RIETI Discussion Paper Series 07-E-029

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RIETI Discussion Paper
April 28, 2007

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I am indebted to Thomas Murtha and Stefanie Lenway for their insights into this topic through several years of research collaborations. I would also like to thank Tsuneo Yahagi, Susumu Sanbonmatsu, Yukihiko Nakata, Susan Wang, Masato Hisatake and other members of our RIETI study group for providing insights and comments on the earlier version of this manuscript.

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Abstract

Japan's dominance in TFT-LCD production share has weakened over time, while Korea and Taiwan have taken over the leading positions. After reviewing conventional wisdom regarding the factors influencing the decline in Japan's production volume, we reframe the entire issue from the perspective of "metanational" learning. Success behind Korean and Taiwanese firms lies in the fact that they have adopted the metanational approach: learning knowledge from Japan and adopting the global best-supplier policy for equipment and materials, regardless of nationality (e.g. Samsung). We argue that the relevance of the metanational approach (as opposed to the domestic "black box" approach) is determined by the competitive advantage of home country/industry and company. While this approach is generally considered appropriate for firms that are trying to overcome their home country disadvantages, we argue that the metanational approach remains appropriate for firms which need to cope with eroding country and industry competitiveness, such as Japanese firms in the TFT-LCD industry.

1. History and background

Japan enjoyed early dominance – 95% or more market share – when the high volume, large format industry launched in 1990. Since then, Japan's dominance in market share has weakened over time, with Korea and then Taiwan gaining parity and then vying for leadership. In the same period, no appreciable production volume emerged in the U.S. Japan lost momentum; its market share plummeted to less than 15%. Both Korea and Taiwan have gained a market share as high as around 40% each. What is the explanation for this turn of events, which many find surprising?

Figure 1 summarizes the trend of national market shares, 1993-2005.

--- insert figure 1 about here ---

There are various explanations within industry and academia, all of which may contain a certain amount of truth. We will show in this paper that a critical aspect of the problem has been overlooked, in particular, a knowledge-based perspective. And if we don't take such a view, public and corporate policy responses to global technology/innovation diffusion currently under discussion in Japan as well as many other countries could take a serious wrong turn, much as U.S. policy toward the TFT industry did in the 1990s.

We first look at different explanations of the factors influencing a decline in Japan's leadership, at least in terms of production volume. To do this, we summarize conventional wisdom in the industry, and present an alternative view by drawing on a knowledge management perspective. Finally, we draw implications for managers and policy-makers.

2. Why Japan declined: Conventional wisdom

In this section, various explanations of Japan's decline in market share are offered, largely based on conventional wisdom:

2.1. Japan's recession

Japanese companies lost their nerve during the Asian financial crisis because they did not have sufficient capital and thought industry too risky. They decided to relocate downstream (manufacturing) to low-cost Asian countries. No third-generation fab investments were made after Sharp and Display Technologies Incorporated (DTI), the IBM-Toshiba manufacturing alliance, followed by Hitachi's Gen. 3.5. Diversification of Japan's large electronics companies in the '80s impeded decision-making, as quite a few senior managers – or so-called *salarii-man keieisha* (salaried managers) – often cannot understand all of the businesses in their charge. Japan's notorious consensus orientation, as opposed to the more centralized decision-making in Taiwanese and Korean firms, slowed the pace of generational changes and outstripped abilities of Japanese firms to make decisions to allocate the huge resources needed to build new fabs. Taiwan and Korean firms had better access to capital: because of giant *chaebol* for Korea, and loose equity markets for Taiwan. Japanese companies may also have been concerned by the continuing evolution of alternative technologies, especially PDP, which could compete with TFT for the future flat-panel TV market.

2.2. Oligopolistic reaction vis-à-vis the Taiwanese market

Korean firms emerged as close followers to Sharp, DTI, and Hitachi in implementing 3G technology when no Japanese companies would follow. They built capabilities on the "Seoul Express" of weekend moonlighting Japanese scientists. Japanese producers responded by aggressively, intentionally transferring technology to Taiwanese firms. Mitsubishi Group member ADI, a joint FPD production venture between Asahi Glass and Mitsubishi (Murtha et al. 2001), was among the first, choosing, because of the lack of capital, to sponsor 3G in Taiwan in collaboration with Chunghwa Picture Tubes (CPT)

rather than build in Japan. It trained many Taiwanese operators and engineers at the facilities in Japan. Japanese companies had been resisting technology transfer with Taiwan until then. But once ADI moved in 1999, everyone rushed to follow.

The whole trend was triggered by the Asian financial crisis: IMF financial crisis in 1998 made Korean firms to secure sufficient financial resource. Mass-production of TFT-LCD by Korean firms lowered the price, which made the Korean product price-competitive and penetrated the Taiwanese market. Japanese firms' market share in Taiwan plummeted. Korean-made DRAM also penetrated Taiwan at that time. Japanese firms, including Mitsubishi, Toshiba, IBM Japan, Sharp, and Matsushita, were forced to start producing TFT-LCD locally, and transferred technologies to local partners.

Transferred labor and knowledge from related industries also facilitated Taiwan's surge: experience from the foundry business in the semiconductor industry was useful for enhancing its manufacturing capability; upgrading manufacturing knowledge, from OEM to ODM, then to EMS; extended know-how gained by the semiconductor industry, which is useful and applicable to the early phase of TFT-LCD; and migration of capable people from the semiconductor to the TFT-LCD industry due to recession in 2001 was also helpful (Shintaku 2006).

2.3. Strategic intent of Korean and Taiwanese firms

Taiwanese and Korean firms took a bold risk by entering during industry downturns within the crystal cycle, because resources become available for the challengers in these downturns (Mathews 2005:21).

> "A firm that targets the industry will utilize the first available downturn to acquire the technology and the technological capabilities – as Korean firms Samsung and LG did during the first downturn in the FPD industry in 1993-94. They hired Japanese engineers who had been made redundant and set up R&D Centers in

> Japan to take advantage of the circulation of resources and knowledge that the downturn unleashed. Then they waited for the next downturn to launch their attack by mounting massive investments in 1995-96. Correspondingly, the Taiwanese firms were building their capabilities during this second downturn and succeeded in negotiating technology transfer from the Japanese firms as they cut back on investment during the third downturn in 1997-98, at which point the Taiwanese ramped up their own investments. During the fourth downturn in 2001, new Taiwanese entrants made their mark, making bets on variants of the fundamental TFT-LCD technology" (Mathews 2005:21-22).

Such a strategy is only effective for the new entrants as downturns would provide them with a small "window of opportunity" for raising investment while the incumbents cannot do so (Mathews 2005:22).

2.4. Independent moves by Japan's equipment and materials makers

Japan's equipment and materials makers were also aggressive and "greedy" – they were anxious to sell their products to a wider market when Japanese firms stopped investing. At the same time, Japanese customers were pleased to see development costs for toolsets amortized over a wider range of buyers. Equipment and materials embody a substantial amount of the critical knowledge necessary to start up new fabs. Since human factors are eliminated through robotization, new fab lines, after the first couple of startups, are essentially turnkey operations.[1]

2.5. National government strategies

[1] Incidentally, equipment and especially materials makers expanded into these new markets by either export or FDI, thereby preserving their competitive advantages. This contrasts with panel-makers who often did not invest or partner but transferred technology, thereby strengthening competitors, setting the stage for their own declines.

Korea and Taiwan's governments played major roles, including a 4-year plan by Taiwan's government-owned Industrial Technology Research Institute (ITRI) to foster the FPD industry since 1993, and the ITRI's 6-year plan to foster FPD industry since 1997, which facilitated the rapid growth. Actually, these roles were minimal in terms of financial resources, and the idea that they were important reflects the idea that government roles in encouraging the FPD industry were similar to the roles they may have played in semiconductors.[2] Repatriation incentives to overseas Taiwanese played a big role with regards to semiconductors, but could not happen in TFTs because there were few engineers in the U.S. who were experienced with the technology. Therefore the impact was relatively small by comparison.

At the same time, the spin-off of ITRI staff to the TFT-LCD industry contributed to the rapid growth of the industry (Akabane 2004, Shintaku 2006). The spin-off project from ITRI was significant, and CMO was founded because of the efforts of one of the ex-ITRI person (Shintaku 2006); Topply was also a spin-off of a national research institute.

2.6. Deverticalization and outsourcing

Many Japanese companies wanted to move up to concentrate on new technologies with supposed higher-value added, such as LTPS, and cultivated Taiwanese suppliers in preference to Korean suppliers as lower-cost providers for outsourcing TFT LCDs (See Akabane 2002). Japanese companies were acting on a national propensity for continually upgrading technologies. Cost structures in Korea and Taiwan actually were lower, with Taiwan the lowest (Akabane 2002). Japanese companies also preferred to redeploy their advanced engineers, skilled operators, as well as financial resources to new technologies rather than to implementing generational transitions.

[2] Alternative views are also presented, which include Wang (2003), Akabane (2002), Murtha et al. (2001), and Shintaku (2006).

3. Knowledge-based view: Stepping back to leap forward

All of these explanations are interesting, relevant, and capture some portion of the truth. But they are not sufficient to explain the phenomenon. The missing element pertains to an understanding of the role of knowledge and knowledge creation in the industry, and the consequent critical role of collaboration in industry advancement. The emergence of high-volume industry in Japan relied on global collaboration between Japanese companies and a set of equipment and materials manufacturers originating in Japan and elsewhere in the world.

The high speed of industry advancement creates a knowledge codification backlog at the leading edge of generational transitions. Much of the critical knowledge in the industry, even in lagging generations, remains tacit or constitutes a verbal tradition that depends on direct human social interaction for sharing, further developing, and putting to use. Critical knowledge is dispersed widely within the industry among producers' experienced scientists, engineers, and operators, and people working within equipment and materials suppliers, all of whom must work together in collaborative networks to set up new generation fabs (Murtha et al. 2001).

The process of setting up new generation fabs, particularly in the first company or two to lead a generational transition is complex. These companies are essentially starting from nothing, as often the larger pieces of equipment may never have been fully assembled and tested as complete machines until the first units are set up in the new generation pioneering firms.

This shows the relevance of stepping back to leap forward – as did the Korean and Taiwanese firms that built knowledge foundations for participating in the industry by building prior generation fabs, for which the toolsets, material characteristics, and manufacturing processes were well understood and well documented. In this way, they gained the necessary experience – adequate learning platforms – to create the teams of

experienced people needed to implement leading generation fab startups, where to the real need is to start from scratch with line integration and process design.

U.S. companies have never been willing to step back, but rather always try to leapfrog. This has been a problem since the beginning of the FPD industry, when U.S. firms based their planning on the prospects of a large, flat TV, which they soon learned would not happen quickly, while Japanese companies implemented the new technology for small calculator and watch displays. As an example, RCA and Sharp/Seiko showed remarkably contrasting approaches back in the '70s. Whereas the former was primarily interested in technological leapfrogging without nurturing new product potential, the latter took a much longer-term view in order to develop the capabilities necessary for new product development (Numagami 1999).

There are distinctions between Taiwanese and Korean strategies. Korean companies continue to vie with Sharp to lead generational transitions, whereas Taiwanese companies, by choice, have not taken generational leads, but prefer to lag behind; an approach that apparently has paid off. Taiwanese firms introduced technologies from Japanese firms, including: CPT from ADI (Mitsubishi), ADT (established by Acer in 1996) from IBM Japan, Unipac from Fujitsu (2000) MVA technology, and Unipac also from Matsushita.[3] They chose to adopt the lagged 3G technology while Japan had 3.5G; Taiwanese engineers were sent to Japan to learn standard operating procedure (SOP); Japanese engineers also visited Taiwan to supervise the local operations. Japanese firms had little concern for leaking core technologies, primarily due to the fact that they were transferring old-generation technologies.

[3] ADT, which was established by Acer in 1996, acquired Unipac in 2001, and changed the name to AUO.

Taiwan firms preferred to lag, but not too much – AUO's "first follower's approach" equates to its not being as fast as the first movers (such as Sharp and Samsung), but makes it a sufficiently quick follower (Mathews 2005, Shintaku 2006).[4]

4. Conceptual Framework

4.1. Organizing mode of technological learning

The mode of technological learning varies by the locus of core technologies that form the basis for the firms' competitiveness. Modes of learning employed by different companies vary accordingly. Patterns are quite different by countries of origin as well. The Japanese pattern shows significant difference from that of Korean and Taiwanese firms.

It is useful to think of alternative approaches in two dimensions: *geographic scope* and *organizational boundary*. The former refers to the locus of value-added activities to be conducted in a single country vis-à-vis across national borders. The latter refers to the extent of collaboration with external parties in conducting value-added activities. These two dimensions were adopted because they are affected by two key factors of industry success: geographic scope depends on a home-country's industry competitiveness, whereas organizational boundary depends on firms' core capabilities. Four categories can be composed based on these dimensions:

---- insert table 1 about here ----

[4] Taiwan's success implies the importance of networks as knowledge creation mechanisms. Country-specific propensities for collaboration are salient in Taiwan as compared to Japan. Japanese companies may have harmed themselves by trying to internalize too much.

We call them *domestic/in-house*, *domestic/collaborative*, *international/in-house*, and *international/collaborative* respectively. According to this framework, there are four types of approach that can be taken by companies in this industry.

4.2. Determinants of selecting a particular mode

The following criteria determine the organizing mode of a firm: 1) *domestic industry*-specific advantage, and 2) *company*-specific core technology.

It is natural to assume that a company adopts the in-house approach when it enjoys company-specific core technology so that it attempts to buffer and isolate itself from the external environment (Rumelt 1991, Barney 1991, Thompson 1967); whereas the company resorts to inter-firm collaboration when its core technology becomes weak and the company needs to acquire new capability through external linkages (Gomes-Casseres 1996); or that the company resorts to international collaboration when the home-country's industry-specific advantage is weak.

Following such logic, the following alternatives can be drawn:

1. If competency continues to reside in the home country industry *and* the company-specific core technology, the company is likely to adopt the *domestic/in-house* approach.
2. If competency does not reside in the home country industry or in the company's core technology, the company is likely to adopt the *international/collaborative* approach.
3. If competency resides in the home country's industry but not in the company's core technology, the company is likely to adopt the *domestic/collaborative* approach.
4. If competency resides in the company's core technology but not in the home country's industry, the company is likely to adopt the *international/in-house* approach

---- insert table 2 about here ----

4.3. Metanational approach

The emergence and evolution of the TFT-LCD industry in the East Asian region is characterized as the process of "metanational" learning (Doz et al. 2001, Murtha et al. 2001). According to Doz et al. (2001), metanational companies "view the world as a global canvas dotted with pockets of technology, market intelligence, and capabilities. They see untapped potential in these pockets of specialist knowledge scattered around the world. By sensing and mobilizing this scattered knowledge, they are able to innovate more effectively than their rivals" (Doz et al. 2001:5). A dominant TFT-LCD manufacturing paradigm emerged in the mid-'90s through competition and collaboration among global firms with organizational capabilities in Japan. Due to the rapid technology evolution which created a knowledge codification backlog, intense interpersonal contact among and within companies remained critical (Murtha and Lenway 2006).

While many US firms were reluctant to establish learning relationships with Asia due to their attachment to the US government's R&D subsidies (Murtha et al. 2001), some firms like Applied Materials, IBM, and Corning did not rely on US government programs and developed close relations with customers and suppliers in Japan (Murtha et al. 2001, Murtha and Lenway 2006). These companies remain the major players in this industry today, largely because of their metanational learning approach: tapping into the hotbed of innovation (i.e. Japan at that time) to overcome their home-country disadvantages (Doz et al. 2001).

Success behind Korean (Samsung and LG.Philips) and Taiwanese (AUO, CMO, etc.) firms in this industry lies in the fact that they have aggressively adopted the metanational approach of learning technologies initially from Japan and adopting the global best-supplier policy for equipment and materials, regardless of nationality (e.g. Samsung) (Murtha and Lenway 2006).

Japan initially adopted the metanational learning approach in the ’70s, when Sharp and Seiko learned TFT-LCD technology from RCA to develop their calculators and watches, respectively. But as Japan became the center for this industry, the firms became more concerned about erosion of core technologies to other countries as opposed to renewing their knowledge through metanational learning. Sharp’s “black box” approach is quite symbolic here, in that core technologies are generated, sourced, and leveraged in Japan.

Such differing patterns can be interpreted by using table 2 presented above. The US case can be plotted in the lower-left quadrant, where national industry-specific and company-specific technological advantages existed. However, because of the lack of learning relationships in Asia, as well as the lack of sourcing equipment and materials from Japan, many US firms eventually failed in this industry.

Japan’s case in the ’90s is similar to that of the US in the ’80s. Japanese TFT-LCD companies enjoyed dominant power in the industry, with a market share as high as 95% in the early ’90s (see figure 1). Japanese firms represented by Sharp can be plotted in the lower-left quadrant, where both the national industry- and company-specific technological advantages are strong. However, due to the erosion of relative technological strengths vis-à-vis Korea (and Taiwan to some extent), the validity and sustainability of the black box approach is sometimes questioned by many critics and industry analysts.

The Korean and Taiwanese cases can be plotted in the upper-right quadrant, where competitive advantages were missing both at the country and firm levels, at least in the beginning. Korean and Taiwanese companies both adopted the lagging technology as a learning platform (Generation 2 for Korean and Generations 3 and 3.5 for Taiwanese) from Japan, and engaged in learning through a global best-supplier policy for equipment and materials, particularly Korean companies. The metanational learning approach is characterized by the Korean and Taiwanese firms that sourced and leveraged knowledge from abroad and overcame both home-country industry disadvantage as well as firm-specific disadvantage. This type of situation is most typical for firms adopting the

metanational approach as they try to overcome the home-country disadvantages. Examples given by Doz et al. (2001), including ST Microelectronics and Nokia, are mostly those "born in the wrong place" yet which overcame such home-country weaknesses by way of learning though alliances and internationalization. This type of learning typically takes the international-collaborative mode in the upper-right quadrant in table 2, as firms need to access knowledge from various parts of the globe through extensive formal and informal collaboration networks.

However, recent evolution of the industry suggests that there is another variant of metanational learning for firms which were born in the *right* place in the beginning, yet the competitive advantage of their home base is rapidly eroding, as was the case for Japanese firms in the TFT-LCD industry. We posit this type in the upper-right quadrant and label it as *Type 2* metanational to differentiate it from the classical metanational proposed by Doz et al. (2001) which we labeled as *Type 1* metanational. Table 3 illustrates the difference between *Type 1* and *Type 2* metanationals.[5]

I define *Type 1* metanational as the "born-in-the-wrong-place firms" (i.e. firms which happen to be based in locations with comparative disadvantages) which resort to metanational learning in order to overcome home-country disadvantages. I define *Type II* metanational as the firms which were initially born in the right place but which continue to engage in metanational learning with the recognition that their home-country advantage is eroding.

--- insert table 3 about here ---

[5] The Type 1 – Type 2 distinction is critical here, precisely because we emphasize that the relevance of the metanational approach goes beyond the typical Type 1 case in which born-in-the-wrong-place firms resort to metanational learning in order to overcome home-country disadvantages. We argue that firms born in the right place at that time might run into a worse scenario when their home-country advantages erode. In the latter case, adopting the metanational approach is often even more challenging than in the former, because of the inertia of overconfidence in the home-country environment and lack of capability for sensing new knowledge elsewhere.

From this point of view, metanational learning, whether type 1 or type 2, is relevant and yet it takes different forms depending on the following conditions: 1) home country's industry competitiveness, and 2) competitiveness in company's core technology. Tables 4a and 4b illustrate this argument.

--- insert tables 4a and 4b about here ---

When both 1) and 2) are weak, as represented by the lower-left quadrant, the firms obviously need to learn through international collaboration by stepping back to the old-generation technology, as Korean and Taiwanese firms did in the early stage of development of TFT-LCD industry. This is a typical case for born-in-the-wrong-place firms which adopt the metanational approach (Doz et al. 2001), or what I call *Type I metanational*.

When both 1) and 2) are strong and sustainable, as represented by the upper-right quadrant, the firms can internalize advanced learning through vertical integration, often called the black box approach. Alternatively, they can engage in advanced learning through arm's-length collaboration with domestic suppliers, without vertically-integrating them. In reality, pure vertical integration is rare, even for Sharp which tried to extend its black box approach to the supplier relations by consolidating suppliers at the Kameyama plant (Nakata 2007). Again, as long as the competitiveness at both levels remains strong and sustainable in the long run, the theoretical choice is a domestic, black box approach because of the availability of resources at home and because of the need for protecting core capability from outsiders. But if the country's industry competitiveness is eroded, domestic collaboration becomes less effective. In such a case, the black box approach becomes less relevant. I call this the relevance of the *Type II metanational* approach: to realize the limit of exclusive dependence on the home-country's resources when the country's industry competitiveness becomes weaker (see table 4b).

----- insert table 4b about here ----

When 1) is strong but 2) is weak, as represented by the upper-left quadrant, the firms need to learn through domestic collaboration. While this type may at first glace contradict with the philosophy of metanational learning, it is natural for the firms to collaborate with their domestic partners from which they can leverage home-country advantage. This holds true theoretically as long as the country's industry competitiveness remains strong and sustained in the long run. But if the country's industry competitiveness is eroded, domestic collaboration becomes less effective. In such a case, cross-border collaboration also needs to be considered. Again, I see the relevance of the *metanational II* approach presented above (see table 4b).

Lastly, when 2) is strong but 1) is weak, as represented by the lower-right quadrant, the firms need to learn through international collaboration in order to obtain advanced technology. Firms in this position have absorptive capacity to tap into overseas hotbeds of innovation. This pattern is similar to the lower-left in terms of the need for learning through international collaboration. In both cases, firms are born in the wrong place. But firms with absorptive capacity can theoretically obtain more advanced technologies.

5. Applying the Framework to the Reality: The Case of Japan

5.1. Industry-specific advantages of Japan

Japan's competitive advantage in the TFT-LCD industry remains strong especially in technologically-sophisticated domains, but the production volume and market share of TFT-LCD panels have plummeted in the past decade, in the wake of fierce competition from Korean and Taiwanese firms (see figure 1).

As for equipment and material makers, Japan remains competitive relative to Korea and Taiwan. However, Korean companies like Samsung, in particular, cannot afford to rely on inefficient strategy for supplying equipment and materials from Japan. Samsung is

rapidly internalizing manufacturing of materials and equipment for TFT-LCD, as well as substituting certain technologies so as not to rely exclusively on Japanese suppliers. For example, Samsung already internalized most of its procurements of core materials production within its group companies or its suppliers networks (Song 2006). Up to G5, Samsung Electronics (SEC) internalized glass substrates, color filter, and driver IC; As for G7, SEC internalized backlight production. SEC also constructed a glass substrate plant next to its own LCD plant. As for LG.Philips and CMO, polarizer can be procured from within their own group companies. The governments of Korea and Taiwan are trying to raise the percentage of internal procurement of materials and equipment (Korea: 50% by 2005; Taiwan: 70% by 2008) (cf. Song 2006, Shintaku 2006).

Under such a condition, Japanese materials and equipment makers cannot afford to simply supply their products only to Japanese panel manufacturers. It becomes critically important for them to participate in Asian commercial and innovation networks in which more potential buyers exist in the growing local markets.

--- insert table 5 about here ---

Such a move substantially affects Japanese firms' strategies. Some firms are more sensitive to such a trend, while others are not. Hence variance in approaches by companies.

5.2. Company-specific core technological advantages

However, variance exists among companies and by categories in terms of the mode of collaboration, as shown in table 6.

---- insert table 6 about here -----

Domestic/in-house is represented by Sharp, which originally adopted the domestic black box approach to core technology development. This is consistent with the conceptual framework presented in section 4 above: the black box approach is most effective when

competitive advantages of a home country's industry and company-specific core technology are all strong and enduring (see table 2). However, this approach becomes vulnerable when any of these competitive advantages begins to erode. Even Sharp is not an exception in that the company has gradually shifted its approach toward the more *international/in-house* type (Nakata 2007).[6] In any case, this approach is most effective when a company tries to buffer its technical core (i.e. its core technology) from competitors (cf. Thompson 1967), at least in the short term. But companies choose to partner with Taiwanese firms outside of their technological core, as seen in Sharp's business alliance with Quanta Display (QDI) in Taiwan, to cope with low-cost competition[7] (Asakawa and Kim 2007:7). In sum, the following pattern is common in this type: 1) core technological knowledge is contained within the firm and within Japan and; 2) peripheral or older-generation technologies are shared with its Asian subsidiaries[8] or with the Taiwanese partners, mainly to cope with low-cost production pressure and to deter Korean dominance in the East Asian market. And as the gap of national industrial competitiveness between Japan and Korea/Taiwan narrows, the pure black box approach becomes challenged by the *Type-II metanational* approach (see table 4b).

Domestic/collaborative becomes more appropriate when the competitive advantages of home country and industry remain strong but that of the company becomes weak, according to the conceptual framework presented above. Japanese panel makers other than Sharp stopped investing beyond 4G in the '90s due to the economic recession and financial crisis in Japan. As followers behind Sharp, they had good reason to collaborate among Japanese firms, given the remaining competitive advantage of Japan's TFT-LCD industry, at least in the high end of the spectrum. For example, when Matsushita and

[6] Sharp's plotted position (between *domestic/in-house* and *international/in-house*) in Table 6 signifies such a trend. The author is grateful to a helpful comment by Professor Yukihiko Nakata on this point.

[7] Sharp adopted a differentiated approach to its outside parties depending on how core the technology is to the company. For example, there was a policy that high-value-added TFT-LCD would be developed and manufactured internally whereas low-value-added would be externalized (Asakawa and Kim 2007:7). Therefore, it is obviously a mistake to assume that Sharp adopts an exclusively domestic/in-house approach.

[8] This includes OEM from Taiwan, LCD module and LCD TV assembly in China, Malaysia, Mexico, and Poland, in the case of Sharp (Nakata 2007).

Toshiba announced that they would integrate their TFT-LCD businesses in October, 2001 (*Nikkei Shimbun*, October 22, 2001), they were both suffering from low-price competition by Korean firms, and found it reasonable to integrate their TFT-LCD businesses to cope with the Korean rivalry (Asakawa and Kim 2007).[9] Another challenge manifests itself in the foundation of IPS Alpha Technology, Ltd.,[10] a joint venture between Hitachi, Matsushita, and Toshiba, along with Hitachi Displays Ltd., founded in January 1, 2005. The aim of this new company is to develop, manufacture, and sell amorphous TFT-LCD panels larger than 23" TVs, with increased production capacity and reduced cost (Asakawa and Kim 2007). The following pattern is common in these two examples: 1) these companies are behind major players such as Sharp and Samsung Electronics in terms of the generation race; 2) they are threatened by low-cost pressure by Korean rivals; 3) they have sophisticated technological niches; 4) they choose to form their domestic alliances to compete against Korean catch-up. However, as the gap in national industrial competencies between Japan and Korea/Taiwan becomes narrower, pure domestic collaboration does not make sense. In reality, it becomes increasingly unusual for firms to stick to pure domestic collaboration among materials and equipment makers, panel makers, and the end producers. Here again, room for the *Type-II metanational* approach can be seen.

International/collaborative, in turn, is represented by Sony, with its alliance with Samsung. This paper's conceptual framework predicts that firms are likely to adopt this mode when the competitive advantages of a country's industry and technological cores remain strong in general but the level is gradually eroding (i.e. *Type 2 metanational*). Sony, in spite of its competitiveness as a company, has been focused on CRT and thus lagged in TFT-LCD technologies. It was relatively easy for Sony to go for international

[9] The new company, TMD (Toshiba Matsushita Display Technology Ltd.) was founded in April 1, 2002, as 60% Toshiba and 40% Matsushita, in charge of development, manufacturing, and sales of TFT-LCD, STN-LCD, and Organic-EL for small- to medium- sized panels, aiming at cost-breakthrough by economy of scale (Asakawa and Kim 2007).

[10] IPS" stands for in-plane-switching, the technology for widening the view angle originally developed by Hitachi (*Nikkei Shimbun*, November 1, 2004; Asakawa and Kim 2007).

collaboration in this case, because of the obvious technological shift from CRT to TFT-LCD, and because of the obvious recognition that the company lagged behind Sharp in this technology. However, it is understood that Sony did not form S-LCD, the joint venture company with Samsung Electronics in 2003 simply to learn state-of-the-art technology from Samsung. Rather, the main purpose for Sony was to secure a stable supply of large TFT-LCD panels beyond Generation 7, which was believed to be much more cost-efficient than the earlier generations (*Nikkei Shimbun*, October 17, 2003; Asakawa and Kim 2007: 14). In this sense, the S-LCD case does *not* entirely present a case to strongly support our earlier assumption that a firm which lags in a certain technological edge is likely to form an international collaboration to absorb advanced technologies.[11] Nevertheless, in broad terms, Sony took advantage of its collaboration with Samsung to overcome its weakness. Many Japanese panel makers engaged in much looser inter-firm collaboration than vertical integration or joint ventures. Typical examples include Japan's TFT-LCD makers that transferred technology to Taiwanese firms for OEM manufacturing with cost advantage to deter fast-growing Korean makers. The case of technology transfer includes: from ADI (Mitsubishi Electrics) to CPT; from IBM Japan to ADT (founded by Acer); from Toshiba to Hannstar; from Sharp to Quanta Display; and from Matsushita to Unipac (Akabane 2005). In sum, the following patterns are observed: 1) this type of collaboration takes place in different ranges of inter-firm arrangements: ranging from joint ventures to OEM manufacturing[12]; 2) The objective of the collaboration also varies, but more for cost and efficiency reasons than pure learning.

5.3. Collaboration by equipment and materials makers

[11] In fact, it was Samsung Electronics which tried to catch up with the Japanese competitors through vertical integration or collaboration with the best equipment and materials makers from Japan and elsewhere (Song 2007).

[12] As for the learning mode, the following spectrum was proposed by Ford (1988): internal R&D, joint venture, contracted-out R&D, license-in, and non-acquisition (i.e. buying final product) (Nakata 2007).

Collaboration between materials/equipment makers and panel makers can be classified as vertical (as opposed to horizontal, among the panel makers), as illustrated in table 5.

--- insert table 5 about here ---

Materials and equipment companies, no matter how competent they may be, cannot survive without collaborating with the panel makers as buyers. Therefore, a pure in-house approach does not make sense. The co-location approach by Dai Nippon (DNP) in Kameyama is symbolic: DNP brought in its color filter manufacturing technology to collaborate with Sharp and to start joint production from 2006.

At the same time, equipment and materials makers cannot afford to ignore their overseas customers in Korea and Taiwan, although the government wishes to protect the core technologies from leaking to Korea and Taiwan. Many firms engage in collaboration with Korean makers. Led by the strong leadership of top management, some firms adopt an aggressive approach of engaging in international collaboration without being a member of Future Vision, a national project. The *international-collaborative* strategy is a high-risk, high-return approach because it may run into intellectual property right (IPR) risks. Nevertheless, Japan's equipment makers are inclined to collaborate with Korean and Taiwanese firms due to their large volume of production. It was reported that international joint research and development (R&D) consists of 70% for Japan's equipment makers; domestic joint R&D consists of 30% (Shintaku 2006). For example, 70% of CMO's R&D is conducted jointly with Japan's materials and equipment makers, and 30% with Taiwan's universities, government, and/or within CMO in Taiwan (Shintaku 2006).

6. Conclusion and Implications

Japan's dominance in TFT-LCD production volume and market share in the '90s has been replaced by that of Korea and Taiwan (see figure 1). While Japan's strengths lie in production technologies, and materials and equipment manufacturing, the gap between Japan and Korea/Taiwan is shrinking. For example, Japan's strength, among others, lies

in ramping up building large-scale, multiple lines rapidly, which Japanese firms need to keep upgraded.

Korea is open in absorbing knowledge and technology from Japan, and yet very closed in disclosing to outsiders; Samsung Electronics has a reputation of initially being very open in terms of knowledge in-flow; but over time it gradually gets closed in a very subtle way once it develops its capability internally – then it becomes reluctant to open up.[13] The same can be said about Taiwan, which is famous for open-sourcing by networking. But once the firms acquire capability from Japan, they try to be very careful about preserving their proprietary knowledge when transferring technologies to China. Balancing openness and closure is an important issue for Japanese companies as well.

Implications for Japanese companies and public policy follow:

If we look back, we recall a sad case of a U.S. government program which caused companies to turn inward to other U.S. companies instead of reaching outward to collaborate in Japan in 1990s, leading to further deterioration of U.S. industry (Murtha et al. 2001).

But Japan faces a similar dilemma today – to close off global collaboration, or to try to stem the tide of disinvestment and technology diffusion, particularly to China. Or it can recommit to the collaborative norms that made it the birthplace of high-volume industry, and the dominant player through the mid-1990s.

The following alternative strategies exist:

Close off knowledge flows via equipment and materials: Hold back or delay sales of leading-generation equipment and materials outside of Japan. However, such a move

[13] For example, Samsung Electronics might have been much more metanational in its semiconductor business in the ’80s than in its TFT-LCD business of today, because of its gained competence and its orientation toward internalization.

may be too late, because Taiwanese have already bought lagging generation tools and equipment. What would such a strategy do to Japanese equipment, materials, and component suppliers? Restrictions or obstacles to equipment export, even if permissible under international trade agreements, would only hasten efforts in Korea and Taiwan to try to further articulate their own supply chains by establishing new firms or encouraging producers to integrate backwards. Merely buying equipment and materials is not an adequate strategy for technology leadership in this industry anyway because 1) unlike semiconductors, there's no roadmap, and 2) knowledge is not entirely embodied, or it is to a far lesser degree than in semiconductors, especially in advanced-generation equipment and materials.

Vertical integration at firm level: This is an expensive solution, and Japanese firms have already shown reluctance to make the large commitments necessary to remain the leading players in both capacity planning and generational advance. Furthermore, it would be very difficult, as well as expensive, for producers to replicate the large body of specialized industry knowledge that equipment and materials suppliers have gained by working together with them. As equipment and materials suppliers are unlikely to want to sell themselves, producers wishing to integrate will need to start from scratch. Korean producers and the Korean government face a similar set of dilemmas, as they would like to alter the balance of trade in equipment and materials in this industry.

Collaborate, but only in Japan: This approach would remain valid as long as Japan's competitive advantage in the industry remains strong in the long run, relative to other countries. However, reality shows otherwise: Korean and Taiwanese firms rapidly catch up to their Japanese counterparts through aggressive procurements of materials and equipment and through internalization of upstream sectors. Domestic collaboration might become vulnerable as Japan's relative strength erodes.

Global collaboration: From the perspective of metanational learning, this is obviously the goal. However, unlike Korea and Taiwan, Japan may end up playing the teacher's role rather than learning from the partners. Japan therefore should identify which

technologies to learn from abroad and it should stay focused. Otherwise, Japanese firms may end up losing more than they gain from the collaborating partners. In spite of potential risk, the metanational (here the *Type-II)* approach remains appropriate for the firms which need to cope with eroding country and industry competitiveness, such as the Japanese firms in the TFT-LCD industry.

While Japan remains strong in many technological domains, there are growing areas in which Korea – and Taiwan to some extent – are rapidly catching up. Under such a circumstance, it seems appropriate for Japanese firms to identify which technological domains need to be Japan-based and which need to be cross-national. The real challenge lies in the fact that even a country's dominance in one area is not stable in the long run. Japan's dominance in any technological area cannot be guaranteed in the near future. The essence of the *Type-II metanational* approach is to highlight the importance of recognizing the potential risk of being complacent for today's home-country advantage and of opening up the mindset for global learning, even though the current home-country advantage still remains. While this paper is focused on the TFT-LCD industry, the framework presented here can be applied to other industries in which metanational learning remains crucial.

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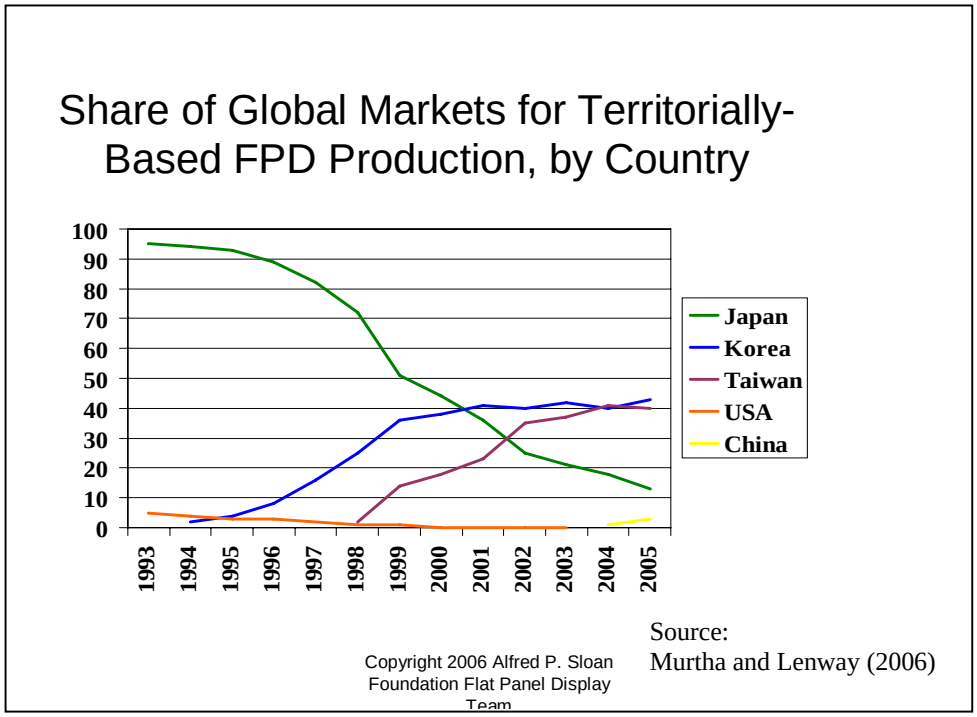
Figure 1



Source:
Murtha and Lenway (2006)

Table 1
Taxonomy

Collaborative	Domestic - collaborative	International - collaborative
In-house	Domestic – in-house (pure “black box” approach)	International – in-house
	Domestic	International

Table 2
Selection of collaborative mode contingent on competencies of home country's industry and company's core technology

	Domestic	International
Collaborative	Competency level: Industry + Company -	Competency level: Industry - Company -
In-house	Competency level: Industry + Company +	Competency level: Industry - Company +

Footnote:

This table illustrates the way competency levels of the home-country industry and a company's core technology would influence a company's selection of a collaborative mode for technological learning. The + and – signs are read as follows:

Example:
When the competency levels of the country's industry and the company's core technology are weak (-), the company is more likely to adopt the "international-collaborative" approach to learn from abroad.

Table 3
Revised Framework: Type 2 Added

	Domestic	International
Collaborative	Competency level: Industry + Company -	Competency level: Type 1: **Type 2:** Industry – **Industry +–** Company – **Company +–**
In-house	Competency level: Industry + Company +	Competency level: Industry - Company +

Footnote:

This revised framework presents two types of conditions under which international-collaborative mode of learning is more likely to take place. Besides "Type 1," "Type 2" is added here. Please read the +and – signs as follows:

Type 2:
Industry + - : The country's industry is basically strong (+) and yet is gradually declining in competitiveness (-).
Company + - : The company's core technology is basically strong (+) and yet is gradually declining in competitiveness (-).

Table 4a:
Differing modes and objectives of learning, contingent on country's industry competitiveness and competitiveness in company's core technology

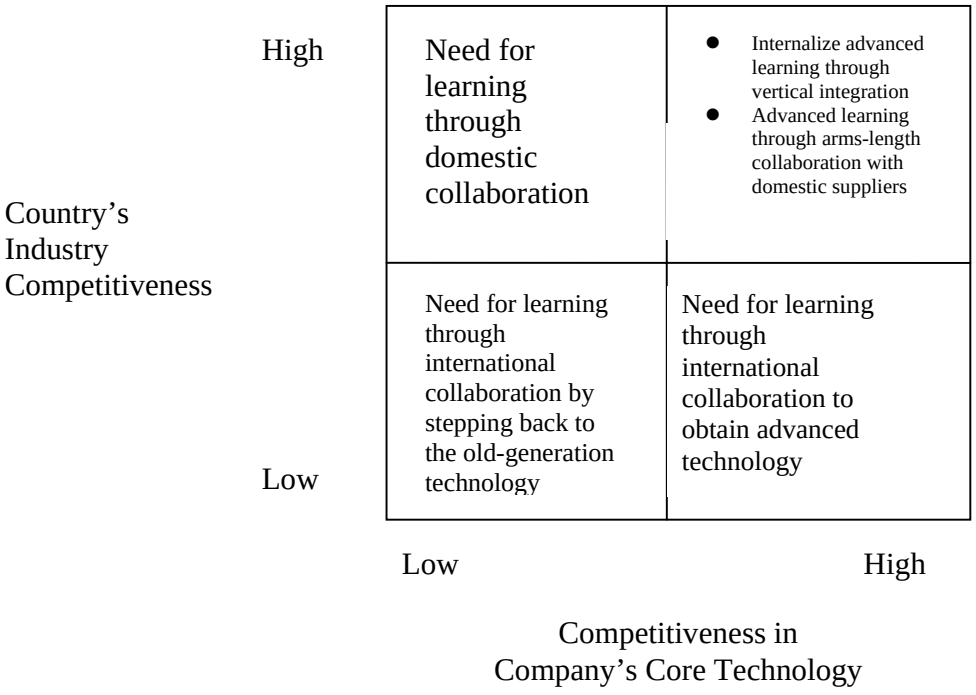


Table 4b
Different approaches, contingent on country's industry competitiveness and competitiveness in company's core technology

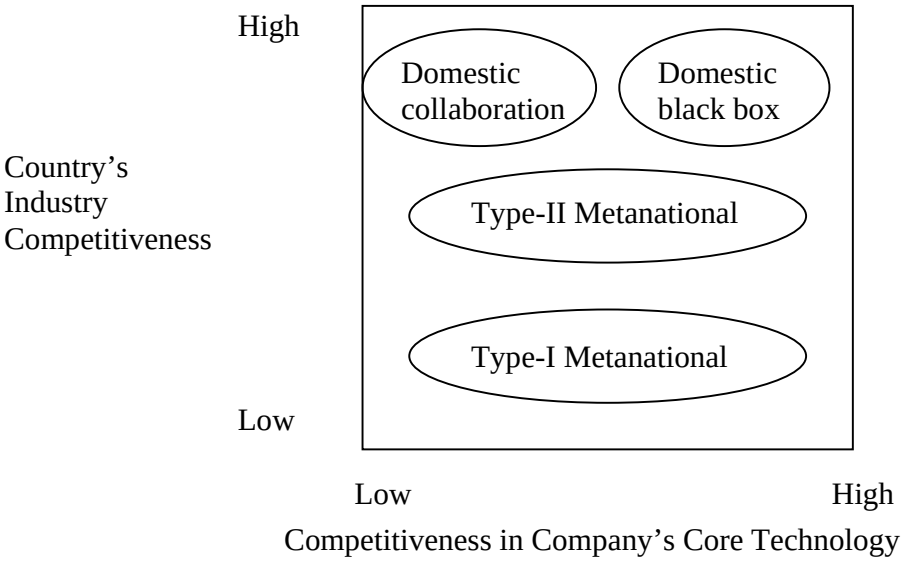


Table 5
Variation and trends among materials and equipment makers in Japan, Korea, and Taiwan

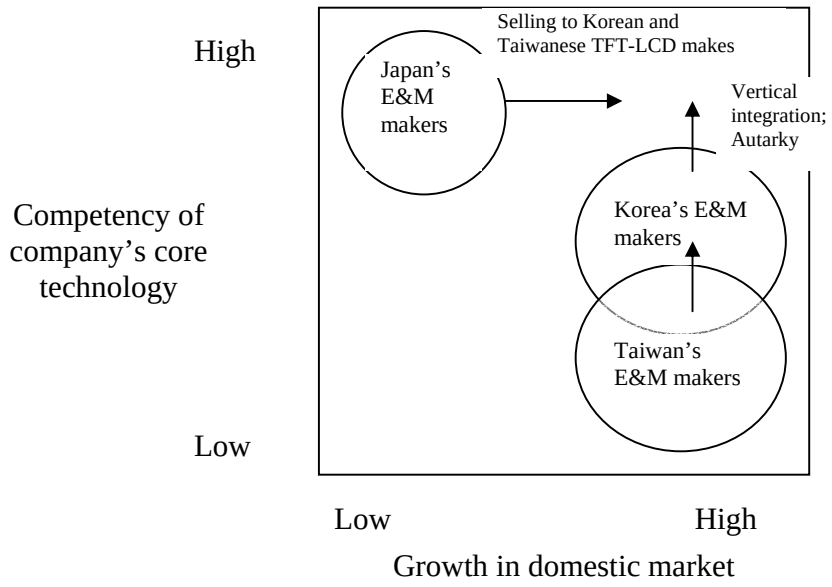


Table 6
Variation among Japanese TFT-LCD Makers