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National Model of Technological Catching Up and Innovation: Comparing Patents of Taiwan and South Korea

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National Model of Technological Catching Up and Innovation: Comparing Patents of Taiwan and South Korea

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ABSTRACT *This paper discusses different patterns of innovation and their institutional roots in Taiwan and South Korea. By using USPTO patent data as indicators of innovation, this paper finds that while individuals and small and medium-sized enterprises (SMEs) still account for a significant proportion of the patents in Taiwan, the large conglomerates are the major contributors of patents in South Korea. Moreover, although electronics is the sector that has gained most of the patents in both countries, Taiwan's patents are more dispersed while those of its South Korean counterparts are more concentrated. These differences come mainly from the institutional roots in their economic catching-up era.*

I. Introduction

The economic development of Taiwan and South Korea are often regarded as being exemplary for comparative purposes in understanding the East Asian miracle (Amsden, 1989; Wade, 1990; Woo, 1991; Haggard, 1990; Hamilton, 1996; Wang, 2007). The purpose of this paper is to add to the already abundant literature so as to further compare the transition of both countries toward innovation-based economies. The central question of this paper is this: How have the differences between Taiwan and South Korea in the catching-up era affected the extent to which they have been transformed into innovation-based economies? Has this transition proceeded in a similar way or in a very divergent manner? The hypothesis that this paper seeks to test is that, due to the path dependence effect, the institutional arrangements of both countries in the early stage of economic development will largely shape the ways in which they pursue technological innovation. To be specific, we propose that innovations in South Korea will continue to be dominated by big firms; while in Taiwan, individuals and small and medium-sized enterprises (SMEs) will continue to be important agents of innovation.

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In order to sustain our hypothesis, we use and analyse patent files that are directly downloaded from the United States Patent and Trademark Office (USPTO) as indicators to compare both countries' performance. Since the patent data are composed of varieties of sectors, ranging from semi-conductors, automobiles and chemicals to tools and toys, we thus use National Bureau of Economic Research (NBER) methodology (to be explained later) to recompose the patent file into main and sub-categories in order to find out which sectors in each country have performed better and which may be characterised by vigorous innovative capability.

Our major findings are as follows. Both Taiwan and South Korea have performed impressively in terms of obtaining patents from the USPTO since the early 1990s, even overtaking traditional advanced industrialised countries, with the exception of the US, Japan and Germany. Both countries have performed very well in the electrical and electronics category. In terms of the ownership of patents, individuals and SMEs still play an important role in the Taiwanese case. This is different from the Korean case where big firms own most of the patents. However, this paper will also show that, despite the high growth in terms of the quantity of patents, both countries still lag behind the most advanced countries in international patent citations and technological trade.

The remainder of this paper is organised as follows. Section II provides the theory based upon which we review the institutional basis of the national model of catching up and its influence on innovation. Section III introduces our methodology and section IV presents our findings. Section V discusses the institutional basis of the divergence between Taiwan and South Korea. Section VI consists of a discussion and section VII is the conclusion.

II. National Models and Path Dependence

Technological learning and innovation are crucial to economic development. The major characteristic of a catching-up economy is that its industrialisation is based on acquiring and improving existing technologies developed in advanced industrial economies (Hobday, 1995; Kim, 1997). Therefore, a catching-up economy has a clear objective to pursue or rather to close the technological gap between itself and the advanced countries. However, as a catching-up economy moves gradually closer toward the frontier area and innovation, it will encounter enormous barriers and uncertainty, because innovation indicates that imitators not only exploit known technology, but also possibly explore unknown frontier technologies that do not yet exist in the market. Uncertainty is the keyword in innovation (Nelson and Winter, 1977).

As the institutionalist perspective maintains, a firm emerges and grows from a territory that involves social institutions in which it is embedded. The social fabrications influence the values, norms, and expectations of managers and workers, as well as the ways in which firms are connected (Granovetter, 1985; North, 1990; Hollingsworth, 1998, 2000). All of these factors tend to evolve historically into an idiosyncratic social configuration (Hollingsworth, 1998, 2000), also referred to as a 'national model' and, to a large extent, influence how technologies are transferred and learned. In other words, a national model is the result of a long-term historical evolution which combines various coupling or complementary institutions that are favourable to some industries, thereby enabling them to emerge and to become prosperous (Amable, 2000; Hall and Soskice, 2001).

Similarly, the national model of catching up and technological learning will shape and affect how a firm learns and moves towards innovation. That is to say, there is a path dependency relationship between technological catching up and innovation. Since institutions both enable and constrain individual behaviour by defining the incentive framework in which agents make decisions, most of the time this inhibits people from choosing more efficient arrangements than the current ones. Institutions, therefore, are generally not optimal (North, 1990), and continue to affect people's behaviour. North argues that this act mainly results from the fixed cost of the institutional architecture and the increasing returns to adoption. As a result, this creates the path dependence or the lock-in effect, which explains the phenomenon in which existing institutions tend to persist and become the growth trajectories that are followed by different countries.

Based on the above institutionalist perspective, we propose that the industrial system or institutional arrangements of a late industrialising country in facilitating technological learning and catching up will continue to play a major role in a country's transition toward an innovation-based economy. The existing socially-embedded institutional arrangements which support a late industrialising country's technological catching up may lead to the creation of both enabling and constraining conditions for the economy to adjust and transition towards innovation. In addition, due to the differences regarding incentive provisions, or as Hall and Soskice maintained: 'the institutions relevant to these activities are not distributed evenly across nations' (Hall and Soskice, 2001: 37), the existing institutional arrangements may favour some, but not all, industries in terms of making them become competitive in the world market.

Innovation in this paper indicates new and improved products and processes, or as Edquist claims, 'technological innovation is a matter of producing new knowledge or combining existing knowledge in new ways – and of transforming this into economically significant products and processes' (Edquist, 1997: 18). Based on this broader definition, innovation not only refers to new products, but also to new processes. It may denote abrupt product innovations, but it may also imply incremental and process innovations. In any case, innovation is a process that involves searching and exploring unknown areas where the result is uncertain.

We propose that both Taiwan and South Korea will follow their own specific routes due to the path dependence effect of their national models on their technological catching-up. It is well known that the Korean catching-up model is based on a chaebol-led development, whereas the Taiwanese development model has been dominated by a SME-networked economy (Amsden, 1989; Haggard, 1990; Wade, 1990; Woo, 1991; Wang, 2007). The difference between these two models has been mainly due to the degree of the state's intervention in the economy, the degree of support provided by the financial system to businesses, and the social roots of business organisations. Although these two countries have undergone democratisation processes in which the developmental states have been waning or have been transformed (Kong, 2000; Weiss, 2003; Pirie, 2005), we suggest that the institutional arrangements in the catching-up era have still largely affected the firm's innovative behaviour. In this regard, we hypothesise that Korea and Taiwan will reveal different innovative strengths in different industries. Korea's innovation will be dominated by chaebols, whereas Taiwan's innovation will, in part, be largely shared by SMEs.

III. Methodology

The use of patent statistics as the indicators of technological innovation has been well developed by many important studies (Patel and Pavitt, 1994; Jaffe and Trajtenberg, 2002) and has been applied to examine the differences in innovation among East Asian countries (Choung, 1998; Mahmood and Singh, 2003; Hu and Mathews, 2005). Despite there being many drawbacks,[1] US patent data are regarded as the most appropriate indicator of innovation. This is because the United States is the biggest market in the world, and global inventors would like their patents to be registered with the United States Patents and Trademark Office (USPTO) to secure their interests. In addition, patents filed with the USPTO can provide interested parties with adequate information, such as the country of origin of the innovator, the year granted, the technological class, the ownership status[2] of the innovator, and so forth. They can provide sufficient competitive specialisation, as well as the technological development route of a country (Patel and Pavitt, 1994; Jaffe and Trajtenberg, 2002; Mahmood and Singh, 2003; Hu and Mathews, 2005).

Apart from directly using the USPTO's public reports (2006), we further calculate the raw data by hierarchically summing-up USPTO online statistics based on the NBER methodology to compare a variety of technological patterns. The main advantage of NBER methodology lies in its clear technological classification in terms of six main categories – such as chemicals, computers, machinery and electronics, rather than the complex preliminary and unsorted 417 technological classifications (Hall et al., 2001). Thus, by analysing the aggregated data based on the above six categories, we can much more easily illustrate the evolution of both countries' innovation capacities at the macro country and industry levels. For the purpose of comparing the pattern of transition toward innovation, we divide the dataset into two periods, with period one ranging from 1990–1999 and period two ranging from 2000–2004. Then we can compare and complement our findings with previous research time frames up to 2001 (Hu and Jaffe, 2003; Chung et al., 2004; Hu and Mathews, 2005; Park and Lee, 2006).

Furthermore, since we are interested in the issue of patent ownership, we use individual types of innovators to denote SMEs, while using the rest to indicate organisations or bigger firms. It is because Taiwanese SMEs have a high turnover rate that innovators tend to apply for patents as individuals rather than on behalf of the organisations, so as to be assured of ownership (Choung, 1998: 364). Therefore, the ownership category can tell us whether or not the innovation pattern has changed in either country.

IV. Findings

From Technological Catching-up to Innovation

Taiwan and South Korea have made impressive progress in terms of obtaining patents since 1990. As Figure 1 shows, the patents of both countries in 1997 reached

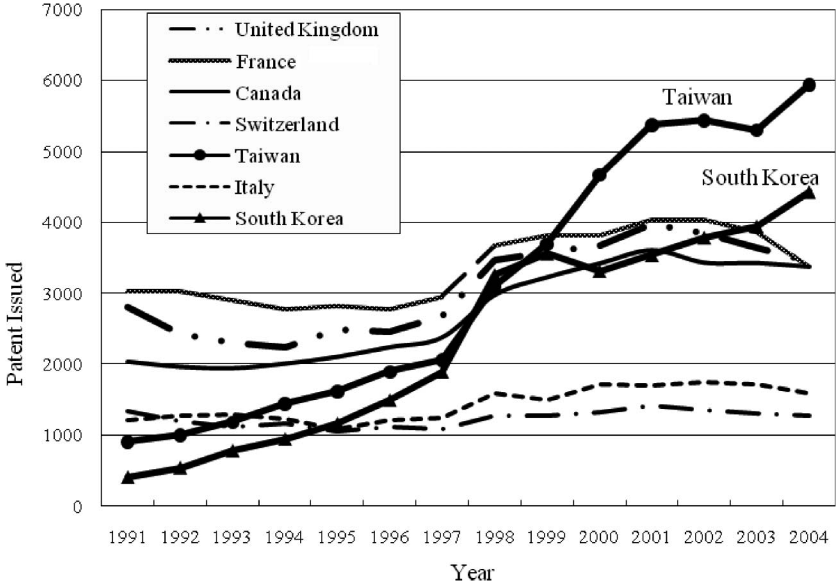

Figure 1. US granted patents of top four to ten countries, 1990–2004. *Source:* USPTO (2006).

levels similar to those of Italy and Switzerland but still lagged far behind those of Canada, France and the UK. However, they leapt over these three developed countries after 1997. Currently, Taiwan and South Korea are the fourth and fifth largest patent recipients, respectively, surpassed only by the US, Japan, and Germany. Their achievements indicate that both Taiwan and South Korea have successfully acquired and assimilated existing technologies developed in advanced industrial economies (Hobday, 1995), and have kept improving them by going ‘beyond imitation towards innovation’ (Kim, 1997), as demonstrated by the impressive increases in the numbers of patents.

In terms of the numbers of approved patents, Taiwan consistently outperformed South Korea from 1990–2004, except in the year 1998. However, each country excelled in different categories. The decomposition of the 2000–2004 data (Figure 2) shows that both Taiwan and South Korea have performed excellently in category 4 (electrical and electronics). This shows the fruitful results of both countries’ Herculean efforts in developing the industries in this category. Nevertheless, they have excelled differently in terms of the second and third largest granted patent categories. For Taiwan, the second and third most innovative industries were category 5 (mechanical) and category 6 (other);[3] whereas for South Korea, they were category 2 (computers and communications) and category 1 (chemicals). Moreover, neither country had a very impressive record regarding category 3 (drugs and medicine), which is also indicative of the latecomer status in terms of developing most frontier technologies such as the biotechnology and pharmaceutical industries.

Nonetheless, if we compare the data for 2000–2004 with that for the previous period (1990–1999), it will be seen that the national specialty in patenting of South Korea remains unchanged, while that of Taiwan has been altered. South Korea still excels in categories 4, 2 and 5, while Taiwan’s figures indicate that the innovations in

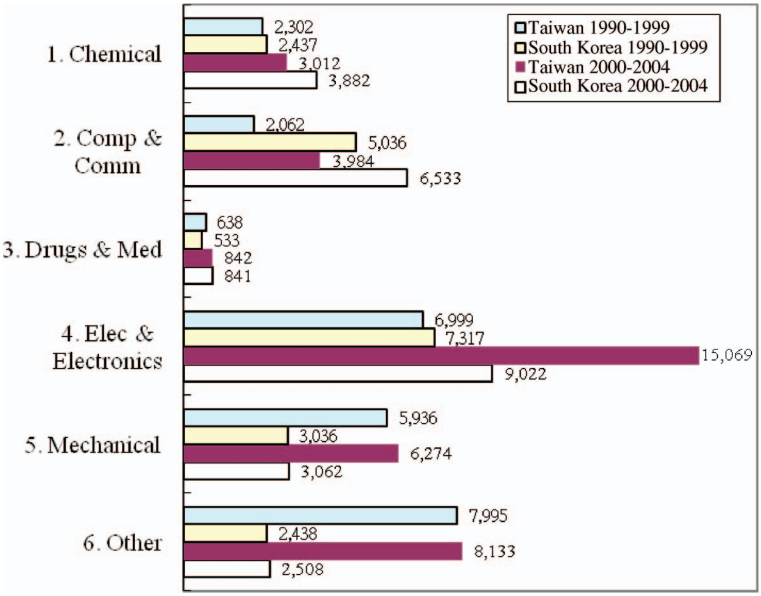

Figure 2. Distribution of patents in Taiwan and South Korea based on NBER main categories.

the ICT industries[4] (categories 4 and 2) have exceeded those in traditional industries (categories 6 and 5). The differences between South Korea and Taiwan reflect their different development models and the ways in which they have been transformed, which will be discussed below.

A more refined calculation of both countries' innovation performance can be indicated by the 'current impact index' (CII) – representing the average frequency of each patent for a given country that is cited by the patents in the current year relative to the frequency of all patents that are cited in the previous five years. According to the research done by the Taiwan Institute of Economic Research (TIER), which uses the same USPTO database, both Taiwan and Korea's figures for patent citations exhibited upward tendencies from 1990 to the early 2000s, and in some years both countries' figures exceeded 1 (indicating that the technological strength of a particular country is above the average for all countries included). This shows that both countries have improved greatly in terms of the quality of their patents. Nevertheless, overall, both Taiwan and South Korea during the period under consideration have cited more than they have been cited, which can be shown and compared with the figures for the US and Japan (Table 1). These figures also indicate that, although both Taiwan and Korea have moved from catching-up to being innovation-based economies, they, in particular, still lag far behind the technological giants, namely, the US and Japan,[5] in terms of the quality of their innovations.

Patent Distribution by Technology Fields

The Taiwanese and Korean states' development strategies in promoting the electronics industry have yielded fruitful results (Hobday, 1995; Mathews and

Cho, 2000). If we combine categories 2 (computer and communications) and 4 (electrical and electronics) into the ICT (information and communications technology) industries, the results (as shown in Table 2) reveal that both countries' patents were heavily concentrated on this sector in period two (2000–2004). The figure in Korea reached as high as 60 per cent, whereas in Taiwan it reached 51 per cent. The high concentration of patents in the ICT industries reconfirms what Patel and Pavitt (1994) had observed in their earlier paper on East Asia, where they claimed that both Taiwan and South Korea had performed well in terms of the technological development of the ICT industries.

There are, however, some marked differences between these two countries: Taiwan performed better in category 4, especially sub-category 46, which is semiconductor

Table 1. Current impact index of patent invention

Country	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
USA	1.04	1.11	1.12	1.13	1.14	1.14	1.14	1.15	1.16	1.18	1.18
Japan	1.22	1.04	1.01	0.97	0.97	0.95	0.93	0.91	0.91	0.89	0.90
Germany	0.76	0.68	0.66	0.64	0.58	0.58	0.59	0.62	0.62	0.61	0.59
Taiwan	0.73	0.92	0.88	0.95	0.93	1.02	1.19	1.14	1.00	0.88	0.85
Korea	0.76	0.95	0.90	1.00	0.98	0.97	0.87	0.85	0.82	0.79	0.85
France	0.74	0.69	0.66	0.66	0.62	0.65	0.66	0.64	0.64	0.61	0.56
UK	0.85	0.80	0.77	0.79	0.79	0.76	0.75	0.76	0.74	0.76	0.80

Source: TIER (2005: 68).

Table 2. Comparison of two periods of patent distribution in the ICT industry

		1990–1999		2000–2004	
NBER main	Sub-category code name	South Korea	Taiwan	South Korea	Taiwan
2 Computers and Communications	21 Communications	1,633	816	2,256	1,460
	22 Computer hardware and software	1,185	595	1,533	1,115
	23 Computer peripherals	383	239	845	664
	24 Information storage	1,835	412	1,899	745
Sub-total		5,036	2,062	6,533	3,984
4 Electrics and Electronics	41 Electrical devices	826	1,519	1,019	3,258
	42 Electrical lighting	718	884	1,089	1,242
	43 Measuring and testing	322	345	441	599
	44 Nuclear and x-rays	155	151	220	243
	45 Power systems	914	919	1,009	2,272
	46 Semi-conductor devices	2,297	2,610	3,975	6,764
	49 Miscellaneous-electrical	2,085	571	1,269	691
Sub-total		7,313	6,999	9,022	15,069
ICT Industry total		12,353	9,061	15,555	19,053
Ratio of ICT Industry to nation		60%	35%	60%	51%

Source: Calculated from USPTO search.

devices, and South Korea performed better in category 2, particularly in sub-category 21 (communications) and sub-category 24 (information storage). Taiwan's excellent performance in semiconductor devices indicates that the process technologies developed especially by the world-class integrated circuits (IC) foundries, Taiwan Semiconductor Manufacturing Corporation (TSMC) and United Microelectronics Corporation (UMC), have continued to be upgraded and innovated. By contrast, South Korea's excellent performance in the communications category has shown that the Korean state's and chaebols' (Samsung, Hynix and LG) efforts in developing dynamic random access memory (DRAM) and code division multiple access (CDMA) cell phones have reaped rewards, and both industries have been said to have gained leapfrogging innovations (Kim, 1997; Lee and Lim, 2001). Interestingly, Taiwan lags behind Korea in the computer category. Although Taiwan has been the world's main producer of desktop PCs, notebook PCs and other peripherals, for example, Taiwanese firms produced over 80 per cent of notebook PCs in the global market (MIC, 2006), Taiwan's shares of patents in related sub-categories (subcategories 22 and 23) still lag behind those of Korea in both periods. We conjecture that this is highly associated with the inclination of Taiwanese firms towards original equipment manufacturing (OEM) in producing these goods, which means that Taiwanese firms produce products based on the designs provided by buyers. This offsets the motivation of Taiwanese hardware producers to engage in intensive research and development (R&D). By contrast, Korean chaebols sell their own products under their own brands, such as Samsung and LG, and thus have the motivation to internalise the R&D effort in order to support their worldwide presence. The OEM method and own brand strategy may, therefore, have given rise to different impacts on the behaviour of innovation as our data have shown.

Besides the quantitative dimension of innovative capability shown above, the qualitative dimension of innovation can be observed by using the Current Impact Index (CII) approach in order to analyse the distribution among technological sub-categories. According to the research results obtained by TIER, the CII distributions are very different in the technological fields of Taiwan and South Korea (TIER, 2005). While Taiwan has received more citations in the fields of materials, metallurgy, transportation, electronic devices, electrical goods, semiconductors and information technology, consumer goods and equipment, South Korea has received more citations in the fields of optics, material processing, textiles, and telecommunications. Coupled with the above-mentioned quantitative patent figures, these qualitative CII outcomes indicate that although both countries' patents have increased over the years, they nevertheless were less cited (less than 1), except for Taiwan's consumer goods and equipment, and Korea's optics and surface technology and coating. The above figures indicate that both Taiwan and Korea have cited more patents from other countries than have been cited (see Table 3). In this regard, they may be regarded as advanced technological followers as opposed to leaders.

Taiwan and South Korea have also performed differently in categories 5 (mechanical) and 6 (others), despite their having similar outstanding performance in the ICT sector (see Figure 2). In Category 6, which includes industries such as toys, shoes and apparel, chairs and seats, locks, special receptacles or packages, tents, canopies, umbrellas or canes, and so on, Taiwan gained the largest number of

Table 3. Current impact index of major countries in selected technological fields

	2003				2004			
Field of technology	USA	JP	TW	KR	USA	JP	TW	KR
5. Biotechnology	1.17	0.42	0.16	0.16	1.16	0.57	0.24	0.36
8. Optics	1.25	0.85	0.79	1.03	1.21	0.91	0.64	1.04
13. Material processing, textiles	1.27	0.89	0.58	0.67	1.32	0.86	0.55	0.67
14. Paper machine tools	1.24	0.95	0.72	0.91	1.20	0.98	0.91	0.85
15. Mechanical elements	1.11	1.07	0.77	0.71	1.14	1.00	0.77	0.86
19. Materials, metallurgy	1.27	1.05	0.86	0.56	1.31	0.96	0.63	0.66
20. Surface technology, coating	1.22	0.86	0.70	0.89	1.23	0.83	0.71	1.03
22. Transportation	1.05	1.17	0.84	0.72	1.09	1.03	0.80	0.78
24. Electronic devices	1.15	1.00	0.95	0.82	1.19	0.93	0.94	0.71
25. Semi-conductors	1.23	0.84	0.88	0.78	1.25	0.83	0.80	0.81
26. Information technology	1.20	0.62	0.60	0.52	1.20	0.63	0.59	0.50
27. Telecommunications	1.19	0.67	0.63	0.60	1.21	0.64	0.54	0.69
29. Consumer goods and equipment	1.04	1.10	1.05	0.77	1.05	1.01	0.99	0.73

Notes: JP = Japan; TW = Taiwan; KR = Korea. *Source*: Abstracted from TIER (2005: 70).

patents in the former period and continued to remain innovative in the second period. This reflects the dynamism of Taiwanese SMEs in terms of industrial upgrading. By contrast, South Korean firms are less innovative than their Taiwanese counterparts in this category, indicating that the Korean model is more chaebol-oriented (Kong, 2000).

As for category 5 (mechanical), it was ranked third in terms of innovative position in Taiwan and South Korea in both periods (Figure 2). However, the significance of the mechanical industry differs in these two countries. Unlike the South Korean case where most of the innovations are concentrated in the ICT-related technologies, Taiwan has a more dispersed pattern in which sub-categories such as tools, land vehicles and exercise devices are still significant in the top 10 of the most innovative sub-categories.[6] This is identical to the CII findings (Table 3), which show that Taiwan received more citations in the fields of materials, metallurgy and transportation in terms of mechanical-related technologies. Overall, these indicate that mechanical industries still play an important role in Taiwan's innovation system apart from the ICT industry. The importance of the innovation in mechanical sectors in Taiwan has also been studied by many researchers (Mahmood and Singh, 2003; Hu and Mathews, 2005; Park and Lee, 2006). These studies have consistently found that Taiwan's technological catching-up during the 1970s and 1980s was particularly focused on industries such as those which produced motorcycles, bicycles, and machine tools. It was only in the early 1990s that the ICT sector started to take off as the main contributor of patents and began to occupy the top position in terms of innovative activities.

Patent Distribution by Ownership

Since Taiwan's industrial structure has long been based on SMEs, we further explore whether this type of industrial system has affected its transition toward innovation.

According to existing studies (Choung, 1998; Jaffe and Trajtenberg, 2002), the ownership of patents in South Korea from 1976–1998 was highly concentrated: the chaebols owned 89.7 per cent of the patents. By contrast, Taiwan's patent ownership has been much more dispersed, and individual ownership of patents reached as high as 64 per cent. Our results are slightly different from the above findings.

First of all, in the South Korean case, the ownership ratio of assigned organisations remained stable and as high as 90 per cent in the second period. For Taiwan, the ownership ratio of individuals declined from 62 per cent in the first period to 37 per cent in the second (Table 4). This indicates that Taiwan's innovation system has been changing, that is, organisations currently play a more important role in innovative activities than before, while the South Korean counterpart has remained unchanged. In order to see the long-term transformation of Taiwan's innovation pattern, we combine the patent data in terms of ownership distribution from 1976–2004, and the results are presented in Figure 3. The findings clearly show that the

Table 4. Patent distribution by organisation ownership (%)

	South Korea		Taiwan	
NBER category	1990–1999	2000–2004	1990–1999	2000–2004
1. Chemical	87.4	89.3	53.1	68.8
2. Computers and Communications	96.5	95.9	65.3	82.9
3. Drugs and Medicine	62.9	68.4	27.0	41.0
4. Electrical and Electronics	94.5	94.4	59.1	80.1
5. Mechanical	87.1	87.6	26.3	43.3
6. Other	76.9	70.2	18.2	36.9
Average	90.2	90	38.2	63.0

Source: Calculated from USPTO search.

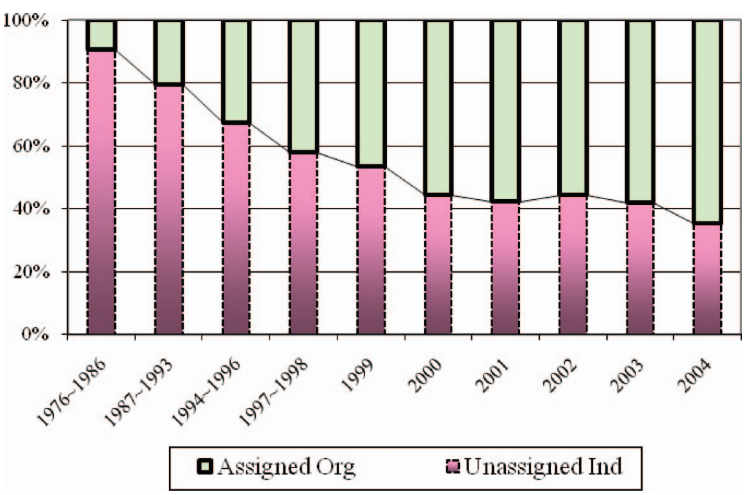

Figure 3. Ownership distribution of Taiwan's patents, 1976–2004.

ratio of individual innovators is decreasing with time, declining from 90 per cent during 1978–1986 to less than 50 per cent in 2000, and reaching merely 37 per cent in 2004. We will discuss this tendency in detail later.

Therefore, there is a tendency for Taiwan's innovation system to be converging towards that of its Korean counterpart in that organisations or big firms are playing a more important role in innovation. In the ICT industry (categories 2 and 4) in the second period, for example, Taiwan's patents exhibit a similar pattern of organisation concentration to that of Korean patents, increasing from around 60 per cent to as high as 80 per cent in Taiwan, as compared to 95 per cent in South Korea. Nevertheless, Taiwan's patents continue to reflect the dynamism of SMEs in categories 6 (others), 5 (mechanicals) and 3 (drugs and medicine), although the general tendency is that the ownership of patents by organisations is increasing, with increases of 18 per cent, 17 per cent and 15 per cent, respectively, in comparison with the previous period.

In order to further differentiate the patent concentration rate of big firms, we adopt Hall et al. (2001)'s Herfindahl Index (HHI)[7] to measure it in terms of patents received during 2000–2004. The results show that the HHI value of South Korea's top 10 organisations is 0.1478, which is as much as 10 times greater than Taiwan's value of 0.01478. Of this top 10 HHI value for Korea, Samsung Electronics alone contributes up to 0.1277. Therefore, it is obvious that, in terms of patent concentration, the South Korean case is much more highly concentrated than that of Taiwan. The concentration rate for patenting in both countries can also be shown by the evolutionary figures of the top organisations in terms of their ownership of patents (see Figures 4 and 5). The figures show that Taiwan's public

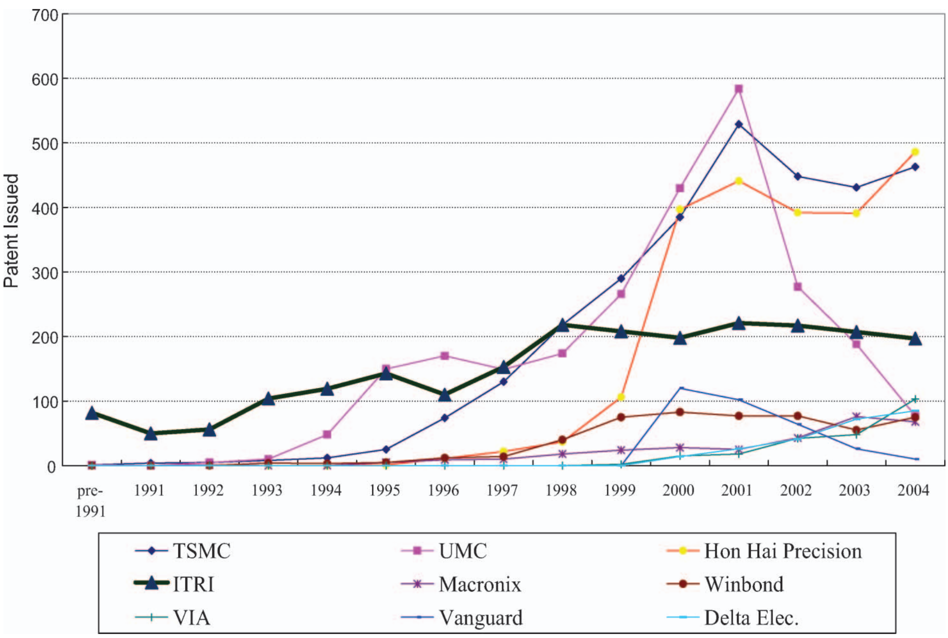

Figure 4. Taiwan's top patented organisation, pre-1991–2004.

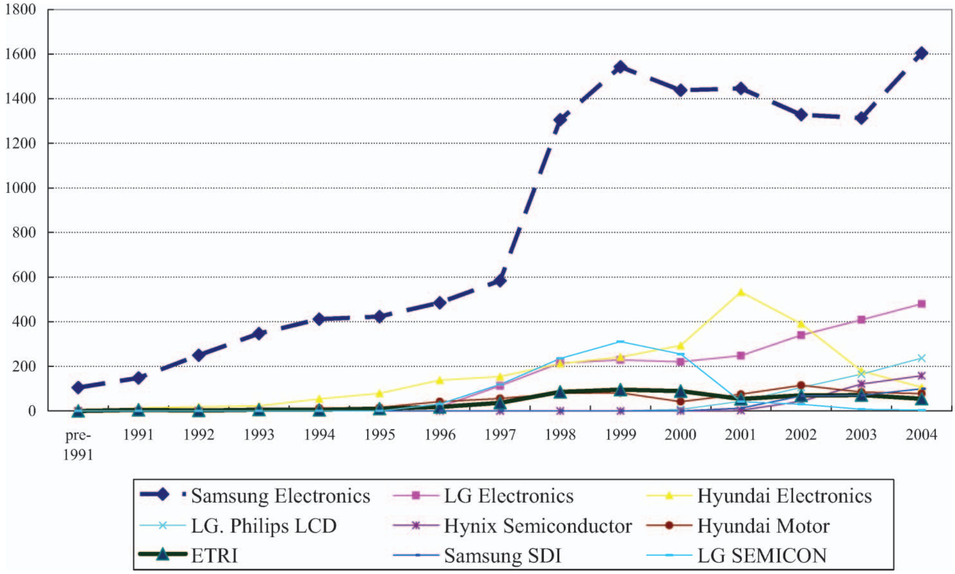

Figure 5. South Korea's top patented organisation, pre-1991–2004.

research institution, ITRI, was the leader of the received patents until 1995 when TSMC and other firms began to take off; whereas in the South Korean case, the chaebols were the leaders while the public research institution, ETRI, played a relatively insignificant role.

The magnitude of concentration in patenting by the chaebols can, in the South Korean case, also be represented by their high ratio of R&D expenditure compared with the national level. According to the Ministry of Science and Technology (MOST, 2004) statistics for South Korea, the top 10 chaebols' expenditure on R&D accounts for about half of the nation's R&D expenditure; it is also these top chaebols that own most of the granted patents (see Table 5). Unlike Taiwan's ITRI, the South Korean counterpart, the Electronics and Telecommunications Research Institute (ETRI), has not played a significant role, and its importance in receiving patents is far behind that of Samsung and other major chaebols. By contrast, Taiwan's ITRI had played a leading role before the mid-1990s. Even after the mid-1990s, ITRI is still an important actor in the overall number of patents granted.[8]

V. National Models and their Institutional Basis

To sum up the above findings, we can find some obvious differences in regard to patenting between Taiwan and South Korea:

(1) In terms of the concentration of innovation in technological fields, Taiwan is more dispersed than South Korea. Although both countries' patents have heavily focused on the ICT sector, the concentration rate in South Korea in both periods (1990s and 2000–2004) reaches as high as 60 per cent; in

Table 5. Concentration rates of R&D expenditure in South Korea (%)

	1998	1999	2000	2001	2002	2003	2004
Top five companies	40.2	42.6	34.8	35.6	37.5	37	40.4
Top 10 companies	49.7	53.3	45.9	43.4	43.2	43.7	47.7
Top 20 companies	60.8	61.9	55.4	49.8	49.6	51.7	55

Source: MOST (2004).

comparison, the corresponding percentages for Taiwan are merely 35 and 51 per cent, respectively.

(2) In terms of the ownership of the patents, both countries also exhibit different patterns. Of the six major categories of innovation, about 63 per cent of the patents are owned by organisations in Taiwan, but the corresponding figure is 90 per cent in South Korea. Moreover, the high value of HHI contributed by Samsung Electronics implies that innovation in South Korea is highly concentrated in the chaebols, whereas a considerable number of innovations are still held by SMEs in Taiwan.

The above findings indicate that Taiwan and South Korea have been transitioning into innovation-based economies, but have been following very divergent routes. The Korean case seems to clearly follow the former scale economies and to have been transformed into the chaebol-led innovation model. The Taiwanese case is currently not as clear as the previous era, neither is it similar to the Korean model. On the contrary, the Taiwanese model is currently a mixed one in which big firms lead but SMEs are still active. How do we explain the differences between Taiwan and Korea in transitioning toward an innovation-based economy?

As has been shown above, the electronics, or to be specific, the semiconductor industry has been the most active innovator in both Taiwan and South Korea. This clearly has to do with both countries' catching-up industrial policies that provided the industry with favourable incentives to develop (Mathews and Cho, 2000). In the case of Taiwan, the state first of all simultaneously adopted state-intervention and market competition principles to nurture the industry. On the one hand, the state built the industry using public funding to establish new companies, and later the state spun-off the companies to become privately-owned and urged them to compete in the world market. In due course, the state required ITRI to learn and diffuse technologies to the new companies. In order to survive in the severely competitive world market, these spun-off companies had to learn technologies quickly and engage in intensive R&D (Chen, 2003). Under these circumstances, although the semiconductor industry was a state-born one, it has nevertheless grown up in a competitive market environment. The most innovative firms in the semiconductor industry, such as TSMC and UMC, all grew up following this route.

Secondly, it is due to the state's construction of the Hsinchu Science Industrial Park (HSIP) and its provision of very generous tax incentives that many of the electronics-related firms were attracted to the park, which resulted in the creation of a highly dynamic industrial cluster. In the late 1980s, it was because of the establishment of the IC foundry firms, TSMC and UMC, in HSIP that most of the semiconductor-related firms, especially the IC design firms, were attracted to the science park. This consequently enabled HSIP to become one of the most innovative IC design regions in the world in the 1990s (Hsu, 2000; Saxenian and Hsu, 2001; Chen, 2003).

Thirdly, the state-sponsored R&D institute, ITRI, has played a very important role in technological learning, development, transfer and diffusion. Due to Taiwan's SME-based economy, the state established ITRI in 1973 in order to use public funding to engage in R&D to compensate for the lack of resources in the private sector for engaging in R&D and technological learning (Dedrick and Kraemer, 1998; Mathews and Cho, 2000; Amsden and Chu, 2003). Furthermore, the ITRI has adopted a new policy since the mid-1990s in which the R&D funding has had to be equally shared by the public and private sectors based on a 50:50 formula so as to bundle the public research with the needs of private firms. This type of public-private collaboration has proved to be beneficial to industrial upgrading in relation to innovation (Liu, 1999; Mathews, 2002). In fact, the main beneficiary sector of this public–private collaboration has been the mechanical sector (category 5). This is also the sector that has been largely run by SMEs, such as machine tools, machinery, land vehicles, and so on (Liu, 1999; Hsu and Cheng, 2001).[9]

Finally, the evolution of patent ownership toward big firms in Taiwan has to do with the changing institutional environment since the 1990s. On the one hand, the state since the 1990s has adopted a more liberal approach toward economic development. One of the most salient state policies has been to liberalise the market, through which the rules that prohibited privately-owned enterprises from entering strategically important sectors, such as those of banks, utilities, petroleum refineries, and so on, were abandoned. Therefore, many state-owned enterprises have been privatised and many privately-owned enterprises have been able to compete in the global market based on their own capabilities. On the other hand, the state has encouraged competitive enterprises to enlarge the scale of their operations so as to compete in the world market. This actually occurred in the period after 2000 when the state felt that it had to fully support the domestic enterprises to compete with their South Korean counterparts. The changing institutional environment has favoured the emergence of large enterprises, which in turn has induced them to invest resources in R&D to enable them to become more competitive.

As for the South Korean case, its development has followed a very different path compared with that for Taiwan. The Korean state has strongly supported the development of chaebols, and the latter have been able to use an unlimited supply of capital to quickly learn and assimilate new technologies into their own. However, the Korean state has also used the 'carrot and stick' policy to support the winners and punish the losers (Amsden, 1989; Woo, 1991). Only those winners who were able to meet the requirements set by the state were able to quickly expand their scale of operations and to aggressively extend their influence to the world market. Under these circumstances, the chaebols were able to learn technologies and to engage in innovative activities without having to be supported by the state-sponsored R&D institutes any longer. In due course, the chaebols – Samsung, LG and Hyundai, for example – have become the main actors in innovation at the expense of the state-sponsored R&D institutes (Kim, 1997). Indeed, the Korean transition from technological catching-up to innovation has been following the model of scale economies, in which vertically-integrated big firms have been the agents of innovation. The neo-liberalist economic liberalisation in Korea after the 1997 financial crisis seems to have reinforced this scale economies tendency (Kong, 2000; Pirie, 2005), through which chaebols have found it easier to obtain new financial resources to expand their global market shares and strategic alliances (Wang, 2007).

Due to their abundant financial resources, these chaebols continue to buy and assimilate technologies from abroad, and to finally create their own new technologies on the frontier. This is especially apparent in the semiconductor, memory chips and TFT-LCD industries. Currently, Korean chaebols are the leading firms in the above areas, and they tend to form strategic alliances with the world's leading firms, such as Intel, IBM, Sony, Phillips, Texas Instruments, Toshiba, Sharp, QUALCOMM, and so on, in order to develop new products for subsequent generations (Cho and Lee, 2003). These chaebols are now no longer technology receivers but, instead, have the capability to become knowledge creators. Currently, Samsung has successfully established its leading status in areas such as cell phones, memory chips and TFT-LCDs in the world market.

Nevertheless, compared to Taiwan's SMEs, the Korean SMEs are very weak and insignificant in terms of innovation. This has to do with the state's support for chaebols which has resulted in the SMEs experiencing difficulties in obtaining the loans from the banking system needed to survive (Woo, 1991). The Korean SMEs have not been able to develop by themselves so as to compete in the world market, but have simply become captive suppliers to chaebols' production networks (Kong, 2000). In contrast to Taiwan, the Korean state has not set up institutes to support SMEs, neither has it required a state-sponsored R&D institute to help SMEs to upgrade. The Korean state's eyes have only focused on the chaebols.[10]

VI. Discussion

By presenting the differences between Taiwan and Korean patterns of transformation into innovation-based economies, one cannot help but ask an interesting question: Can we discern which route of the transition is better for economic development? This is a difficult question to answer, but we have the following conjectures.

First of all, if we separate technological innovations into radical, incremental, architectural and modular types (Henderson and Clark, 1990), then larger firms have more resources to engage in research in areas that can fundamentally change the architecture of an industry, whereas the smaller firms tend to follow the architecture set up by bigger firms and engage in research in areas such as modular and incremental or process innovations. In Taiwan's case, most of the firms in both the electrical, electronics and mechanical industries have been engaged in manufacturing industrial goods for the world's leading firms through the OEM method, and they have therefore tended to follow the existing design architecture to produce goods for others, namely modular and process innovations, in order to increase the yield rate and reduce their costs (Ernst, 2000; Sturgeon, 2002). Taiwanese firms do not want, and do not need, to invest in high-risk areas due to their smaller size and limited financial resources. Modular and incremental innovations with low cost and flexibility have become the base of the competitiveness of Taiwanese firms in the world market. On the contrary, the Korean firms have tended to engage in architectural innovation because their own brand-name products have had to compete head-to-head with other brand-name products in the world market. It is also because of their abundant financial resources that chaebols have developed the ambition to invest enormously into the architectural arena. The best example of this case is the Korean chaebols' leapfrogging into CDMA cell-phone production and they now lead the world in 3G communications (Lee and Lim, 2001). In this regard, Korean firms have produced products with higher levels of technological complexity than Taiwanese firms (Mahmood and Singh, 2003).

Secondly, in terms of patent citation and international technological trade, there are no significant differences between Taiwan and South Korea. For one thing, as shown above, in terms of international patent citation, both countries have cited more from advanced countries than they themselves have been cited. Most of the CII year values for both countries during 1990 and 2004 were less than 1. For another, both countries' ratios for their technology balance of payments after 2000 are approximately 0.25 (OECD, 2005; NSC, 2007). This indicates that both countries are importers rather than exporters of technology. In other words, they have mainly purchased or licensed-in technologies from advanced countries, and assimilated and improved them in manufacturing. However, they have less capability in fundamental and cutting-edge innovations.

Thirdly, the productivity of patenting can also be shown by the ratio of patents to per million of the population. In the year 2002, Taiwan received 5,431 patents from USPTO whereas South Korea received 3,786. The ratio of Taiwan's received patents to every one million population was 236 (5431/23), whereas for South Korea it was 78 (3786/48). In the year 2005, Taiwan received 5,118 patents from USPTO and Korea 4,352, the ratios thus being 222 and 90, respectively. From this perspective, Taiwan is a very lively and innovative country, and this has to do with the active role of SMEs in its national innovation system as we discussed above.

Therefore, we do not reach a conclusion on the issue as to which country has chosen a better route in transitioning from a catching-up to knowledge-based economy. Both countries are moving toward innovative economies, although both are still lagging behind the most advanced countries in terms of technological trade. While Taiwan's system is more innovative in terms of received patents, the Korean system is inclined to engage in more complex types of innovation. Both have their strengths and weaknesses that deserve to be investigated more carefully in the future.

VII. Conclusion

This paper discusses and compares Taiwan and South Korea in terms of their technological catching-up and transformation into innovation-based economies. By using USPTO patent data, we compare the innovation patterns in terms of the ratio of individual/organisation ownership types of these two countries. We have found that both Taiwan and Korea have followed their own divergent catching-up routes and have shown some degrees of path dependency. While the Korean pattern of transition has strongly followed the same route as in the former period, that is, the chaebols still dominate the economy and own most of the innovations;

by contrast, Taiwan's pattern of transition has been more complex, having been transformed from an SME-based catching-up system into an innovation system in which big firms lead but SMEs are still important. We have explained that the transition also has to do with the state's policies and the institutional environments in which the firms are embedded. Our findings confirm what Wang (2007) has pointed out recently, that the Korean transition is based on a neo-Schumpeterian model that is largely shaped by economies of scale, whereas the Taiwanese case is very much based on a neo-Marshallian model in which industrial clusters, production networks and vertically-distintegrated industrial structures are the major characteristics. However, this paper's findings have added two more elements to the Taiwanese case beside Wang's neo-Marshallian model. They are the role of the state in the creation of innovation networks and the rise of the big firms in its neo-Marshallian innovation system.

Finally, there is a tendency that deserves to be observed in the future. That is, will Taiwan's development converge with Korea's case in terms of big firm-led technological innovation? Or, will big firms play a leading role in innovation and replace industrial clusters in Taiwan? The Taiwanese data have shown that bigger firms have increased their shares in gaining patents. We suggest that this big firm-led innovation in Taiwan is an irreversible tendency, due to the resource dependency of innovation activities. Nevertheless, as discussed above, the state's promotion of private–public collaboration in R&D and the dynamism of industrial clusters in Taiwan seem to have become institutional supports for SMEs engaging in innovation activities. Therefore, we propose that the SMEs' innovation will not disappear in the future. Instead, it will become a part of Taiwan's innovation system that is accompanied by a big firm-led innovation tendency. The national model still prevails.

Notes

1. For example, first, not all innovations are technically patentable, such as manufacturing processes and operations. Second, patents would not be applied for all innovations by the owners due to the consideration of possible technology leakages. Lastly, innovators may consider filing patents in the domestic market rather than in the US market owing to the cost and for market penetration reasons, not to mention the fact that the application for a patent in different countries involves different procedures with different rates of entry.
2. The USTPO offers independent inventor(s) name(s) and/or assignee name(s) – the latter could be individual person(s), firm(s), and institution(s), regardless of whether they are domestic or foreign.
3. The industries in category 6 can be regarded as traditional industries, because the sub-categories in this category include: agriculture, husbandry, and food (61); amusement devices (62); apparel and textiles (63); earth working and wells (64); furniture, house fixtures (65), heating (66); pipes and joints (67); receptacles (68); and miscellaneous others (69).
4. Although the technological classes are not equivalent to related industries, for example, sub-category 24 (information storage) and sub-category 46 (semiconductor devices) do not comprise the whole of the semiconductor industry, they can still represent most of the semiconductor industry, including upstream devices, downstream manufacturing activities, as well as memory products (Chung et al., 2004).
5. Hu and Jaffe (2003) examined international knowledge flows from the United States and Japan, to Taiwan and South Korea in terms of patent citations made by the latter group to the former group. The results show that Taiwan obtained more knowledge from the United States than from Japan, whereas South Korea learned more from Japan than from the United States.

6. Based on the USPTO (2006) patent report, the sub-categories of tools (081), land vehicles (280), and exercise devices (482) were ranked sixth, seventh, and ninth, respectively, among Taiwan's top 10 most innovative subcategories.
7. Originally, the HHI value reflected the balance of technology development: the higher the HHI value, the less concentrated the development of a country's technology.
8. As to whether public institutions diffuse knowledge to the industrial sector, Hu (2008) discovered that public research institutions have had no more of a positive impact on the TFT-LCD industry after the mid-1990s than they used to have on the semiconductor, PC, and chemical industries (Hu and Tseng, 2007). However, a recent survey found that ITRI has continued to play an important role in improving the innovation performance of SMEs (Tsai and Wang, 2005). This is because ITRI has shifted its role from leading to supporting the private sector (Hsu and Chiang, 2001; Hsu, 2005).
9. The argument here is similar to Nagano's (2006) research findings in which the author argues that the effects of public funding on the private sector's R&D in Taiwan is positive and in Korea is neutral. That means that the more the state in Taiwan expends on R&D, the more that private firms will expend on R&D. However, there is no positive correlation beween these two in the case of Korea.
10. Although the Korean state enacted the 'Support for SMEs Establishment Act' and the 'Act on Special Measures for the Promotion of Venture Business' in 1997 in order to stimulate the growth of SMEs (Kim et al., 2005), the Korean industrial structure is still dominated by chaebols which have hampered the development of technological-based SMEs (Sohn and Kenney, 2007).

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