of time. Despite the reluctance of technological transfer by Japanese electronics giants, how did Taiwanese TFT-LCD industry successfully complete to learn new technology? What is

the main reason that Taiwanese TFT-LCD industry's output and shipping volume exceeded Japanese and Korean counterparts, and became world largest TFT-LCD manufacturer? Especially, TFT-LCD industry was Japan's specialty, Japanese electronics giants introduced basic technology related LCD from U.S. and it took almost twenty years for them to develop mass production technology. Until late-nineties, we would almost say that Japan was a core country of TFT-LCD industry whether production volume or shipping volume. However, at this moment, Taiwan moved from the semiperiphery country to core country in TFT-LCD industry. How did this upward mobility happen? What is the main driving force that made Taiwanese firms be able to transform their power relationships between Japanese counterparts despite their inferiority relative to Japanese firms in technology? I attempted to investigate this transformation process of dependency between Taiwanese TFT-LCD industry and Japanese counterparts from knowledge introduction strategy, knowledge flow and diffusion perspective. As management scholars pointed out, neoclassical economists' assumption that any companies in every country can secure equal access to the technological knowledge in global knowledge exchange market is a mistake. Technological knowledge is imperfectly diffused over time and across actors, firms, and industries. Every state and firm therefore must construct their own knowledge introduction strategy( Almeida, 1996; Almeida and Kogut, 1999; Hakanson and Nobel, 2000; Rosenkopf and Almeida, 2003, Stolpe, 2002 ). My question is how Taiwanese TFT-LCD industry established its own cross-national knowledge introduction strategy and increase competitive ability of learning to transform its semiperipheral position into core position in the current large size TFT-LCD market. In order to answer this question, I had depth interviews with Taiwanese TFT-LCD manufacturers and Japanese related firms in Taiwan during 2003 and 2004. From 2004 to 2005, I also conducted field research of Japanese electronics manufacturers in Tokyo city, Osaka city, Nara prefecture and Kanagawa prefecture. Additionally, I launched field research of Taiwanese LCD parts manufacturers and Japanese counterparts in Taiwan during 2004 and 2005.

The paper is organized as follows. First, I will review theoretical background on world system approach and show the limitation of dependency theory in the cross-national learning network of Taiwanese industry. Second, I will overview Taiwanese firms' catch-up process in TFT-LCD Industry. Third, based on my field study, I argue government-initiated technological development and the process of technology introduction from Japan in Taiwanese TFT-LCD industry. It is also suggested that the technological knowledge introduced from Japan flowed and diffused in Taiwanese whole TFT-LCD industrial world within an extremely short period of time. The final section summarizes the discussion and highlights the knowledge introduction strategy of Taiwanese TFT-LCD industry from the role of government and flexible inter-firm mobility of technical personnel point of view.

## **Departure from Dependence on Technological Core Country**

With regard to the economic growth of developing countries, dependency theory and world system theory is often introduced as an appropriate theoretical starting point for further testing empirical aspects. Dependency theory suggests that the control of peripheral group of developing countries and reproduction of wealthy by the core states is fundamental to the discourses and practices of world system. Underdevelopment is the consequent of expanding global capitalism and its internal contradiction (Amin, 1974; Frank, 1967;1974). Wallerstein(1974) also sharply criticized traditional Marxist thought in underdevelopment, and tried to explain social world from historically specific totality. He runs counter to the orthodox version of Marxism that claimed linear and evolutionary development path of underdeveloped country, and pointed out that economic structure of underdeveloped country is not an earlier stage in the transition to developed country. Instead, it is involved in the system of world-economy as peripheral country (Wallerstein, 1974).

From the 1970s until now, many empirical studies have been conducted to examine the context of system of dependency. Volker, Chase-Dunn and Rubinson focused on the assumption that dependence retards development, and verified the process that foreign investment and foreign aid caused slow economic development and income inequality (Chase-Dunn, 1975; Volker, Chase-Dunn and Rubinson, 1978). In recent years, similar notion was passed on to the theory of economic globalization, for example, the relationships between multinational company and global division of labor (Dicken, 1998, Dicken and Yeung, 2001), the theory of global commodity chain (Gereffi, 1994). Gereffi pointed out that dependency theory is applicable to the East Asian economies including South Korea, Hong Kong, Taiwan and Singapore as well as Latin America. East Asian economies just handle “dependency management” in the better way than Latin America. Specifically, East Asian peripheral firms are playing an international-subcontracting role in the global commodity chain and control the production stage of the finished-consumer-goods. However, more profitable export, distribution, and retail marketing stages are controlled by core capital, such as American, European and Japanese Transnational Corporations (TNCs) in the world economy. Gereffi also mentioned that Taiwanese producers tried to make the transition to the high-value-added field of product innovation. However, without their own internationally viable company brand names, distribution channel, it will be difficult to move away from the international subcontracting role (Gereffi, 1989).

Thus continuing discussion and empirical examination on the system of dependency had been carried out in the past 40 years. However, some scholars had paid attention to the phenomenon in East Asian countries whose experience seems in conflict with dependency theory. According to a study by Barrett (1982), Taiwan has received massive foreign

investment and foreign aid, however, it has maintained sustainable, stable economic growth and its income inequality also decreased to a large extent. In terms of Gereffi's dependency relationships between core brand companies and peripheral subcontracting firms, empirical study results of Taiwanese industrial development provided new perspective to become free from dependency theory. Hsu and Cheng pointed out that international brand companies and Asian local subcontracting firms are establishing mutually supportive collaboration networks. Their relationships are no longer unequal and unilateral dependency. Instead, they are constructing interdependent relationships. Specifically, core companies' operation is impossible without peripheral OEM (original equipment manufacturer), ODM (original design manufacturer) and other subcontracting firms' cooperation (Hsu and Cheng, 2001). In the analyses about the survival strategy of Taiwanese Automobile industry, Cheng also pointed out that global competition among international brand firms is significant condition that accelerates cooperation between core brand firms and peripheral OEM and ODM firms. International outsourcing or subcontracting has now undoubtedly become the most effective strategy for brand companies in order to reduce cost and overcome reduced demand caused by downturn in economy (Cheng, 2007).

Global network theorists also provided us similar perspective against the context of dependency theory. As mentioned above, the relationships between core brand firms and peripheral subcontracting firms are not also competitive but also collaborative in the global market. In this transformation process of relationships, Taiwanese IC (Integrated Circuit) firms have upgraded the level of technology through cross-national collaboration learning network (Jou and Chen, 2001). Chen (2008) also pointed out that Taiwanese open inter-firm organizational network structure boosted cross-national collaboration relationships with American and Japanese IC related firms.

### **Taiwanese Firms' Catch-up Process in TFT-LCD Industry**

The history of LCD industry started in 1888. When Austrian botanist F. Reinitzer researched plant crystallization characteristics, discovered the existence of crystallization liquid (liquid crystal). In 1968, RCA research institute successfully applied the technology of liquid crystal to the manufacturing of monitor. At that time, Japanese consumer-electronics giants, for example, Hitachi, Ltd, Mitsubishi Electric Corporation, NEC Corporation have not started any liquid crystal related research. However, their research institutes were introducing liquid-crystal display related technological information from academic literature or RCA research institute directly. In 1969, some researchers in Sharp Corporation (one of the Japanese consumer-electronics giants) watched the TV program "the world enterprise" in NHK (Japan Broadcasting Corporation), and noticed that RCA developed liquid-crystal display. In 1973, Sharp succeeded in developing mass production technology of TN-LCD for the first time in the world. TN-LCD is a

monochrome twisted nematic liquid crystal display, and it is mainly used on telephone, facsimile machine, digital watch. However, its panel size is just only in 2 inches below.

Liquid-crystal display evolved from TN-LCD to STN-LCD during the 1980's. STN-LCD is super-twisted nematic liquid crystal display, and this is the world first color panel that unifies glass panel and color filter. At first, STN-LCD was used in industrial instrument, electronic dictionary. However, in the early 1990's, its size expanded to 10-inch above, STN-LCD came to be used in monitors of laptop computer and notebook computer. In 1993, NEC Corporation released 10-inch TFT-LCD priced at below 950 US dollars, and traditional CRT display was substituted by the TFT-LCD gradually. TFT-LCD is different from passive matrix drive system display, for example, TN-LCD as well as STN-LCD, it belongs to active matrix drive system. Matrix drive system display does not use multiplex drive design, but transistor activates picture element, and color filter is equipped in each picture element of TFT-LCD. Transistor activates and controls display's voltage directly, thus, quality of moving images, color, contrast, rapid reaction and viewing angle characteristics are better than STN-LCD (Hong and Lu, 2001; Wang, 2003:58-102).

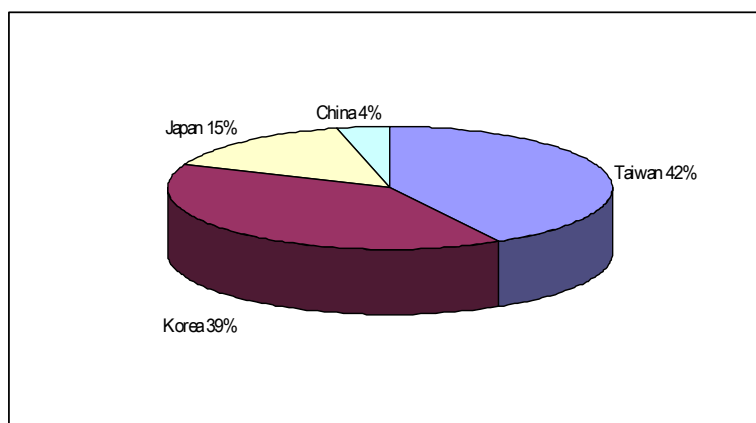
The development of Taiwanese LCD industry started during the late 1970s. In 1976, chairman of Jing Ye Electronics Corporation (Taiwanese electronics manufacturer), Zhou Tian Xiang introduced technology from Hughes Aircraft Company through Li Yi Shi who worked for Hughes Aircraft Company, and started cooperative production of TN-LCD for digital wristwatch. However, in Taiwanese LCD industry, almost all firms were small business from the 1970's to the 1980's. Some firms introduced experimental or basic research technology from American companies, because of the lack of funding and experienced engineers, they were unable to transform these experimental technologies into mass production technologies. In 1980, Lin Wen Bin who worked for Honeywell invested 50,000 US dollars set up Polytronix, started to produce special purpose LCD. In 1991, Taiwan's Picvue Electronics took over Polytronix, and introduced STN-LCD mass production technology from Polytronix. Later, some of engineers in Picvue Electronics went work in another STN-LCD manufacturer such as Wintek, Giantplus Technology, and TFT-LCD manufacturer such as CMO, AUO. Key technologies of LCD flowed and diffused into follow-on Taiwanese LCD firms through job transfer of engineers in Picvue Electronics. In the 1980s and the 1990s, although Japanese electronics manufacturers did not transferred advanced TFT-LCD technology to Taiwanese LCD related firms, however, Taiwanese LCD industry merged the technology that was accumulated by Taiwanese entrepreneurs and engineers in US and Taiwan local technology, and established the initial technology base of LCD industry (Wang, 2003:105-113).

In 1997, Asian economic crisis had negative influence on the world economy, and Japanese LCD industry confronted South Korean counterparts' catch up phenomenon. Therefore, Japanese LCD related firms started to collaborate with Taiwanese counterparts to avoid catch up by Korean firms. Especially, from 2000 to 2003, competitive relationships

between Japanese LCD related firms and Korean counterparts accelerated technology transfer from Japanese LCD firms to Taiwanese counterparts. In 1997, ADI (affiliated business of Japan's Mitsubishi Electric Corporation) and CPT (Taiwanese TFT-LCD manufacturer) concluded collaboration agreement of third generation TFT-LCD technology. In 1998, Acer Display Technology (affiliated business of Taiwan's Acer Group) introduced 3.5 generation TFT-LCD technology from IBM Japan, and in 1999, Hannstar (Taiwanese TFT-LCD joint business that was launched by Winbond<sup>1</sup> and Walsin group<sup>2</sup>) successfully introduced technology from Japan's Toshiba (Japanese electronics manufacturer). In 2000, Acer Display Technology adopted MVA (Multi-domain Vertical Alignment) technology from Fujitsu (Japanese computer manufacturer), made breakthrough in large size TFT-LCD production (Wang, 2003:187-205).

As a result of high production cost and labor costs, currently, Japanese electronic big companies such as Mitsubishi Electric Corporation, Toshiba, Hitachi, NEC have not been able to manufacture large size TFT-LCD in Japan. Besides Sharp (Japanese TFT-LCD leading company), other Japanese electronics manufacturers withdrew continuously from large size TFT-LCD business, and started to switch into the middle-sized TFT-LCD business. Therefore, in the whole of Asia, just only South Korean and Taiwanese related firms invest in large size TFT-LCD industry aggressively during recent years. According to iSuppli (American market research firm) statistics, South Korean shipping ratio of large size TFT-LCD is 45.96% in 2004, and Taiwanese shipping ratio also reached 43.84%. However, Japan's shipping ratio went no further than 10.07% (iSuppli market report, 2005/5/02). Taiwan has grown to the world largest TFT-LCD supplier in terms of production volume and shipment, dominating 42% of the global TFT-LCD and module packaging market in 2007, knocking off South Korea's 39 percent (PIDA Online Monthly, February, 2008).

Figure1: Global TFT-LCD Panel Market Share



Source: PIDA, 2008/01

[http://www.pida.org.tw/pidapost/200802/080201d\\_web.htm](http://www.pida.org.tw/pidapost/200802/080201d_web.htm)

- 1 Winbond Electronics Corp is a Taiwanese major IC manufacturer founded in 1987.
- 2 Walsin Lihwa group is Taiwanese manufacturer of aluminum conductor cables founded in 1966.

## Technological Knowledge Introduction Mechanism of Taiwanese TFT-LCD industry

**Government Support and Technological Introduction**

As previously mentioned, after confronted with Korean LCD industry's catch-up phenomenon, Japanese electronics manufacturers actively started to transfer TFT-LCD related technology to Taiwanese counterparts. It is particularly worth noting that Taiwanese government research institute, Industrial Technology Research Institute (ITRI) improved the level of basic research of LCD technology introduced from U.S. firms, and transferred basic technology to private LCD firms, before the acceleration of technology transfer from Japanese electronics manufacturers. Factory manager of TFT operation department TI factory in CPT (Taiwanese TFT-LCD manufacturer) explained:

ITRI is a public research institute financed by Taiwanese government. But, the type of technology that ITRI is developing is not applied and mass production technology, but basic and experimental technology. So, ITRI is able to produce sample model of TFT-LCD, however, engineers in ITRI cannot guarantee stable yield ratio. Specifically, under ITRI's basic technology, when we produce 100 sheets LCD, just only under 90 sheets are available for use. However, under Japanese firm's mass production technology, over 90 sheets are non-defective products. If we produce 100 sheets LCD, as long as over 90 sheets are available for use, our plant will be profitable. After Japanese firms started to transfer related technology to Taiwan, ITRI also introduced mass production from Japan. I mean, ITRI established necessary commercialized technology by learning American basic technology and Japanese mass production technology. Taiwanese TFT-LCD industry needed both basic and mass production technology in the initial stage of development. (T-T1)<sup>1</sup>

As factory manager in CPT mentioned, Japanese firm's mass production technology played a crucial role in an early phase of Taiwanese TFT-LCD industrial development. However, improvement of U.S. firm's basic and experimental technology by ITRI is the significant precondition for effective learning of Japanese technology. At the beginning, CPT introduced experimental technology from ITRI and successfully produced sample product. Upon a solid basic and experimental technological foundation, technical personnel in CPT learned Japanese mass production technology smoothly and established process technology of large screen size TFT-LCD. Like the process of cross-national technological introduction in Taiwanese IC (Integrated Circuit) industry, returnees from U.S (Taiwanese engineers and entrepreneurs who have job experience in U.S. LCD firms) also performed significant role in TFT-LCD industry's foreign technological knowledge introduction and

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<sup>1</sup> Each quotation from an interviewee in this paper was given a code to mark the source of information. The first letter of the code refers to the main product grouping of the company interviewee belongs to. The following letters stand for the country of the interviewee. The Arabic numbers refers to the serial number of interviewee.

diffusion. Taiwanese government supported the basic and experimental technology development of private LCD firms founded by returnees from U.S. through ITRI. In Taiwanese LCD industry, the exchange of human resources between ITRI and private firms is extremely frequent, for example, the vice president of TPO Displays (LTPS manufacturer) was former vice president of ITRI in the start-up period. TPO Displays has a high proportion of technical personnel and executives transferred from ITRI. (T-T1)

According to my research about the mobility of human resources from Japan to Taiwan, recruitment of Japanese knowledge workers is popular in Taiwanese TFT-LCD industry. Taiwanese government (ministry of economic affairs) also supports local TFT-LCD firms' looking for Japanese technical personnel and executives in Japanese major electronic manufacturers through Industrial Technology Research Institute Tokyo Office (Taiwanese government affiliated research institute)(Tabata, 2008). Thus, Taiwanese government accelerated foreign technological knowledge introduction in TFT-LCD industry through the support for basic technological development and recruitment of Japanese knowledge workers.

### **Flexible Inter-Firm Mobility of Technical Personnel and Knowledge Diffusion**

As preceding section shows, government are taking an important facilitating role in the process of foreign technological knowledge introduction of Taiwanese TFT-LCD industry. In this section, I focus on the knowledge flow and diffusion process after the introduction of foreign technological knowledge. Japanese electronics manufacturers took about 20 years to develop their mass-production technology and built up their whole manufacturing system. However, Taiwanese TFT-LCD firms took only about 5 to 10 years to introduce and learn Japanese mass-production technology and established their own large size TFT-LCD production system. Chen's study shows that foreign technology introduction, technology diffusion and innovation occurred at the same time in the development model of Taiwanese TFT-LCD industry. More specifically, as soon as local firms introduced a key technology from a foreign country, this technological knowledge would quickly diffuse among Taiwanese TFT-LCD industry and related technological innovation was immediately launched by local firms(Chen, 2008). Possible reason is advantage of backwardness proposed by Gerschenkron(1962), Taiwanese TFT-LCD firms were able to save time to develop their commercialized technology through introduction of Japanese mass production technology. However, I think that frequent mobility of experienced engineers in local high-tech industry also boosted rapid and efficient foreign technological knowledge flow and diffusion in the whole TFT-LCD industrial world.

CPT is the first successful Taiwanese firm to introduce Japanese TFT-LCD mass

production technology. However, the first Taiwanese LCD firm undertook research and development of TFT-LCD was Prime View International (Taiwanese small/medium TFT-LCD panel company). Prime View was founded in 1992, and constructed the first TFT-LCD mass production factory in Taiwan. Unlike CPT, Prime View did not have any opportunity to introduce mass production technology from Japan. Therefore, engineers were enthusiastic about addressing to transform basic technology introduced from U.S. firms into mass production technology for their selves. Though it was a difficult going, they could accumulate know-how and knowledge of technological development through a trial and error process. These engineers who experienced and accumulated knowledge about TFT-LCD technology development went to work in another TFT-LCD related start up large companies, accelerated technological knowledge flow and diffusion in the whole Taiwanese TFT-LCD industrial cluster through frequent mobility of technical personnel. As Director of administration division in Prime View explained:

Why did Taiwanese high-tech industry achieve rapid development in such a short time? I think, the main reason is rapid manpower mobility. Just like bees carry pollen from flower to flower, shed pollen everywhere and help trees to yield more abundant fruits. In addition, Taiwan is a small land area, especially, a number of high-tech firms are concentrated in Hsinchu Science Park, such a small industrial cluster. In this closed industrial cluster, colleagues are closely connected, and inter-firm social relationships among engineers are also close interaction. A cross-firm boundary knowledge exchange is very frequent. (T-T6)

Hsu pointed out that the frequent mobility of human resources is also a behavioral norm in Taiwanese IC industry (Hsu,1999). Unlike in the case of Japanese norm, in Taiwanese high-tech industry's labor market, switching jobs is not seen as a bad habit of employees, but an opportunity of skill improvement. According to the news report of Commercial Times (2001/3/07), every time new high-tech industry starts to take off, related firms confront serious shortage of experienced engineers in Taiwan. Therefore, latecomer conventionally headhunts skilled technical personnel from firstcomer. In germination term of TFT-LCD industry, firstcomers, such as Prime View and UNIPAC (affiliated business of Taiwan's UMC), introduced a number of engineers from IC industry. Then, these technical personnel who accumulated experience and know-how of TFT-LCD technology went to work in latecomers, for example, CPT and Acer Display Technology. Emerging TFT-LCD firms that were subsequently established, Quanta Display and Toppoly Optoelectronics headhunted experienced engineers from CPT. Thus the mass production technology of TFT-LCD was rapidly flowed and diffused in Taiwanese TFT-LCD industry through the cross-firm boundary mobility of technical personnel, and TFT-LCD firms did not need to introduce mass production technology from Japan after 2003.

## Conclusion

The context of system of dependency led us to infer that the economic structure of underdeveloped country is involved in the system of world-economy as peripheral country. The system of world-economy is a quasi-static process, peripheral and semiperipheral countries rarely get the chance to transform the power relationships with core country in the global market. The case of Taiwan, however, goes against the theory. Taiwanese TFT-LCD industry successfully introduced mass production technology from Japan, and established its manufacturing system in a short period of time. Finally, Taiwanese TFT-LCD industry has become the world largest TFT-LCD supplier, surpassing Japanese counterparts.

How did this power transformation between Taiwanese TFT-LCD firms and Japanese counterparts happen? One possible conclusion is that Taiwanese government support and flexible inter-firm mobility of technical personnel accelerated foreign technological knowledge introduction and its diffusion. Taiwanese government facilitated foreign technological knowledge introduction through the support for basic technology development and recruit of Japanese knowledge workers. Frequent inter-firm mobility of experience engineers in local high-tech industry boosted rapid and effective foreign technological knowledge flow and diffusion in the whole TFT-LCD industrial cluster.

This study has taken a first step in the direction of analyzing the power transformation process between technological core country and peripheral counterparts. It is possible of course that other high-tech industrial segments that Japanese firms have still competitive advantage might produce very different results. For example, both in terms of production value and shipment, Japan-made liquid crystal material, component, manufacturing equipment dominate in global LCD market.

The approach designed in this study should be conducted in other high-tech industry as well as in other area's power relationships between core and semiperiphery (Japan and Korea, Japan and China), in order to develop an understanding of power transformation mechanism in global competitive market.

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