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Analysis on the Multi-technology Capabilities of Korea and Taiwan Using Patent Bibliometrics

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Summary

This paper explores multi-technology capabilities between Korea and Taiwan by analyzing the pattern of inventive activities concerning technology fusion by using patent bibliometrics. Although two countries exhibit a similar level of invention activities and high degree of specialization in emerging technologies measured by the number and technological fields of their US patents, innovation systems in two countries differ. MTCs (multi-technology corporations) are stronger in Korea national innovation system while small innovative firms play important roles in Taiwan national innovation system.

Technology fusion has been an important source of technological innovation, and it suggests possible advantage for the Korean innovation system because it is a common belief that global size firms - most of them are multi-technology corporations - can perform better in multi-technology fusion and scientific research. The result of patent bibliometrics suggests rather complex answers to the belief. Even though Korea shows slight advantage, it may not be ascribed to the large MTCs.

Key Words: multi-technology capabilities, invention activities, patent bibliometrics, Korea, Taiwan

1. Introduction

In recent years, Korea and Taiwan exhibit much higher US patenting activity than the emerging economies and even began to exceed advanced countries particularly in emerging technology fields. They achieved innovation capabilities by specialization in fast-growing industries. However, Korea and Taiwan are considered as having different economic systems.

The major difference between the economies of Korea and Taiwan has been identified as

the Chaebol based system vs. small and medium firms (SMEs) based system in the previous studies (Amsden, 1989; Amsden and Chu, 2003). Although Taiwan has ramped up large sized firms to catch up in semiconductors and display industries, the fundamental difference still remains in innovating activities as well as in market share. Patent statistics shows that the large proportion of patents come from SMEs in Taiwan (Park, 2004). In terms of market share and export performance, small and medium enterprises (SMEs) in Taiwan outstrip Korean counterparts.

Whether an economic system that is dominated by large business group can perform better in innovation has been a serious question (Mahood and Mitchell, 2004). The Asian crisis in the late 1990s provoked a debate over the two different innovation systems in Korea and Taiwan. It is argued that Taiwan's is less vulnerable to financial crisis (Ernst, 2000).

However, SMEs have advantages and disadvantages in dealing with the new trend of technological change. The new trend can be dubbed as 'digital convergence', 'technology fusion', 'fused technology', etc. In the academic circle, technology fusion has been discussed mainly with large Japanese corporations and their dexterous management of emerging technology (Kodama, 1991; Kodama, 1995). If SMEs cannot deal with technology fusion dexterously then the Korean system of innovation based on the large business group may perform better than Taiwan. Considering large Korean firms are multi-technology corporations (Granstrand and Sjölander 1990), this hypothesis is plausible.

However, the issue on the relationship between national systems of innovation based on multi-technology corporations and the capability to deal with multi-technology fusion has never been addressed so far. Therefore, it is meaningful to compare inventive activities related to technology fusion in two different national systems of innovation: innovating small firm based Taiwan vs. MTCs based Korea.

This paper analyses multi-technology capabilities between Korea which is considered as MTCs centered innovation systems and Taiwan which is characterized as innovating SMEs centered innovation systems concerning technology fusion by using patent bibliometrics. We will, first, review national systems innovation of Korea and Taiwan focusing on different industrial structures. Literature on the relationship between firm size and innovation activities will be examined. Issues concerning the firm size and technology fusion will also be elaborated. Data and the results on the multi-technology capabilities between Korea and Taiwan by using patents bibliometrics will be presented. Finally we will put forward conclusions on the comparison multi-technological capabilities between Korea and Taiwan.

2. Overview of National Innovation Systems of Korea and Taiwan

There are many similarities between two economies. The income levels of the two countries are similar. Both economies have developed through export-oriented policies with rapid industrialization. Export contribution to GDP is 59.4% in Taiwan and 37.3% in Korea.[1] Their exports were interlinked with imports of capital goods mainly from Japan, and both of them show strengths in manufacturing information technology goods. R&D activities indicate that product improvement had accounted for the main activities in the two countries. As the economy develops, previous OEM firms evolved to ODM with increase in design intensive innovation (Hobday, 1995; Kim, 1997). Both countries have put an emphasis on science and technology innovation in the process of economic development. The transition from imitation to innovation appears to have been successful.

However, Korea and Taiwan shows different technological capabilities building process. In the case of semiconductor industry, Korea having mastered manufacturing technologies moved to design capabilities while Taiwan having first expanded its design sector and moved to the development of its manufacturing sector (Chen and Sewell, 1996). In addition, Taiwan exhibits a surge in patenting activity in the late 1980s while the Korea achieved rapid increase in patenting in 1990s (Mahmood and Singh, 2003).

Different paths of technology capabilities building process of the two countries reflect different setting of national systems of innovation. As Mathews (1997) points out, Taiwan's semiconductor industry was built upon mainly by small firms under high-technology cluster policies - mainly by the government's efforts of following a Silicon Valley type of innovation. In contrast, Korea pursued large firms favored policies in the development of semiconductor industry (Kim, 1998).

Interestingly, however, the levels of patenting activities are similar in terms of both quantity and technological fields. Korea and Taiwan show a high degree of specialization. The profile of the most frequently patented technology fields confirms that both of them heavily invest in information and communication technology (ICT). Korean and Taiwan have a majority of patents in semiconductor (Table 1). Five of the top six patenting areas in Korea overlap Taiwan's top six patenting fields. The only difference is that the 4th most patenting area in Korea (W04 Audio/Video Recording and System) does not appear in Taiwan's Top six. Korean consumer electronics groups show strong inventive activities but Taiwan does not have global consumer electronics firms that match Korea's. The 5th rank in Taiwan is also ICT related - U12 Discrete Devices.

1) Word Trade Organization (2005), *Statistics 2005.*

Table 1: Top Six Patenting Technology Areas in Korea and Corresponding Ranks in Taiwan

(Unit: %, Year: 1999)

Top Patenting Area (Derwent Class)	Korea	Rank	Taiwan	Rank
U11 Semiconductor Materials and Processes.	7.3	1	11.4	1
U14 Memories, Film and Hybrid Circuits.	6.1	2	4.5	4
L03 Electro-(in)organic, chemical features of conductors, resistors, magnets, capacitors and switches, etc.	5.1	3	10.5	2
W04 Audio/Video Recording and Systems.	4.8	4	U12 Discrete Devices	(5)
T01 Digital Computers.	4.3	5	4.1	6
U13 Integrated Circuits.	3.8	6	5.4	3
Total	31.4	-	40.3	-

Source: Author's search in Delphion database

However, there is prominent contrast in the role of SMEs. This can be easily identified if we extract the top ten inventors (patent assignees). The majority of Taiwanese patents were 'none reported' as they are individually own (Table 2). If we consider 'non-reported' as being patents of SMEs, the share of SMEs and individual owned patents is very high in Taiwan. In contrast, Korea has very small number of individual patents and the majority of patents belong to large corporations, Samsung Electronics, Co, in particular, large firms dominate the patent activities.

Table 2: Top Assignees of Korea and Taiwan in the U.S. Patents

	Korea	%	Taiwan	%
1	Samsung Elec. Co. Ltd.	43.2	None reported	42.7
2	None reported	18.2	United Microelectronics Corp.	5.4
3	Hynix Semiconductor Inc.	15.4	Industrial Technology Research Institute	5.2
4	Daewoo Electronics Corp.	7.6	Taiwan Semiconductor Mfg Co.	4.7
5	LG Electronics Inc.	6.7	Vanguard International Semiconductor Corp.	2.6
6	Hyundai Motor Co.	2.5	Winbond Elec. Corp.	1.9
7	Assignee Not Standardized	1.4	Hon Hai Precision Co. Ltd.	1.9
8	KIST	1.1	National Science Council	1.6
9	LG Industrial Systems Ltd.	1.0	United Microelectronics Corp.	1.2

Note: non reported can be considered SME and individuals, and patents issued in 1999.
Source: Author's search in Delphion database.

Divergent national innovation systems were identified more than a decade ago (Nelson, 1993). National innovation systems of Korea and Taiwan mainly have been explored in order to show the differences between newly industrialized countries and advanced countries. However, technological capability building processes of Korea's large corporations and prominent role of Taiwan's SMEs are visible. The industrial structure is a very important aspect of the national system of innovation. The propensity to tap into external resources appears to be different between small and large firms, and the network of small firms usually different from large firms (Motohashi, 2004).

The shares of SMEs' employment are almost equal in Taiwan and Korea, but their roles in national systems of innovation in both countries are different. For example, the top thirty business groups have a market share of 73.7% in Korea while it is 31.3% in Taiwan (Abe and Kawakami, 1997:395). The share of US patents in both countries also confirms the importance of SMEs in Taiwan.

Taiwanese SMEs are aggressive in export but Korean SMEs are likely to be within keiretsu system and less prominent in export (Table 3). Korean SMEs are rather characterized as stable suppliers to large conglomerates, now most of them have been transformed to MTCs (Multi-technology Corporations). Levy (1991) praised that both systems for equally functioning in export-oriented growth.

Table 3: Performance of SMEs in Korea and Taiwan

	Korea	Taiwan
SME export share (of 100%)	42.4	52.6
SME productivity index (10)	4.52	7.78
SME value added (of 100%)	57.4	73.2

Sources: IMD WCY Executive Opinion Survey (2005), Abe and Kawakami (1997).

However, the difference between the two systems is revealed later when the Asian financial crisis changed environment significantly. The advantage of the SME-based economy was further highlighted in the Asian crisis when Korean chaebols were collapsing and putting pressure on the national economy, while SMEs collapse would not be so serious since they tend not to collapse simultaneously. The SME based economy was illustrated as less risky. In economics, active SMEs can act positively to reduce the concentration of market by few firms, which is interpreted as avoiding the risk of facing unfair exploitation by monopolistic corporations.

Taiwan has never been behind Korea in terms of GDP per capita until 2003, but the gap between Taiwan and Korea has been narrowed as large Korean corporations, such as Samsung, recently have been outperforming Taiwanese information technology firms. The rise of mainland China has also affected Taiwan more vigorously.

In short, although Korea and Taiwan shows similar economic and technological performance and heavy specialization in some emerging technology fields, they follow different technological capabilities building processes resulting in contrasting industrial structure. The role of large firms - MTCs is prominent in the Korean systems of innovation while SMEs have played important role in the Taiwanese systems of innovation.

3. Firm Size and Innovation

There have been many empirical studies on the relationship between firm size and innovation activities but it seems to be still controversial. Becheikh et al. (2006) point out in their review of the literature from 1993-2003 that 36 studies concluded that size has a significant positive effect on innovation while 4, 11, 5, and 3 studies respectively found the relationship between firm size and innovation to be negative, not significant, bell-shaped, or U-shaped.

Table 4: Empirical Studies on the Relationship between Firm Size and Innovation between 1993 and 2003

	Positive	Negative	Not Significant	bell-shaped	U-shaped
Number of article	36	4	11	5	3

Source: Becheikh et al. (2006).

These results suggest the relationship between firm size and innovation is rather complex and is possibly affected by other factors such as industrial and technological environments.

Main arguments proposed by Schumpeter and many researchers are: (1) large firms are better able to obtain financing for R&D projects and support risky activities that do SMEs, (2) firms with larger sales volume over which to spread the fixed R&D would experience higher returns than firms with lower sales volume (Cohen and Klepper, 1996), (3) large firms are also likely to have better-developed complementary activities and greater global reach to obtain information or other resources, (4) large firms can also exploit advantage of size resulted from scale and learning effects.

However, there are arguments that smaller firms have greater advantages in innovation. A smaller firm might be more innovative because it would be expected to be more flexible and therefore be better able to accept and effect change (Damanpour, 1992). In other words, large firm have sources of inertia such as high number of employers, large fixed asset bases, and a large base of existing customers or supplier contracts.

In general, larger firm size will allow a firm to accumulate a larger store of technological knowledge and capabilities to cover diversified technological areas and produce multi products while small innovating firms tends to be specialized in their technological competence and product range. Innovating SMEs are also more likely to involve product innovation than process innovation.

The relative advantages of the large firms-based economy compare to the SMEs-based economy can also be interpreted in many ways. As the industry life cycle advances in emerging industries, the advantage of Taiwan can diminish as the cycle reflects transition from Schumpeter Mark I with many 'Jeffersonian SMEs' to Mark II with 'Hamiltonian large firms'. The Schumpeterian Mark II regime, where large monopoly firms can accumulate resources and experience to invest in expensive research and development, can be favorable to large Korean firms. Process innovation can be exploited again as large firms have a good record in keeping the cost down. The economies of scale favor process innovation. Therefore, Taiwan also increased the share of the large corporation in national innovation system, intentionally fostering large LCD producers. However, many Taiwan SMEs remained at their original size because not all component producers can enjoy market growth of the ultra mass market.

4. Issues of Multi-technology Fusion and Firm Size

As digital convergence in information and communication technology (ICT) advances, the possible impact of digital convergence on countries that specialize heavily in the electronics industry could be significant. This can be applied to Korea and Taiwan where information technology related goods are one of the most important items in export. As digitalization enabled the merger of information, image, and sound in creating, disseminating, and storing, corresponding industries, such as media companies and electronics companies, come much more closer (Yoffie, 1997). Digital convergence indicates integration within the ICT sector, but integration between different technologies is also visible. Increasing integration has led to the appearance of 'hyphen technologies', such as opto-electronics, electro-chemical machining and bio- informatics. This development is commonly known as 'technology fusion' (Kodama, 1991.). In fact, digital convergence is

a sister concept of technology fusion in smaller scale.

Previous literatures indicate the possible limitation of SMEs in multi-technology fusion. The concept of the multi-technology corporation highlights the fact. The pervasive inter-diffusion of technology has spawned an explosion in the range of technologies involved innovation, and forced many businesses to become multi-technology corporations (Granstrand and Sjőander, 1990; Granstrand, 1994). Multi-technology corporations may have an organizational structure - quasi-integrated systems (i.e. families of firms) - in order to reap technology-related economies of scale, scope, speed and space.

The most difficult part for small firms to tackle with multi-technology fusion is the scope of technologies to master. It would be possible for small firms to master two or three distinct technologies, but building technological capabilities in a number of different technological fields could be a daunting task for SMEs. However, the majority of innovation can be achieved by concentrating on combining a few core technologies and outsourcing peripheral technologies. Hicks and Hedges (2005) point to the existence of serial innovators, highly innovative small firms in the market for technology. Developments of markets for technology encourage the innovative division of labour (Arora et al., 2001).

The scope of invention has been studied in previous research. SMEs cannot possess a wide range of technologies as large corporations do (Breschi et al., 2003). However, in defense of SMEs innovative capacities, Hwang (2006) argued that NTBFs (New Technology-base Firms) possess as wide a range of technologies as large firms do if the comparison is restricted to a certain type of product invention - within a specific patent database. Large corporations have wide scope of technologies because of different product divisions not because of size.

After the pioneering work of Kodama on the technological opportunities of technology fusion, many researchers paid attention to the possible implication of technology fusion. The most highlighted aspect of technology fusion is its association with emerging technology and high technological opportunities. Kodama mentioned that it surpasses just the simple sum of components. He argued that tight integration of different technologies create new values, and Levinthal further confirms that technology fusion containing meaning of creating noble product lineage (Levinthal, 1998). Unlike Rosenberg concept of technological convergence that emphasizes generic technology, technology fusion emphasizes 'integration' characteristics.

Although Kodama did not mention much about science-based technology, it is highly likely that technology fusion is associated with science-based technology (Hwang, 2005). Science bridges divergent technologies with fundamental understanding of working principles. Technology fusion demands intensive research to understand the interaction of information, material, and energy

at the most basic levels－including the atomic and molecular. For example, scientific research on specific organic chemicals has reduced the separation between chemistry and biology. Therefore, it is meaningful to examine both characteristics, integration and science-intensity when investigating the patenting activities of two countries with regard to technology fusion.

5. Methodology

In this paper, we will investigate differences between MTCs-based technological capabilities of Korea and innovating SMEs-centred technology capabilities of Taiwan and in terms of multi-technology capabilities. Patents bilbliometrics is used to constitute empirical investigation. A patent contains various information, such as citations and technology classification codes.

Three indices are chosen as proxies to reveal the level of multi-technology fusion: share of multiple class patent, originality, and average number of non-patent literature. The former two (the share and originality) are chosen to detect technology integration level, and the latter for science-intensity level in invention.

1) One indicator is the appearance of multiple technologies (classes) in a patent. Joint appearance of technological classes in a patent－so-called 'co-classification'－is an indicator of technology fusion. The share of multiple class patents represents integration aspect of the inventor's (or inventor group's) capability to combine different technologies. It is not always 'technology fusion' when SMEs own patents with multiple class patents, but it works fine as a relative index to measure 'integration' or in comparative research on two different inventor groups. Those who have many multiple class patents are likely to actively participate in technology fusion. Therefore the share of multiple class patents in SMEs will be compared with that of large firms. In the same manner, the share of multiple class patents in Korea will be compared with that of Taiwan. The number of classes in a patent may indicate the scope of the invention.
2) Another indicator that measures the combinative aspect of invention is originality. The concept is to measure whether the patent cites different kinds of patents; in other words, how much the invention draws from different kinds of technologies. (Jaffe and Trajtenberg, 2002)

$$\text{Originality i} = 1 - \sum_j^{n_i} s_{ij}^2$$

Sij : the percentage of citation that patent i makes on patents with j class

3) Patents also contain non-patent literature (NPL) references that may provide clues as to the science-intensity of the patent. By calculating the number of NPL references per patent, researchers can calculate the science-base (here, the science-intensive research in a patent) of a technology (Grupp, 1994; Narin, 1994).

Technology fusion is the phenomena of technological sphere and co-classification to detect technology fusion between two kinds of technology is very widely used method. To detect technology fusion type invention, it is also possible to use the number of multiple inventors with diverse disciplinary backgrounds. Although the latter method is very powerful, it is difficult to obtain inventor's profile and specialty, thus it is dropped from this research.

6. Data

US patents of Taiwan and Korea issued in 1999 and 2004 were used.

1) NBER patent citation complied by academics (Jaffe and Trajtenberg, 2002)
   NBER citation database retains the US patents from 1963 to 1999. It is open to the public and has many valuable indexes, such as generality, originality, and number of citation received.
2) Thomson Delphion US patent database on 1999 and 2004 to get patent classes in patent as NBER does not have a complete class list of a patent.
3) KISVALUE by KISINFO, Co. (audited firms in Korea) was used to identify SME assignee in Korean patents.
4) Kompass register, Hoovers, and Thomson Gale database was used to identify Taiwanese SMEs assignees

Among total 3,563 Korean patents in 1999, the patents that assigned to non-US assignees, 3,559 patents were chosen up. In Taiwan, after having selected non-US assignees, 3,634 patents are included in the analysis.

In the case of Taiwanese firms, the size of firm information is missing for the 1999 data, so second patent data set on the year of 2004 is collected. As the firm name may be missing due to incomplete coverage by firm database, patents are categorized into five cases: individually owned, owned by SMEs, by not identified firms, by large firms, and by public institutions and foreign firms. For the analysis, patents those by public institutions and identified foreign

firms are excluded from analysis. As a result of it, 3,731 Korean patents and 5,537 Taiwan patents are finally examined.

7. Patent Bibliometrics Results and Discussions

7.1. Multi-technology Capabilities between Korea and Taiwan

Patent bibliometrics reveals a delicate difference between Korea and Taiwan in terms of inventive activities. For statistical test, the non-parametric Mahn-Whiteny

test is used because of its robustness. This method is coarse but very efficient in comparing two data sets without concerning much for the normality of distribution.

Patent bibliometrics analysis shows that Korea is slightly better than Taiwan with respect to technology fusion related invention features. Korea exibits higher numbers in all three indices in 1999. The share of multi-class patent of Korea (9.4%) is higher than that of Taiwan (8.2%) (Table 5). The originality indicator of Korea (0.326) is significantly higher than that of Taiwan (0.281). Korean patents also have a higher level of science intensity than Taiwanese ones, and it is statistically significant. Even though we select patents set restricted to individual and firm patents (excluding university and institute patents), the result is almost the same: Korean patent is superior in the originality and average number of NPL in the patents.

Table 5: Comparison of Korean and Taiwanese Patents in 1999

	Total patents			Patents by individuals and firms		
	Korea	Taiwan	Mahn-Whiteny	Korea	Taiwan	Mahn-Whiteny
No. of patents in 1999	3,559	3,634	-	3,277	3,412	-
Share of multi-class patent	9.4%	8.2%	0.063	9.1%	8.1%	0.155
Originality	0.326	0.281	0.000	0.327	0.275	0.000
Average No. of NPL	0.507	0.343	0.000	0.385	0.297	0.000

The null hypothesis - Taiwan and Korea have similar patenting activities in terms of technology fusion (integration & science intensity) can be dropped with 10% statistical significance. Although it is statistically slightly short of the 5% significance level, the share of multi-class patent is higher in Korea. However, the difference may attribute to patents by Korean public institutes.

Excluding these patents, the difference is not significant. This result can support the proposition that innovating large firms-based country is better than innovating small firms-based country in term of multi-technological capabilities.

In order to find out the dynamic aspects of multi-technological capabilities of Korea and Taiwan, we have investigated patent bibliometrics using 2004 patent data. Due to lack of information on originality, the percentage of multi-class patents and the average number of NPL are compared (Table 6). The categorization of firm are individually owned, SME's, large firms, and not available in firm profile DB (likely to be SMEs). Patents owned by foreign firms and public institutions are excluded in the analysis. The distribution of these patents indicates the large share of individually owned patents in Taiwan. Again, the share of 'presumably' SMEs'patents (including individually owned and not identified in the firm DB) is very high in the case of Taiwan, as expected.

Table 6: Composition of Patent Activities between Korea and Taiwan in 2004

	Korean		Taiwan	
	No. of patent	%	No. of patent	%
Large firms	3,066	82.2	2,420	43.7
SME	32	0.9	581	10.5
Individual	240	6.4	1,844	33.3
Not identified	393	10.5	692	12.5
Total	3,731	100	5,537	100

The results show that the gap between Korea and Taiwan in terms of the share of multi-class patents has been narrowed (Table 7 and Table 8). Share of multi-class patents of Korea in 1999 and 2004 were respectively 9.39% and 9.46% while that of Taiwan increased from 8.15% in 1999 to 9.59% in 2004. This result implies that technological integration capabilities of Taiwan firms improved faster than those of Korean firms. Interestingly, peer to peer comparison, that is Korean SME vs Taiwanese SME and large firm vs. large firm comparison shows that Korean firms are slightly higher even in the share of multi-class patent. In the case of multi-class patent, Korean SME patent records 12.0 while Taiwanese 10.4, and large Korean firms 8.9 vs. large Taiwanese 8.5.

Table 7: Comparison of Korean Patents between SMEs and Large Firms in 2004

	Korean SME+				Korean Large Firms	Total	Mahn-Whiteny statistical test SME+ vs. large firms
	SME	Not identified	Individuals	Total SME+			
No. of patents	32	393	240	665	3,066	3,731	-
Share of multi-class patent (%)	18.8	12.2	10.8	12.0	8.9	9.46	0.013
Average No. of NPL	.781	1.234	.733	1.031	.681	0.744	0.439

Table 8: Comparison of Taiwan Patents between SMEs and Large Firms in 2004

	Taiwan SMEs+				Taiwan Large Firms	Total	Mahn-Whiteny Statistical test SMEs+ vs. large firms
	SMEs	Not identified	Individuals	Total SMEs+			
No. of patents	581	692	1,844	3,117	2,420	5,537	-
Share of multi-class patent (%)	9.3	10.8	10.6	10.4	8.5	9.59	.016
Average No. of NPL	0.150	0.094	0.317	0.236	0.168	0.160	.000

However, the difference in terms of science intensity in invention remains as Korea firms produce patents with high number of NPL. Average number of NPL of Korean patents increased from 0.507 in 1999 to 0.744 in 2004 while that of Taiwan patents decreased from 0.343 in 1999 to 0.160 in 2004. This result can be interpreted as Korean firms tend to generate more science-intensive patents than before while Taiwan firms appears to focus on less science-intensive patents than before. In short, Korean SMEs is not inferior to Taiwan SMEs as their patents show higher share of multi-class patent and higher number of NPL.

7.2. Firm Size and Multi-technological Capabilities

Surprisingly enough, the results show the quality of patents by SMEs is always surpassing those of large firms in both the technology integration and science intensity levels. The average NPL value of SMEs' patents is higher than that of large firms in Korea but it does not follow same pattern in the case of Taiwan. Taiwan large firm patents show significantly low NPL

that Taiwanese individually owned patents, but higher than identified SMEs.

The superiority of Korean patents in these indices alludes to the role of large corporations, such as Samsung and LG. However, as we can see in Table 5, Korean SMEs have good records. However, the statistical test shows that SME patents have no significant difference in terms of NPL number. It is rather the share of multi-class patent statistics that significantly matters. The share of multi-class patents is higher in SME cases, which is completely opposite to expectation. Even the level of scientific linkage (measured by NPL) is higher in SME patents. Therefore, the difference between Korea and Taiwan can be ascribed to more prudent attitudes of Korean SMEs when they apply to the US patent office. They apply inventions that are considered to be high qualities.

This also indicates that the superiority Korean SME patents to large firm patent could be ascribed to prudent application of SMEs - when Korean SMEs apply to the US patent office, they only select best invention with formal research result due to high application cost. While large Korean firms may apply easily because the large firms have special supporting department to help patent application, inventors in the large firm apply rather easily. Therefore, the superiority of SME patent needs to be under further scrutiny.

Finally, the inter-temporal comparison between 1999 and 2004 is presented in (Table 9), the share of SMEs and unidentified firm (possibly SMEs) has increased. The share of multi-class patent has not changed, but the level of science intensity in patent - NPL has increased. Due to lack of information on Taiwanese firms in 1999, the comparison is restricted to the case of Korea.

Table 9: Inter-temporal Comparison of Korean Firm Patent

Categories		No. of patents		Share of multi-class patent (%)		Average No. of NPL	
Issued Year		2004	1999	2004	1999	2004	1999
Korean SME+	SMEs	32	29	18.8	13.8	0.781	1.034
	Not identified	393	66	12.2	13.6	1.234	0.818
	Individuals	240	154	10.8	11.7	0.733	0.468
	Total SMEs+	665	249	12.0	12.4	1.031	0.626
Korean Large		3,066	3,028	8.9	8.8	0.681	0.365
TOTAL		3,731	3,277	9.5	9.1	0.744	0.385

8. Conclusion

This paper analyses multi-technology capabilities between Korea and Taiwan which presenting different national systems of innovation characterizing MTCs based and innovating SMEs-based industrial structure although they are converging to some extent. Multi-technology capabilities are very important in the technology fusion phenomenon particularly in emerging technologies and industries. Many empirical researches on the firm size show that both innovating SMEs and large firms have advantages and disadvantages. However, larger firms and a large firms-based economy are expected to perform better than smaller firms and a SMEs-based economy in terms of multi-technological capabilities.

Korea and Taiwan exhibit similar level and profile of innovative activities measured by patent data. Both countries' innovation systems also appear to converging in emerging sectors. Most Korean large firms in emerging technology sectors have been transforming to multi-technology corporations and recently began to promote innovative small firms. In Taiwan some innovating small firms have been grown into large and powerful firms such as UMC, TSMC, and Winbond (Mathews, 1997).

However, the patent bibliometrics analysis in this research shows that Korea and Taiwan present different pictures in terms of multi-technology capabilities. The patent bibliometrics analysis shows that Korea is slightly better than Taiwan in 1999 with respect to technology fusion related invention. Korean patents exhibit higher numbers in all three indices than Taiwan including the share of multi-class patent, originality and the level of science intensity. However, technology integration capabilities of Taiwan improved from 1999 to 2004 while those of Korean firms didn't changed during the same period. The gap of patents' science-intensity between Korea and Taiwan appears to have been widened.

The first result on the comparison between Korea and Taiwan is as expected mainly because of existence of many multi-technology corporations in Korea. However, this research then reputes the expectation - it is not because of MTCs in Korea - because Korean SMEs are not inferior rather they are sometimes superior in patent content with regard to technology fusion. It is confirmed in both cases of Korea and Taiwan. The patent biliometric shows SMEs have better in terms of technology integration capabilities measured by the share of multi-class patents while there are not differences of science-intensity of patents between SMEs and large firms. In addition, Korean SMEs also demonstrates relatively stronger science-based technology fusion type inventive activities than those of Taiwan It can be interpreted that Taiwanese SMEs may have relative weakness in formal research and development to combine diverse technological knowledge

compared to the Korean ones.

However, the weakness in Taiwanese SMEs cannot be easily judged with patent data only. For many decades the problem of using patent data has been alarming especially when applying the method to investigate SMEs' innovative activities (Pavitt, 1985; Griliches, 1990). The measure of technology fusion level is also limited when using share of multi-class patents. This invites further research that employs various indies and measures about technology fusion in the future.

Finally, it is also important to note that the divergent competence of SMEs. New technology based firms show strong innovative activities by exploiting the labor division of innovation as market for technology is developing. Interestingly, in recent US industrial history, the rise of 'multi-technology' solutions and the growing importance of small, innovative firms in newly-emerging industries coincided.

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