Seoul Journal of Business
Volume 15, Number 2 (Dec 2009)

Technological Catching-up and Latecomer Strategy: A Case Study of the Asian Shipbuilding Industry

EUNHEE SOHN*
MIT
Cambridge, USA

SUNG YONG CHANG**
Seoul National University
Seoul, Korea

JAEYONG SONG***
Seoul National University
Seoul, Korea

Abstract

This paper investigates the role of imitation and innovation in technological catching-up. On the one hand, excessive innovation and no imitation can never provide latecomers with absorptive capacity to embark on catching-up along the existing technological trajectory. On the other hand, excessive imitation and no innovation can debilitate the ability of latecomer firms to leapfrog incumbents by creating a new trajectory and further reducing the technological gap. Thus, we argue that successful technological catching-up in the long term can hardly be achieved without a fine balance between imitation and innovation at the early stage of catching-up. We also propose that occurrence of technological uncertainty at the later stage of catching-up allows latecomers with such balance to

* Main author, Ph.D. Student, Sloan School of Management, MIT (sunenxi@gmail.com)
** Coauthor, Master Candidate, The College of Business Administration, Seoul National University (csy0103@snu.ac.kr)
*** Corresponding Author, Professor of International Business, The Graduate School of Business & the College of Business Administration, Seoul National University (jsong@snu.ac.kr)
Acknowledgement: This research was funded from the Institute of Management Research at Seoul National University.

realize radical technological leapfrogging. By conducting a case study on the shipbuilding industry in the 20th century, we find supporting evidence that validates our argument.

Keywords: Technological catching-up, latecomer strategy, imitation, learning myopia, technology regime, shipbuilding industry

INTRODUCTION

The rapid technological catching-up achieved by the East Asian economies in late 20th century, has boosted a large amount of research on the mechanisms behind these phenomena of technological catching-up (Lee and Lim 2001). However in fact, such rapid technological catching-up as found in East Asian countries such as Korea and Taiwan, is not a phenomenon commonly found in other latecomer economies or technological sectors. As Cantwell (1989) argued, most industries rather remain dominated by a few countries over long periods of time. An explanation for this persistence in leadership is provided by the endogenous growth theory, which suggests that technological catching-up is difficult because of the increasing return to scale of physical and human resources and the geographical localization of technology (Romer 1990).

Despite such gloomy predictions from the new growth theories, Korea and Taiwan indeed stand out as examples of latecomers that succeeded to catch up with advanced nations. Transfer of foreign technology has historically played an important role in the technological catching-up of Korea and Taiwan (Freeman and Soete 1997; Song, Almeida, and Wu 2001). Looking back at their successes in the semiconductor and consumer electronics industry, we can find that these latecomers successfully transitioned "from imitation to innovation"- adopting and assimilating foreign technology in order to create indigenous technology (Kim 1997).

The shipbuilding industry is yet another representative example of technological catching-up undertaken by latecomer East Asian countries. Japan, itself once a latecomer in the global shipbuilding industry, caught up with the European incumbents in the 1950s, replacing Britain as the new number one. Since then, Japan had been reigning over the industry for almost 40 years. Korea only entered the global shipbuilding market in the 1970s as a latecomer

Table 1. World Shipbuilding Market Share in Terms of Construction Volume* (unit: %)

Ranking	1955	1965	1975	1985	1998	2000	2005
1	Britain (18.3)	Japan (43.9)	Japan (50.1)	Japan (52.3)	Japan (42.0)	**Korea (40.7)**	**Korea (35.2)**
2	Norway (14.5)	Sweden (9.6)	Germany (7.1)	**Korea (14.4)**	**Korea (28.9)**	Japan (39.0)	Japan (28.6)
3	Germany (9.9)	Britain (8.8)	Sweden (6.9)	Germany (3.1)	China (4.8)	Germany (3.3)	China (14.5)
4	France (4.7)	Germany (8.4)	Spain (4.6)	Spain (3.0)	Germany (4.2)	China (3.2)	Germany (3.6)
5	Japan (4.6)	France (3.9)	Britain (3.6)	France (1.1)	Italy (3.2)	Taiwan (2.1)	Poland (2.3)
6			**Korea (1.2)**	China (0.9)			

* According to the source of Lloyd's Register & Korea National Statistical Office

to Japan. In the 2000s, Korea caught up with Japan and rose as the leader, boasting cutting-edge technology in manufacturing of specialized vessels and offshore structures. However, Taiwan and China, which entered the shipbuilding industry at about the same time under equally active governmental support and intervention, fail to achieve such technological maturity. This phenomenon brings up an interesting question of what determines the success of technological catching-up.

Korea's technological success in the shipbuilding industry and contrasting failures of Taiwan and China provide us with an ideal setting to understand the driver of technological catching-up. By delving into the history of the Asian shipbuilding industry, precisely that of Japan, Korea, Taiwan and China, this study looks at how different strategic choices regarding imitation and innovation lead to differing degrees of technological catching-up.

In this paper, we suggest that the different results in technological catching-up were due to the "dual" effect of imitation strategy. Drawing on the absorptive capacity view and the path-dependence view, we analyze the dual nature of imitation strategy and propose a theory about latecomer's technological catching-up. At an early stage of catching-up, imitation is indispensible for fast learning and survival. Adhering to self-exploring innovation without initial imitation cannot lead to successful catching-up. On the other hand, excessive reliance on imitation at an early stage also erases out the possibility of successful catching-up.

In addition to examining how the degree of early imitation can influence the probability of long-term catching-up, we take one step further to examine how changes in the technological environment can also influence latecomers' catching-up. Rise of technological uncertainty in the industry functions as a catalyst to facilitate technological 'leapfrogging'. Latecomer firms that maintained a balance of imitation and innovation at the early stage of technological catching-up can exploit technological uncertainty to create new technological trajectory and radically leapfrog industry incumbents.

THEORY AND HYPOTHESES

Technological Catching-up

Whereas many early literatures focused on the role of the government and market in economic catching-up of developing countries, there also exists a plethora of technology-oriented literature that attribute the successful catching-up to the development of technical capabilities (Dahlman, Westphal, and Kim, 1985; Hobday 1995; Kim 1997). Technological catching-up refers to a decrease in technological gap between competitors by relatively faster technological learning on the part of latecomers. Whereas previous studies used to define technological catching-up on a cumulative and linear technological trajectory, more recent studies propose the possibility of radical "leapfrogging", skipping of existing technological trajectory and creation of new ones (Lee and Lim 2001). The phenomenon of radical catching-up or 'technological leapfrogging' is due to the shift of technological paradigm itself. The advent of new technologies and the institutional rigidities of incumbents ultimately render the old technology obsolete (Brezis, Krugman, and Tsiddon 1993). Such perspective is consistent with a stream of studies that dealt with the topic of how radical, competence-destroying innovations or 'creative destructions' can weaken incumbents and boost the growth of newcomer (Anderson and Tushman 1990; Christensen 1997; Christensen and Bower

1996; Tripsas 1997).

Of course, it is very difficult for young latecomer firms to create by themselves a technological discontinuity that can change the competitive horizon. Few organizations internally generate all the knowledge required for continuous technological development, and most depend upon external sources (Song, Almeida, and Wu 2001). This is especially true for latecomers that lack sufficient technological competencies. Imitation of advanced technologies is an indispensible learning process for latecomers' catching-up, since the influx of external knowledge at an early stage lays down the fundamental building block which further technological development can be based upon. Initial driver of latecomers' catching-up is the gradual adoption and assimilation of incumbent technology that resides in advanced countries or competent firms (Kim 1997; Song, Almeida, and Wu 2001). Yet, passive imitation of existing knowledge cannot suffice for successful technological catching-up in the long-term. Latecomers at an early stage of catching-up can generally receive transfer of obsolescent technology from incumbents, but once they reach a certain technological level, most incumbents become reluctant to transfer brand-new technology and knowledge to latecomers. Thus, active innovation through own R&D becomes a crucial factor in technological catching-up (Kim 1997).

By shedding a new light on the frequently visited issue of exploitation and exploration, our study attempts to look at the impact of early imitation upon latecomers' technological catching-up. We argue that latecomers' early imitation facilitates the catching-up process by building the knowledge base and enhancing absorptive capacity, but excessive imitation at an early stage of catching-up prevents further leapfrogging by having latecomers stuck into an imitation trap.

Positive Aspect of Imitation: Absorptive Capacity View

Technological capability can be defined as imitation capability, the ability to learn, absorb and improve already existing knowledge and innovation capability, the ability to search for and produce new knowledge (Kim 1997). Narrowly defined imitation refers to a market-induced diffusion of technology in contrast to organizationally-induced, legal technology transfer (Mathews 2001;

Zander and Kogut 1995). However, our paper defines imitation in a broader sense, as exploitation of existing knowledge by using both formal and informal modes of knowledge diffusion such as licensing, reverse engineering, mobility of engineers and marginal improvement of existing products (Grabowski and Vernon 1987; Kim 1997). Innovation on the other hand is defined as exploring and creating new knowledge based upon internal capabilities.

The foremost option for latecomers with weak technological background is imitative learning through gaining access to advanced technology. Initially, most newly entering latecomers are at a disadvantageous position to produce their own knowledge. Even though some latecomers manage to develop indigenous technology, a huge technological gap makes their products seriously inferior to those of incumbents. Even though a cost advantage in wage or procurement can neutralize the technological weakness to a certain extent, such a strategy is at best tentative and only works in technologically simple and labor intensive industries. An organization cannot survive in the long run unless it can survive in the short run – it has to come up with marketable products to cover up initial investment. Thus, most latecomers resort to acquisition of advanced technology in the form of licensing and joint ventures. Codified and explicit knowledge transferred through licensing and joint ventures are beneficial to rapid catching-up because it can be easily absorbed and understood by recipients (Zander and Kogut 1995). Existing technology is also safe from technological uncertainty as it has already gone through evaluation and verification by the incumbent competitors and the market. Thus, imitation can lower the failure risk of technological invention, prevent the squandering of firm's resource and facilitate catching-up of an incumbent's technological expertise (Lake 1994). In other words, latecomer firms can enhance their probability of short-term survival by resorting to learning and imitating incumbents.

More fundamentally, the long-term objective of imitation is to build a learning ground upon which innovative capability can be further developed. As shown in the argument that innovation comes from borrowing rather than invention, new knowledge is not created on its own but from understanding and learning existing knowledge (Cohen and Levinthal 1990; March and Simon 1958).

Cohen and Levinthal (1990) argued that the ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends is critical to its innovative capabilities. Firms that develop substantial cumulative experience and knowledge bases are better positioned to acquire target technologies (Song and Shin 2008). Latecomers have to accumulate a substantial amount of absorptive capacity until they become able to acquire sophisticated, cutting-edge technology. For instance, learning how to build an LNG vessel is impossible without technological know-how and experience accumulated by continuously building other types of vessels. Absorptive capacity is built during the process of imitative learning such as duplication and reverse engineering of existing products. Imitation also takes place in the form of codified knowledge transfer such as licensing, as well as tacit knowledge transfer through mobility of engineers (Song, Almeida, and Wu 2001, 2003). In this process, latecomers build their absorptive capacities and continue to learn and acquire more sophisticated technological knowledge.

Negative Aspect of Imitation: Path-dependence View

Strategic choice between imitation and innovation can be examined from the perspective of evolutionary economics (Nelson and Winter 1982) and the theory of exploration and exploitation (March 1991). Organizations allocate resources between two broad kinds of activities: exploration and exploitation. They engage in exploration to acquire new knowledge, or pursue exploitation to use and develop already known knowledge. Imitation as defined in our paper is a form of exploitative learning, whereas innovation defined in our paper can be seen as exploratory learning.

In doing so, organizations become easily prone to the trap of self-destructive learning that leads to either excessive exploration or excessive exploitation. Especially, accumulation of experience in a certain field of technology runs a risk of becoming trapped in the particular field and blinded to alternative opportunities. This is a phenomenon named as “learning myopia” (Levinthal and March 1993). The literature warns that excessive exploitation of the existing technology may lead a firm to be locked out of opportunities in the long run. This is particularly true when an incremental gain in performance declines with the use of existing technology. An undue focus on exploitation eventually leads to technological exhaustion in the market in which firms compete to develop new products (Lee and Ryu 2002). In this perspective, exploitative learning strategies tend to increase long run vulnerability of organizations (Lee, Lee, and Lee 2003; Levinthal and March 1993).

Perez and Soete (1988) pointed out that ‘a real catching-up process can only be achieved through acquiring the capacity for participating in the generation and improvement of technologies as opposed to the simple “use” of them’. Latecomers are not aiming at a static target but rather a moving one, as technological leaders continue on with their innovation. It is no use simply importing today’s technology, for by the time it has been introduced and assimilated the leaders have moved on (Freeman 1988; Malecki 1997). Early dependence upon imitative learning can debilitate the development of knowledge-creating capability by framing the technological trajectory of latecomers, preventing the possibility to make a radical leapfrog at a later stage. Maintaining a balance between imitation and innovation from the initial stage of catching-up is crucial for latecomers to catch up with the incumbent. Hence, we propose,

> ***P1:*** *When a latecomer organization show one-sided dependency upon either imitation or innovation at an early stage of technological catching-up, successful long-term technological catching-up is unfeasible.*

Technological Uncertainty and Technological Catching-up

A firm’s innovative activity is often a cumulative, path-dependent process, which constrains its future search behavior for new technologies and makes it more likely to pursue R&D along its existing trajectories (Dosi 1982; Song and Shin 2008). A firm’s strategic advantage often lies in its accumulation of asset stocks and the characteristics of the accumulation process: the existence of time diseconomies and asset mass efficiencies endow early-mover advantages to incumbents (Dierickx and Cool 1989). When an incumbent is proceeding ahead along the existing technological trajectory, it is very difficult for a latecomer with lower absorptive and innovative capacity to surpass the incumbent on the same trajectory. Faster catching-up is feasible when a latecomer can adopt the strategy of leapfrogging, by skipping an existing trajectory or creating a new one (Lee and Lim 2001).

Technological uncertainty, which rises from the emergence of a disruptive technological discontinuity or competing technological alternatives, functions as a catalyst that facilitates leapfrogging of latecomers. As stated in Song and Montoya-Weiss (2001), incumbent proficiency in marketing, technical and competitive intelligence may not be beneficial in highly uncertain technological environments. When the future of technological trajectory is in doubt, betting on previously unexplored alternatives and preempting a new trajectory may bring much better payoff than staying with the existing technological trajectory, if successful. Since the competitive advantage and existing knowledge of incumbents will be rendered obsolete by a shift in the technological paradigm, incumbents tend to shun from investing in a new technological trajectory. On the other hand, latecomers with less 'core rigidities' tend to be more open about accepting a new possibility.

Although the payoff may be high, opening up a new technological trajectory accompanies two major risks – risk of choosing the right technology and the risk of initial market creation (Lee 2005). Existence of such risks may bring difficulties to latecomers' strategy formulation and implementation. Thus execution-wise, it is easier for latecomers to build absorptive capacity or implement an imitative strategy when the industry evolves along a fixed technological trajectory. The more fluid is the technological trajectory, the more difficult it is for latecomer firms to fix the R&D target and thus lower the possibility of catching-up (Lee and Lim 2001).

Latecomers at an early stage of technological catching-up are prone to the aforementioned risks. Due to lack of accumulated capabilities, they can only follow the given technological trajectory. However, the mode of catching-up does not merely include 'following up' of the given trajectory, but also 'leapfrogging' of the existing trajectory. If the technological trajectory is fluid, this may lead to difficulties for latecomer firms to follow up the given trajectory, but on the other hand, this provides a window of opportunity to leapfrog. Latecomers at a later stage of catching-up differ from ones at an early stage in that they have not only acquired absorptive capacity but also the highly crucial combinative capability (Kogut and Zander 1997) to synthesize and apply current and acquired knowledge and dynamic capability (Eisenhardt and Martin 2000; Teece, Pisano, and Shuen 1997) to adapt to changing customer and technological opportunities. Dynamic capabilities refer to the abilities to sense market and technological opportunities and seize them (Teece 2007). Without dynamic capabilities, a firm may be blinded to existent opportunities, incorrectly evaluate them or fail to devise or execute the strategies or tactics needed to seize them. A fresh off-the-board latecomer may lack such abilities, but more established latecomers evolve to equip the dynamic abilities to spot and preempt potentially fruitful opportunities.

In other words, more "mature" latecomers have accumulated capabilities to produce new technological knowledge or choose a highly potential technological alternative abandoned by the incumbents. Although technological uncertainty is not just a risk that makes following-up more difficult, but rather an opportunity to surpass the leaders by creating a new technological trajectory or leapfrogging the existing trajectory. Thus, a rise of technological uncertainty enables latecomers to undertake rapid technological catching-up that may not have been possible under a stable technological trajectory.

In sum,

> ***P2:*** *Rise of uncertainty in the technological trajectory at a later stage of technological catching-up provides a window of opportunity for radical technological catching-up of latecomers, also known as "leapfrogging".*

CASE RESEARCH

Research Method

This study employed the case study method to validate the propositions regarding latecomers' technological catching-up in the Asian shipbuilding industry. Like previous researches about the shipbuilding industry (Cho and Porter 1986), the analysis was conducted at the national cluster level, rather than at the firm level. Since achieving economies of scale is extremely crucial in the shipbuilding industry, shipbuilders in the same country form national clusters of large-scale shipyards. In other words, firm strategy differs across country, not within country. Thus, although the level of analysis is the nation, what we are examining in this study can be interpreted as inter-organization differences. For example, 'Japan' or 'Korea' used in this text refers to Japanese shipbuilders or Korean shipbuilders. Our study does not discuss exogenous variable such as national economy, exchange rate, resources and wage. We solely focus on the impact of endogenously chosen innovation strategies upon the degrees of technological catching-up.

Previous studies that examined the phenomenon of technological catching-up generally adopted statistical analysis of patent registration counts (Lee and Lim 2001; Park and Lee 2006). In these studies, catching-up is defined as a relatively faster increase in patent registration. Although using patent data is a common method in quantifying the strength of technological capabilities owned by firms, there are some difficulties in directly applying the quantitative analysis to the shipbuilding industry. First, patent registration in the shipbuilding industry is not viewed as critical as in the semiconductor or pharmaceutical industry. Second, tacit knowledge embedded within the manpower play a critical role in shipbuilding. Labor productivity shown as man-hour, man-year/CGT[1] is also an important measure of technological capabilities. Such measures can only improved by a significant amount of learning-by-doing and high degree of process automation (KOSHIPA 2005). Instead of patent data analysis, our study provides a historical account of the shipbuilding industry by inter-country case analysis and productivity measures.

Definition, General characteristics and Core Competencies of the Shipbuilding Industry

The shipbuilding industry is a group of firms that develops and builds ships, underwater equipments and naval architectures for the shipping industry, fishing industry, naval defense and extraction of ocean resources. There are three major product

1) CGT: Compensated Gross Tonnage. The ship's volume adjusted by a factor to render the amount of work at the yard equivalent for different types and sizes of ship

Table 2. Buyers' Major Purchase Criteria by Ship Type*

Vessel Category*	Vessel Sophistication	Purchase			
		Price	Delivery	Quality	Government
Oil Tankers	Low	8	2	0	0
Bulk Carriers		7	3	0	0
General Cargo Ships		6	3	1	0
Container Ships		4	3	3	0
LNG Carriers		2	2	6	0
Passenger Ships		1	2	7	0
Oil Rigs		1	3	3	3
Navy Ships	High	0	1	4	5

*Taken from Cho and Porter (1986)

**In each vessel category, the total of 10 points is assigned to the four purchase criteria according to their relative importance. The assigned numbers reflects the opinions of four shipbuilding experts: one British, two Japanese, one Korean (Cho & Porter, 1986)

classes within the shipbuilding industry: commercial vessels (bulk carriers, Very Large Crude Oil Carriers *a.k.a.* VLCC, general cargo ships, container carriers, LNG carriers), naval architectures (Floating Production Storage and Offloading *a.k.a.* FPSO,[2] Drillships[3]), and special-purpose carriers (navy ships, cruise ships) (Kim 2006).

The characteristics of the shipbuilding industry are as follows: first, the shipbuilding industry is a purely global shipbuilding industry in which firms compete against other national builders, not their domestic competitors (Cho and Porter 1986). Since national shipbuilders are subject to identical input and output environment, it is more reasonable to look at the competitive dynamics of the shipbuilding industry in the perspective of countries rather than specific firms. Therefore, our case study will also focus on the history of individual countries, not individual firms. Second, although it is a labor-intensive industry that requires a huge pool of highly skilled workers, it also requires

2) FPSO: Floating Production Storage and Offloading Vessel. It refers to a facility in which oil or gas produced from offshore locations are stored and processed until it is offloaded onto tankers.
3) Drillship: A maritime vessel with drilling facilities to excavate oil or gas buried deep in the sea

cutting-edge technology in engineering and operation management. Becoming a leader in the shipbuilding industry requires cutting-edge technology in both design and production. It differs from a labor-intensive lightweight industry that generally gets trapped in a technological plateau and in which the price of inputs become the only competing factor. For example, building highly sophisticated vessels such as LNG and FPSO calls for the utmost in precision of both design and production, which is comparable to what is required in the aeronautics industry. Technological sophistication of the shipbuilding industry often gets underevaluated since innovation frequency in this industry is lower. Advancement in the shipbuilding technology cannot be just easily captured in visible, easy-to-compare figures as in the semiconductor industry, but this should not be mistaken for lack of technological sophistication. Third, complementary assets (Teece 1986) such as brand presence, distribution networks which are considered important in consumer goods industry are not important in this industry. Low cost and technological sophistication are the only two differentiating factors in this industry. This makes it easier to separate out any argument regarding the influences of non-technological factors upon catching-up and only focus on the role of "technological capabilities." Regarding "technological capabilities," Kim (2001) defines elements of technological capabilities as production capability and innovation capability. Production capabilities in the shipbuilding industry include technological capabilities related to design, building of ships and operation management of the shipbuilding process. Innovation capabilities are reflected in the development of new process and product-related technology (KOSHIPA 2005).

Asian Latecomers' Technological Catching-up in the Shipbuilding Industry

The history of the shipbuilding industry can be summarized as the continuous catching-up of latecomers and the recurrent shift of leadership. With the adoption of highly productive welding and block assembly that increased manufacturing productivity by threefold, Japan defeated European countries and became a new market leader. Since this technological transition from the old riveting method to new welding in the 1960s, Japanese shipbuilding industry had stayed at the top of the industry

Table 3. Shipbuilding Productivity Comparison between Korean, Chinese and Japanese Shipbuilders

	Korea	Japan	China
Relative Productivity Operation Time (For DH-VLCC)	0.86~0.91 480,000~530,000H (7~9Months)	1.0 430,000~450,000H (6~7Months)	0.21~0.29 220,000~250,000H (20~28Months)
Relative Labor Hour (Annual)	1.3 6 Days/Week	1.0 5 Days/Week	1.2 5 Days/Week
Wage Rate (Dollar/Hour)	3/4 (12~15)	1.0 (22.0)	1/6~1/12 (2.0~4.0)

*Source: KOSHIPA(2005)

for more than 30 years. Due to labor disputes and worsened productivity, the majority of European incumbents closed down their shipyards and exited the industry.

For the three decades that Japan had been reigning as the leader both in terms of market share and technological capabilities, other late-industrializing countries such as Korea, Taiwan and China had also been committed to promote the growth of their shipbuilding industry. Three countries each had a more or less nascent shipbuilding industry from the 1950s, but the paces of technological catching-up were significantly different.

Korean shipbuilders' shipbuilding productivity has now caught up with those of Japan. Not only that, Korean shipbuilders are evaluated as having superior design and shipbuilding capabilities regarding highly sophisticated vessels. Taiwan managed to catch up in terms of shipbuilding productivity, but their R&D capability remains far behind that of Korea and Japan. China remains inferior in both shipbuilding productivity and R&D capability.

Latecomer Strategy at an Early Stage of Technological Catching-up

Among many latecomer countries that entered the shipbuilding industry in the mid 20th century, China was the first latecomer country to promote the shipbuilding industry under the national initiative. Whereas Korea and Taiwan made a late entry after 1960s, China had been actively conducting research and development on its own from as early as 1950s. In 1950, the year after the Republican government was established, the Chinese government founded the national institute of shipbuilding and ocean engineering. Under the strong government initiative to make the shipbuilding industry the backbone of the Chinese economy, they embarked upon R&D with the technical assistance of Russia. In the beginning, China was able to achieve a certain amount of technological innovation, building an 18,000 DWT[4] (deadweight ton) bulker and a 12,000 HP tug boat (Lee 1984). However as the diplomatic relations between the Chinese and Russian government deteriorated, Russian shipbuilding engineers left China. Furthermore, the Great Proletarian Cultural Revolution in 1966 banned all kinds of technology transfer from foreign countries. During the 10 years of the Cultural Revolution before Deng Xiaoping adopted an open-door policy in 1976, the Chinese government strictly adhered to the principle of building national ships only with national technology (Lee 1984).

The technology policy of the Chinese government makes a stark comparison against other Asian countries that maintained open attitude towards adopting advanced technology from foreign countries. As the political propaganda and diplomatic relations rejected any form of foreign influence, so was foreign technology. Self-exploratory R&D efforts that were cut off from the mainstream industrial technology did not contribute much practical value to the shipyard. Despite active governmental efforts such as building more than 60 research institutes and developing a sufficient pool of human resources, their technological level was evaluated to be lagging behind the international standard by more than 20 years (Lee 1984).

On the other hand, it was early 1960s when Korea and Taiwan entered the modern shipbuilding industry. Both governments nationalized the existing shipyards and started to operate them under strong government control. In 1962, the Taiwanese government nationalized the shipyard that Ingalls Shipbuilding Co., an American shipbuilder, had been operating and established Ingalls-Taiwan Shipbuilding and Dry Dock Co. (Zhang 2007). In the same year, the Korean government launched the First Five-Year Economic Plan (1962-1966) and nationalized Korea Shipbuilding Corporation by acquiring its outstanding bonds (O

4) Deadweight tonnage: a measure of weight that a ship can safely carry

2001). Their moves were the first step towards developing the modern shipbuilding industry in Asia.

In comparison to the closed technology policy of China, Taiwan and Korea both openly adopted advanced shipbuilding technology from Japan and Europe. Taiwan maintained especially open attitude towards acquiring foreign technology. After nationalizing the shipyard, The Taiwanese government entered into a joint venture agreement with a Japanese shipbuilder, Ishikawajima Harima Heavy Industries in 1965 (Zhang 2007). Through this joint venture, Taiwan received a direct and rapid transfer of advanced Japanese shipbuilding technologies. Even though it was a shipyard built in Taiwan, it was close to a duplication of a Japanese shipyard — the Japanese shipbuilder took in charge of the design, procured engines and mechanical components from Japan, and the production process was under the surveillance of Japanese supervisors (O 2001). In 1975, China Ship Design and Development Center was established under the strong support of the Taiwanese government, with its focus of research upon ship design.

As for Korea, steel ships were begun to be built with local technology and facilities after the restructuring of the Korea Shipbuilding Corporation (KSC; a predecessor of the current Hanjin Heavy Industries) in 1962. After the expansion and modernization of the shipyards, KSC's shipbuilding capacity reached 66,000 ton per annum. In 1967, KSC built a 6,000-ton steel ship to first receive quality accreditation from the American Bureau of Shipping (ABS). Due to lack of shipbuilding technology and infrastructure in 1960s, the Korean shipbuilding industry was only making a slow progress.

However in 1970s, the government established a plan to promote the heavy industries and induced major chaebols such as Hyundai (Hyundai Heavy Industries), Daewoo (Daewoo Shipbuilding & Marine Engineering) and Samsung (Samsung Heavy Industries) to enter the shipbuilding industry. Their technological capabilities were not strong enough to directly compete with foreign shipbuilders in the global market, and openly adopted advanced technology from Japan and Europe. Technology transfer took place in the form of importing foreign machinery and equipment, and receiving technical assistance from foreign engineers. In some cases, engineers and supervisors were directly dispatched from foreign countries. In other cases, local engineers were sent overseas to received short-term training. Computerized systems for shipbuilding design (SEAKING, FORAN, PRELIKON) and production (VIKING, AUTOKON) were adopted in the mid 1970s and 1980s from European countries such as Sweden and Norway. The engineers not only strived to absorb and assimilate the transferred shipbuilding and design technology, but also to experiment, modify and adapt the technology according to local needs (KOSHIPA 2005).

When KSC received an order for a product carrier for the first time in 1970 from Gulf Corporation, they virtually had to start from scratch. Design technologies and shipbuilding techniques had to be transferred from advanced countries. For this project, KSC signed a technical assistance contract with a German shipbuilder, HDW. HDW provided ship design and machinery and dispatched their engineers to provide technical assistance and surveillance (Kim 2006). In 1971, Hyundai Heavy Industries also received technology transfer from Appledoor Shipbuilders and Scott Lithgow of Britain after winning their first bid for a VLCC, which was later named Atlantic Barron.

Although Korean shipbuilders remained open to the import of foreign technology, they did not just remain at imitative learning of foreign technology, and strived to come up with their own innovation and technology. Their intent was to keep the level of imitative learning to the least possible level, so that they can strike out their own path of learning. After successful building of the product carrier, KSC was offered a long-term technology transfer agreement from the Japanese shipbuilders. Japan suggested that they provide building technology, worker training, component procurement and even machinery lease in the same way as the Japanese joint venture were run in Taiwan. However, Korean shipbuilders were concerned with a possibility that a unilateral technology transfer may bring a long-term technological subordination of the Korean shipbuilding industry to the Japanese (O 2001), and turned down the offer.

The Korean government also actively promoted local companies' R&D and exploration of new technology, establishing the Shipbuilding and Ocean Technology Research Institute in 1968. The role of the institute was to develop local technologies related to ship design, ship production, welding, engine and machineries.

Private shipbuilders such as Hyundai, Daewoo and Samsung also invested substantial amount of money in establishing their own research institutes and procuring necessary equipments for tests and experiments. In 1982, Hyundai established HMRI(Hyundai Maritime Research Institute) and HWRI(Hyundai Welding Research Institute) in order to conduct their proprietary R&D and test the performance of their vessels, engines and welding equipments. In the same year, Daewoo also opened their own research institute and Samsung also followed suit in 1984.

Another important endeavor was to promote local production of shipbuilding machineries and ship parts. Among others, engine is the most crucial part in shipbuilding, which accounts for almost 10% of the total ship's price. However, Korean shipbuilders had been entirely dependent upon imported engines. Hyundai first entered the engine business in 1976. They initially licensed the engine design from a German company called Man B&W located in Augsburgs. After signing alliance contracts with Man B&W and Sulzer, a Swiss company, Hyundai began to manufacture engines and received major orders. However at this point, the European counterparts refused to provide Hyundai with the engine design with an intention to get the orders themselves. In response to this, Hyundai decided to invest in making their own engine design. They had to invest more than 40 billion won and wait until 2002 to finally produce their proprietary engine called HiMSEN engine. Such an endeavor is a typical example of how Korean shipbuilders pursued both imitation and exploration.

Inter-Country Difference in Learning Strategy and the Results of Technological Catching-up

Due to this full-fledged knowledge transfer from Japan, Taiwan's shipbuilding technology stayed ahead of Korea and China during the 1960s and the early 1970s. When Korea was exporting 250-ton fishing boats to Taiwan in 1969, Taiwan was already building a 100,000-ton oil tanker. During the period from 1969 to 1978, Taiwan built nine 100,000-ton oil tankers. Among them, the most impressive one was Burma Endeavor, a 450,000-ton oil tanker delivered to the British Merchant Navy. At the time, it was the third largest oil tanker in the world (Zhang 2007). During the early phase of technological catching-up, Taiwanese shipbuilding industry definitely showed faster pace of catching-up compared to Korea and China.

However after then until now, Taiwanese shipbuilding industry did not make a further progress and lost out to Japan, Korea and China. This is not because their shipbuilding capability was particularly inferior to other competing latecomers. Although lower in absolute shipbuilding capacity, process technology of Taiwan was evaluated as almost equivalent to that of Korea (Chou and Chang 2004). However, Taiwan had been only intent upon learning of the shipbuilding process, and neglected to develop new core technologies. They failed to diversify their product portfolio into higher-level vessels. Dependence on Japan meant less exploratory efforts to diversify its product portfolio and develop new technology. Whereas Korean shipbuilders started transitioning from oil tankers to more technologically sophisticated vessels in the early 1980s, Taiwanese shipbuilders was still depending more than 60% of their sales upon oil vessels (Lee 1984). Thus, the two oil shocks during the 1970s and the depressed demand for oil vessels in the 1980s were especially devastating to the Taiwanese shipbuilding industry. Their product diversification remained at technologically unsophisticated level — bulk carriers, general container ships and yachts. This meant that Taiwan failed to climb up the technological ladder and took a retreat. The short-term technological catching-up of Taiwanese shipbuilders fell apart in the long term.

How about the case of China, which obviously shows strong preference of innovation over imitation? As of the late 1990s, China's technological capabilities were continuously lagging far behind those of Japan and Korea in all aspects, from design, building and to core components and machinery. Orders to Chinese shipyards were mostly confined to unsophisticated and low-cost bulk carrier vessels. Chinese shipbuilders were evaluated as seriously inferior in shipbuilding technology, process automation, shipyard layout and operation management (KOSHIPA 2005). Until early 1980s, technologically unsophisticated bulk carriers accounted for more than 80% of the ships built by Chinese shipbuilders. Even as of 2007, bulk carriers still accounted for 50% of the ships ordered to Chinese shipbuilders. Chinese shipbuilders are incapable of building highly sophisticated vessels because of incompetent design skills. Their shipbuilding productivity also lags far behind that of Korea and Japan due to lack of appropriate

Table 4. Technological Capability Comparison between Korean, Chinese and Japanese Shipbuilders

		Japan	Korea	China
Design	Basic Design	100	95	80
	Detail Design	100	105	60
	Production Design	100	105	60
Production	Cutting	100	95	70
	Welding	100	90	70
	Equipment	100	90	60
	Erection	100	95	60
Operation Management	Cost Mgmt	100	85	40
	Material Mgmt	100	85	50
	Production Mgmt	100	90	40
	HR Mgmt	100	85	60

* Source: KOSHIPA (2005)

operation management.

China had maintained an extremely closed attitude towards adopting foreign technology until 1980s, and this was the major reason behind their failure in technological catching-up. From early on, China had been more actively investing R&D workforce and institutes than other latecomer countries had, but their technology lagged far behind the international standard (Lee 1984). Ever since the reign of Deng Xiao Ping in the late 1970s, the Chinese government saw a turnaround in its technology transfer policy. In 1982, the state-owned Chinese State Shipbuilding Corporation was established with an aim to restructure the stagnant shipbuilding industry (Lee 1984). China changed their policy and started to adopt advanced technology from Japan and European countries since then. However, it was difficult for China to cover up for the lost two decades. Their independent exploration without any influx of advanced technology had led to a serious lack of absorptive capacity.

However during the same period, Korea not only outcompeted Taiwan and China, but also rapidly caught up with Japan by maintaining a balance between technology adoption and self-exploration. By building absorptive capacity through adapting and improving foreign technology, Korean shipbuilders could acquire greater technological breadth. Both the Korean government and firms actively invested not only in design and shipbuilding, but also in proprietary R&D and local production of machinery and equipments. For instance, Hyundai Heavy Industries (HHI) entered the engine business in 1977 to obtain technological independence and minimize cost. In mid-1980s, Korean shipbuilders were already adopting self-developed cutting, welding and assembly techniques to the shipbuilding process. They were also starting to design their own product carriers and container vessels (Lee 1984). After building a stable technology base through these endeavors, Korean shipbuilders were challenged into building of cutting-edge, higher-technology vessels. The beginning was in 1978 when HHI organized a task force team to acquire LNG vessel technology. Korean shipbuilders licensed LNG vessel design from Kvaerner of Sweden and GTT of France, but their own effort was required to commercialize the technology. In 1994, HHI became the first Korean shipbuilder to build a Moss-type LNG vessel and Korea rose as one of very few countries that could build LNG vessels. As building of LNG vessels require cutting-edge technology from design to actual building and operation management, Korea's success in the LNG vessel market could be seen as a sign that their innovative capability caught up with that of Japan.

Not only that, Korean shipbuilders came up with new technologies such as on-land shipbuilding, underwater dam use welding, mega-block assembly and new products such as self-propelled FPSO (FPSO with its own engine), drillship and LNG-RV(LNG Regasification Vessel). This shows that the innovative capability of Korean shipbuilders have not just caught up with, but rather surpassed that of Japanese shipbuilders.

Technological uncertainty and latecomers' technological leapfrogging

Adoption of welding techniques and the leapfrogging of Japan. Japan could displace Britain and become the new leader in the global shipbuilding industry by substituting riveting method with welding method. Riveting method is a previously used way of connecting steel plates by drilling holes in the plates and inserting metal pins. It required a substantially larger amount of time and manpower compared to the welding method. Current shipbuilding employs welding and block assembly — separately built blocks are assembled together on the dock by welding.

It is generally mistaken that Japan invented and adopted the welding and block assembly method to shipbuilding. They were actually first invented and put to use by the U.S navy. The U.S had to build supply ships as fast as possible against the attacks of German submarines, and thus invented welding and block method to reduce shipbuilding time. Welding method greatly improved the building productivity, but had safety issues. Welded ships were vulnerable to low temperature and there were many accidents in which welded warships became severely damaged (Motora 1997). Due to the safety issues and employee resistance, European shipbuilders did not adopt welding technique. On the other hand, Japanese shipbuilders assumed that they could overcome European shipbuilders by adopting the welding technique for mass shipbuilding. They adopted the automatic welding machine from the U.S in 1951. The ratio of welding to the total work dramatically increased from 25% in 1948 to 100% in 1955. In 1960, the “Lotus System,” which allowed more efficient downward welding, was developed by the Mitsui. In 1965, the single-side welding method was also developed by a Japanese shipbuilder, contributing to an increase of work efficiency. By actively improving the welding and block assembly method, Japanese shipbuilders were able to substantially cut down building time and cost (Motora 1997).

Thanks to the improvement in metal engineering after 1950s, shipbuilders were supplied with steel plates that were strong against low-temperature brittling. Learning-by-doing greatly improved the productivity of welding, helping Japanese shipbuilders to take the reign of the industry since 1958. British shipbuilders that used to occupy 80% of the global shipbuilding market were driven out of the market.

The Standard Competition in the LNG Vessel Market and Korea’s Leapfrogging. LNG carrier is known as the ultimate symbol of cutting-edge shipbuilding technology. LNG carriers price over 200 million dollars, and the required level of technological sophistication is at the frontier of the modern shipbuilding technology. The fact that Korean LNG carrier shipbuilders are now dominating the global LNG vessel market is the very proof of Korean shipbuilders’ successful technological catching-up. Korean shipbuilders outcompete foreign competitors in performance criteria such as quality, delivery, and price. In 2005, they won 33 orders out of the total world demand of 42 (which is equivalent to a share of 76%), and 22 orders out of 27 as of August 2006(82%) (KOSHIPA 2005). How did this become possible? The standard competition between the two competing LNG vessel technologies became a window of opportunity for Korea's catching-up.

An LNG carrier is classified as either Moss type or Membrane type, following the name of the containment system that it is adopting. Moss type containment system is a spherical aluminum tank, whose design is owned by the Norwegian company Moss Maritime. Membrane type containment system is a tank embedded inside a ship's body. The French company GTT owns the patent of the system (Kim 2006). Different strengths and weaknesses of two containment systems were the reason of competition. Moss type was superior in terms of safety because containment system and body were kept separate. On the other hand, Membrane type was regarded to be less safe than Moss type but could hold larger capacity.

Japan, the first country to commercialize the LNG carrier, chose the Moss type. The first LNG carrier built by Hyundai Heavy Industries was also a Moss-type vessel. At the beginning, Korean shipbuilders wanted to adopt Japanese technology in building their LNG vessels, but Japanese shipbuilders, in apprehension of Korean shipbuilders' rapid technological-catching-up, intervened to prevent the transfer of technology to Korea. According to a newspaper interview of an HHI engineer, the price of production components Japanese shipbuilders charged to Korean shipbuilders was twice as much as what was charged to other countries. Faced with Japanese reluctance to transfer the LNG vessel technology, Korean engineers even had to invent a new method to weld Moss containment tanks.

After going through such difficulties in receiving technology transfer from Japan, Korean latecomer firms began to consider the Membrane type as the new alternative. At the time, the Membrane technology had not been widely commercialized, and Japanese shipbuilders did not have a competitive advantage in this new technology. The merit of Membrane technology was that it allowed building high-capacity tanks. Korean shipbuilders saw the potential in Membrane technology in that increasing oil price and LNG demand will bring increased demand of high-capacity LNG vessels. Soon, all Korean shipbuilders started to shift towards the Membrane type. Hanjin Heavy Industries became the first Asian shipbuilder to build an LNG vessel in 1995 (Kim 2006). Samsung Heavy Industries and Daewoo Shipbuilding & Marine Engineering (DSME) also chose the Membrane technology.

Even though the original Membrane technology itself was licensed from GTT, Korean shipbuilders had to conjure up ideas to develop new production technology for this venture. Their risk-taking paid off as the global demand for LNG increased after 2000. Membrane technology not only made it possible to embed higher-capacity containment tanks in LNG vessels, but also was later proven to be as safe as the Moss technology.

Before 1999, Japanese shipbuilders used to occupy more than 50% of the global LNG vessel market, but the market share of Korean shipbuilders took a sharp increase after 2000. As the market demand shifted from Moss type to Membrane, Japanese shipbuilders' expertise in Moss type carrier was rendered obsolete. Korean shipbuilders that have been building Membrane type vessels since early 1990s rose as new market leaders, and they even "reverse-exported" Membrane technology to Japanese shipbuilders. Korean shipbuilders now lead the technology frontier of the LNG vessel market, inventing more advanced types of LNG vessels such as sLNGc (Sealed LNG Carrier) and LNG-RV(LNG-Regasification Vessel).

VALIDATION OF PROPOSTIONS THROUGH CASE-ANALYSIS

Validation of Proposition 1

By reflecting upon Proposition 1 in the context of technological catching-up of three late-industrializing countries, Korea, Taiwan and China, we could confirm the fact that moderate amount of knowledge transfer, in balance with self-exploration, is most advantageous for successful technological catching-up. From the historical case analysis, we found that Taiwan had been entirely dependent upon external knowledge transfer from Japan during the early phase of catching-up, whereas China did not receive any knowledge transfer and explored on its own. Cases of both Taiwan and China show that a learning strategy without a balance between imitation and innovation leads to a failure in technological catching-up.

It can be seen from the failure of Chinese shipbuilders that a certain amount of imitative learning is indispensible in order to start the process of technological catching-up in the very beginning. As technological catching-up means decreasing the amount of technological gap between competitors, a latecomer has to absorb or create knowledge at a faster speed than the leader. Most latecomers resort to licensing and technological alliances because such imitative learning is the only way that they can accumulate technological knowledge and absorptive capacity at fastest speed. Latecomers require a substantial amount of accumulated absorptive capacity in order to create sophisticated technological knowledge by themselves. This cannot be done just by depending upon their own exploration. China had already invested a vast amount of resources in technological R&D before opening up to foreign technology in 1980s. However, proprietary technological knowledge created by the Chinese shipbuilders before 1980s was unpractical and lagging far behind the international standard. Despite their early efforts, China could only remain at mainly building low value-added vessels because their lack of absorptive capacity seriously hindered later development of design and production skills.

On the other hand, Taiwan became the failure case because they were only intent upon imitative learning and did not pursue innovative learning. Taiwan assimilated technological knowledge transferred from Japan, and this led to fast development of process technology. However, a shipbuilder needs to have innovative capabilities in order to build highly sophisticated vessels that can differentiate themselves from its competitors. Taiwan's focus upon fast imitative learning led to neglecting innovative learning. Learning by doing does not contribute to the diversity that is critical to learning about or creating something that is relatively new (Cohen and Levinthal 1990). As a result, Taiwan became known for their efficiency in building unsophisticated vessels such as oil tankers and container ships, but could not reach the stage of developing new core technologies and highly sophisticated ships as Korea did.

Compared to excessive exploitation of Taiwan and excessive exploration of China, Korea received a moderate amount of external knowledge transfer, and maintained a balance between exploitation of transferred knowledge and exploration of unknown knowledge. Unlike China, Korea maintained an open attitude towards advanced foreign technology and rapidly closed the gap between incumbent competitors. Unlike Taiwan, Korea did not neglect the importance of innovation and remain technologically stagnant. Korean shipbuilders refused long-term, unilateral technology transfer from Japan and chose project-based contracts to maintain independent learning. Instead, Korean shipbuilders established research institutes for basic technology research and continued to explore and apply new knowledge.

These continuous efforts enabled Korean shipbuilders to build more differentiated, cutting-edge vessels. The invention of different shipbuilding techniques such as mega-block assembly (Samsung), on-land shipbuilding (Hyundai) and floating-dock shipbuilding (DSME) led to successful building of ultra-large container ships and LNG vessels. By applying the mechanism of steam pressure rice cookers to LNG vessels, DSME first developed sLNGc that minimized evaporation of LNG. These are only a few examples among many technological innovations produced by Korean shipbuilders.

Validation of Proposition 2

Proposition 2 suggests that technological uncertainty can act as a catalyst to latecomers' radical technological leapfrogging. By looking into the history of latecomer shipbuilders' technological catching-up, we can confirm our argument that a rise of technological uncertainty has a great impact upon the shift of industrial leadership and latecomers' radical leapfrogging. Emergence of technological discontinuities and competition between alternative standards brought a significant amount of technological uncertainty to the industry. Generally, the industry goes through an era of ferment until a new technological discontinuity becomes a dominant design. During this period, incumbent firms with strategic inertia tend to adhere to existing technology knowledge to protect their competitive advantage and minimized risk. On the others hand, latecomers without a sunk cost in the existing technology are better positioned to explore a new technological trajectory (Christensen 1997).

When a new technological trajectory is found out to be superior to the older one, latecomers can make a radical leapfrogging over the incumbents that are tied to their past investment and nullify their prior technological advantages. Lee and Lim (2001) define such mode of technological catching-up as path-creating catching-up or technological leapfrogging. Catching-up of the Korean semiconductor industry is a representative example of technological leapfrogging. At important junctures in their history, latecomer Korean manufacturers "leapfrogged" and created their own technological trajectories, choosing the newly introduced CMOS and Stack structure over NMOS and Trench structure. This strategic exploration of a new technological trajectory, enabled by their continuous pursuit of balanced learning, was their key success factor.

In the shipbuilding industry, latecomer firms could outcompete incumbent leaders by a preemptive choice of a new, uncertain technological trajectory. When British shipbuilders were sticking to the old riveting method, Japan took a challenge to adopt the welding method from the U.S and saw a dramatic increase in productivity. Likewise, Korean shipbuilders' choice to select Membrane technology led to overcoming Japanese dominance in the LNG vessel market. These cases are good examples to show that exploration of a new technological trajectory can effectively incapacitate incumbent firms.

Unless these latecomer firms possessed independent innovative capability built on the basis of sufficient absorptive capacity and combinative capability, they would not have been able to explore new technological paths ahead of other competitors. Such capabilities were developed because they had maintained a balanced learning strategy from the early stage of technological catching-up. In this sense, Proposition 1 and Proposition 2 cannot be separately understood.

DISCUSSION AND CONCLUSIONS

Prior literatures regarding the latecomers' technological catching-up and their imitation strategy presupposes that they must go through the imitation stage in order to transition to the innovation stage. However, these studies fail to provide a compelling argument about why only a few latecomers can become true innovators, whereas most others remain as imitators. Kim (1999) suggest that existing knowledge base and intensity of effort are required for latecomers to evolve from duplicative imitation to creative imitation and innovation. However, without an appropriate learning strategy, having just knowledge and effort does not necessarily create successful catching-up. This is the fundamental argument which our study is based upon.

The purpose of our study is not just to examine the impact of different learning strategy upon latecomers' technological catching-up, and but also to provide a historical, real-life account of technological catching-up that actually occur in the industry. Thus, instead of quantifying catching-up by using patent counts, out study adopted case analysis method to give a detailed examination of how latecomers' choices in accumulating their technological capabilities lead to different results in catching-up.

Through a historical case study of the Asian shipbuilding industry, we could find support for our propositions. Findings from the shipbuilding industry showed that successful catching-up was most likely with an appropriate combination of knowledge transfer and self-exploration from an early stage of technological catching-up. Japan's success by adopting welding technique and Korea's success by choosing Membrane technology show that latecomers can exploit technological uncertainty to implement radical leapfrogging.

The implications of this research are as follows: First, our paper enriches the understudied subject of technological catching-up by latecomer firms. Previous studies in catching-up used the idea of technological regime to find out sectoral or industrial differences in technological catching-up, making an inter-industry comparison to find out which industry provides a favorable environment for latecomer's catching-up (Malerba and Orsenigo 2001). Although they provide an answer to which industry to enter, they did not answer the question of how latecomers can catch up incumbent competitors after entering the industry. Our study provides more generally applicable advice about making strategic choices at the firm level to facilitate the process of catching-up.

Second, this is a rarely precedented piece of study regarding the modern shipbuilding industry during the mid-to-late 20^{th} century. Although there have been numerous studies regarding Korean firms' technological catching-up in the semiconductor, consumer electronics, wireless communications and automobile industry, absent was a study of their success in the shipbuilding industry. Our historical case analysis of the Asian shipbuilding industry allows a rich understanding of the competitive dynamics and major issues of the shipbuilding industry.

Third, this study has an implication for research in technology transfer and firm learning. By borrowing concepts from the well-known theory of learning myopia, absorptive capacity, combinative capability, this study makes yet another extension of the well-established topic of exploration-exploitation.

This study was conducted in the setting of the Asian shipbuilding industry in the mid-to-late 20^{th} century, but the propositions in this study may be applied to other industries such as the semiconductor or the wireless communications industry. For example, reflect our proposition 1 upon the catching-up case of Korean semiconductor firms. Korean semiconductor firms not only established R&D institutes in the Silicon Valley to absorb and assimilate the licensed technology, but also to independently explore and create new knowledge (Song, Almeida, and Wu 2001). On the other hand, our Proposition 2 about technological uncertainty and leapfrogging can be reflected upon the catching-up case of the Korean mobile phone manufacturers. During the era of analogue communications, Korean firms were dependent upon adoption and imitation of foreign technology. However, they were also simultaneously pursuing independent R&D, as shown in their effort to localize the electronic telephone exchanger. Such prior innovative efforts made it possible for Korean firms to aptly react to technological uncertainty of digital communications, strike out a new trajectory of CDMA technology and radically leapfrog incumbent competitors. Such catching-up process is essentially similar to the process in the shipbuilding industry. Comparing the process of catching-up across different industries may be an interesting piece of work for future researchers.

The most important message of this study is that latecomers' balanced learning at the early stage is of utmost importance. However, although early overreliance upon external knowledge should be warned against, the importance of early imitation cannot be denied. As many studies have argued before, innovation in part starts from an extension and combination of existing pieces of knowledge. Thus, what is important is how the knowledge is transferred and combined. Certain modes of knowledge transfer can guarantee better balance of imitation and innovation, while others greatly gravitate towards imitation. Transfer of codified knowledge may only foster imitation, but transfer of tacit knowledge may better combine with independent exploration and take the organization to a higher level. For instance, Song, Almedia and Wu(2003) argue that the mobility of engineers not only transfers codified knowledge that can be transferred through licensing, but also transfers tacit knowledge that are relevant to knowledge creating and innovation. Analysis of different modes of technology/knowledge transfer to see how they affect imitation and innovative learning of latecomers may make an interesting future research.

REFERENCES

Anderson, Phillip C. and Michael L. Tushman (1990), "Technological Discontinuities and Dominant Designs: A Cyclical Model of Technological Change," *Administrative Science Quarterly,* 35(4), 439-465.

Brezis, Elise S., Paul R. Krugman and Daniel Tsiddon (1993), "Leapfrogging in International Competition: A Theory of Cycles in National Technological Leadership." *American Economic Review,* 83(5), 1211-1219.

Cantwell, John (1989), Technological Innovation and Multinational Corporations, B. Blackwell Cambridge, Mass., USA.

Cho, Dong-sung and Michael E. Porter (1986), "Changing Global Industry Leadership: The Case of Shipbuilding," in *Competition in Global Industries*, Michael E. Porter ed., Harvard Business School Press, 539-568.

Chou, Chia-Chan and Pao-Long Chang (2004), "Core Competence and Competitive Strategy of the Taiwan Shipbuilding Industry: A Resource-based Approach," *Maritime Policy & Management*, 31(2), 125-137.

Christensen, Clayton. M. (1997), *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail*, Harvard Business School Press.

Christensen, Clayton. M. and Joseph. L. Bower (1996), "Customer Power, Strategic Investment, and the Failure of Leading Firms," *Strategic Management Journal*, 17(3), 197-218.

Cohen, Wesley M. and Daniel A. Levinthal (1990), "Absorptive Capacity: A

New Perspective on Learning and Innovation," *Administrative Science Quarterly,* 35(1), 128-152.

Dahlman, Carl, Larry E. Westphal and Linsu Kim (1985), "Reflections on Acquisition of Technological Capability," in *International Technology Transfer: Concepts, Measures and Comparisions*, Nathan Rosenberg and Claudio Frischtak eds., Praeger,

Dierickx, Ingemar and Karel Cool (1989), "Asset Stock Accumulation and Sustainability of Competitive Advantage", *Management Science*, 35(12), 1504-1511.

Dosi, Giovanni (1982), "Technological Paradigms and Technological Trajectories: A Suggested Interpretation of the Determinants and Directions of Technical Change," *Research Policy,* 11(3), 147-162.

Eisenhardt, Kathleen M. and Jeffrey A. Martin (2000). "Dynamic Capabilities: What Are They?" *Strategic Management Journal*, 21, 1105-1121.

Freeman, Christopher (1988), "Technology Gaps, International Trade and the Problems of Smaller and Less-developed Economies," in *Small Countries Facing the Technological Revolution*, Christopher Freeman and Bengt-Ake Lundvall eds., Pinter Publishers, London.

Freeman, Christopher and Luc Soete (1997), The Economics of Industrial Innovation, MIT Press.

Grabowski, Henry G. and John M. Vernon (1987), "Pioneers, Imitators, and Generics — A Simulation Model of Schumpeterian Competition," *The Quarterly Journal of Economics,* 102(3), 491-526.

Hobday, Michael (1995), "East Asian latecomer firms: Learning the technology of electronics," *World Development*, 23(7), 1171-1193.

Kim, Hyo-Chul (2006), *Ships of Korea*, Jisung Press, Seoul, Korea.

Kim, Linsu (1997), *Imitation to Innovation: The Dynamics of Korea's Technological Learning*, Harvard Business School Press.

_______ (1999), "Building technological capability for industrialization: analytical frameworks and Korea's experience," *Industrial and Corporate Change*, 8(1): 111-136.

_______ (2001), "The Dynamics of Technological Learning in Industrialisation," *International Social Science Journal*, 53(168), 297-308.

Kogut, Bruce and Udo Zander (1997), "Knowledge of the Firm. Combinative Capabilities, and the Replication of Technology," *Knowledge in Organizations*.

KOSHIPA(The Korea Shipbuilders' Association) (2005). *The Korean Shipbuilding Industry - Growth and Challenge (originally in Korean)*, Pure communications, Seoul, Korea.

Lake, Arthur W. (1994), "Technology Creation and Technology Transfer by Multinational Firms," in *Technology Transfer to Developing Countries*, Edward K. Y. Chen, John H. Dunning eds., Taylor & Francis, London,

U.K.
Lee, Jeho and Young U. Ryu (2002), "Exploration, exploitation and adaptive rationality: the neo-Schumpeterian perspective," *Simulation Modelling Practice and Theory*, 10(5-7): 297-320.
Lee, Jongseok, Jeho Lee and Habin Lee (2003), "Exploration and Exploitation in the Presence of Network Externalities," *Management Science,* 49(4), 553-570.
Lee, Keun (2005), "Making a Technological Catch-up: Barriers and Opportunities," Asian *Journal of Technology Innovation*, 13(2), 97-131.
Lee, Keun and Chaisung Lim (2001), "Technological Regimes, Catching-up and Leapfrogging: Findings from the Korean Industries," *Research Policy,* 30(3), 459-483.
Lee, Keun, Chaisung Lim, and Wichin Song (2005), "Emerging Digital Technology as a Window of Opportunity and Technological Leapfrogging: Catch-up in Digital TV by the Korean Firms," *International Journal of Technology Management*, 29(1/2), 40-63.
Lee, Sang-Kyu (1984), *A Comparative Analysis of the Shipbuilding Industry of Korea, Japan, Taiwan and China (originally in Korean)*, KIET(Korea Institute for Industrial Economics & Trade), Seoul, Korea.
Levinthal, Daniel A. and James G. March (1993), "The Myopia of Learning," *Strategic Management Journal,* 14(8): 95-112.
Malecki, Edward J. (1997), *Technology and Economic Development: the Dynamics of Local, Regional and National Competitiveness*, Longman, Essex, U.K.
Malerba, Franco and Luigi Orsenigo (2001), "Technological Regimes and Sectoral Patterns of Innovative Activities," *Industrial and Corporate Change,* 6(1), 83-118.
March, James G. (1991), "Exploration and Exploitation in Organizational Learning," *Organization Science,* 2(1), 71-87.
March, James G. and Herbert A. Simon (1958), *Organizations*, John Wiley & Sons Inc.
Mathews, John A. (2001), "Catching-up Strategies in Technology Development with Particular Reference to East Asia," Background paper for World Industrial Development Report, UNIDO.
Motora, Seizo (1997), "A Hundred years of Shipbuilding in Japan," *Journal of Marine Science and Technology*, 2(4), 197-212.
Nelson, Richard R. and Sydney G. Winter (1982), *An Evolutionary Theory of Economic Change*, Harvard University Press, Cambridge MA.
O, Wonchol (2001), "*Korea Model for Economic Development(originally in Korean),*" Mimeo, http://ceoi.org/9ceoi(text)/9ceoi(main2).htm
Park, Kyoo-Ho and Keun Lee (2006), "Linking the Technological Regime to the Technological Catch-up: Analyzing Korea and Taiwan Using the US Patent Data," *Industrial & Corporate Change,* 15(4), 715-753.

Perez, Carlota and Luc Soete (1988), "Catching Up in Technology: Entry Barriers and Windows of Opportunity," in *Technical Change and Economic Theory,* Giovanni Dosi ed., Pinter Publisher, 458 -479.

Romer, Paul M. (1990), "Endogenous Technological Change," *The Journal of Political Economy,* 98(5), 71-102.

Song, Jaeyong, Paul Almeida, and Geraldine Wu (2001), "Mobility of Engineers and Cross-border Knowledge Building: the Technological Catching-up Case of Korean and Taiwanese Semiconductor Firms," *Research on Technological Innovation, Management and Policy,* Henry Chesbrough, Robert Burgelman, eds., 59-84.

________ (2003), "Learning-by-Hiring: When Is Mobility More Likely to Facilitate Interfirm Knowledge Transfer?," *Management Science,* 49(4), 351-365.

Song, Jaeyong and Jongtae Shin (2008), "The Paradox of Technological Capabilities: A Study of Knowledge Sourcing from Host Countries of Overseas R&D Operations," *Journal of International Business Studies,* 39(2), 291-303.

Song, Michael and Mitzi M. Montoya-Weiss (2001), "The Effect of Perceived Technological Uncertainty on Japanese New Product Development," *Academy of Management Journal,* 44(1), 61-80.

Teece, David J. (1986), "Profiting from Technological Innovation," *Research Policy,* 15(6), 285-305.

_______ (2007). "Explicating Dynamic Capabilities: the Nature and Microfoundations of Sustainable Enterprise Performance," *Strategic Management Journal,* 28(13), 1319-1350.

Teece, David J. and Gary Pisano, and Amy Shuen (1997). "Dynamic Capabilities and Strategic Management," *Strategic Management Journal,* 18(7), 509-533.

Tripsas, Mary (1997), "Unraveling the Process of Creative Destruction: Complementary Assets and Incumbent Survival in the Typesetter Industry," *Strategic Management Journal,* 18(Supplement 1): 119-142.

Zander, Udo and Bruce Kogut (1995), "Knowledge and the Speed of the Transfer and Imitation of Organizational Capabilities: An Empirical Test," *Organization Science,* 6(1): 76-92.

Zhang, Jian-ren (2007), "Introduction to Shipbuilding Engineering: The Present and the Future of the Taiwanese Shipbuilding Industry (originally in Chinese)," Lecture material, Taiwan.

Received October 07, 2008
Revision received May 03, 2008
Accepted May 17, 2009