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 the USPTO patent data as indicators of innovation, this paper finds that both Taiwan and South Korea has progressed rapidly in terms technological innovation since the 1990s, overtaking many of the advanced countries. Nevertheless, there are major differences in the patenting behavior: while individuals and small and medium sized enterprises (SMEs) comprised of a large part of the patents in Taiwan, the chaebol or the large conglomerates are the major contributors of South Korea's patents. Moreover, although electronics is the sector that gains most of the patents in both countries, Taiwan's patents are more dispersed while South Korean counterparts are more concentrated. These differences, this paper argues, come mainly from the institutional roots in their economic catching up era in which Taiwan was based on a SMEs-dominant industrial structure while the South Korean was the Chaebol-based, instead. This paper further argues that the institutional roots have largely shaped both countries' diverse road toward innovation-based economy: the South Korean case is transitioning toward a neo-Schumpeterian model where big firms are the major actor of innovation; while the Taiwanese one is transforming toward a neo-Marshallian model in which both big firms and SMEs are major actors that are densely networked in industrial clusters.

I, Introduction

The economic development of both Taiwan and South Korea are often regarded as pair exemplars for comparative purpose (Amsden 1989; Wade 1990; Woo 1991; Haggard 1990; Hamilton 1996). For example, both countries' states are viewed as instances of the developmental states that have led their respective economies to achieve remarkable development. However, the South Korean state was much more ambitious than Taiwan's counterpart that undertook a big push approach in promoting economic growth which incurred enormous foreign debt and sacrificed its economic stability. On the contrary, the Taiwan state was more cautious in undertaking its economic development policy which put economic stability prior to economic growth. In order to keep the economy in stability, the Taiwan state purposefully keep large amount of foreign reserve in order to secure itself from any possible financial crisis. Moreover, the Korea state intentionally nurtured domestic big private firms, or Chaebol, in order to push its economy to develop based on domestic ownership. Due to the state's strong intervention and its 'unlimited supply of capital' policy, the South Korean industrial structure was highly concentrated. In comparison, the Taiwan state did not promote big private-owned enterprises, due to its state capitalist ideology, which resulted in Taiwan's industrial structure becoming a small- and medium-sized enterprise (SME) based economy until the late 1980s. The differences between these two countries also show in their divergent routes in technological catching up and transitioning toward innovation. Whereas South Korean route was based on a scale economy in which the Chaebol is the agent of learning and innovation, the Taiwanese model is much based on external economies in which the state sponsored R&D institutes, the foreign expatriates, domestic and international production networks are complementary to the massive SMEs as agents of learning and innovation (Hamilton, et al, 2000; Wang forthcoming).

The purpose of this paper is to compare Taiwan and South Korea in terms of their difference on the patterns of innovation. The central question of this paper is this: how the above mentioned featured differences between Taiwan and South Korea affect their routes in transforming toward innovation based economies? Will they proceed this transition in a similar way or in a very divergent manner? The hypothesis that this paper holds 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 for technological innovation. Specifically, we propose that innovations in South Korea will continue to be dominated by big firms, while in Taiwan, individuals and SMEs will continue to be important agents of innovation.

In order to sustain our hypothesis, we use and analyze patent files that are directly download from the United States Patent and Trademark Office (USPTO) as indicators to compare both countries' performance. Because the patent dada composed of varieties of sectors, ranging from semiconductor, automobile, chemistry, to tools and toys, we thus use NBER methodology (to be explain later) to recompose the patent file into subcategories in order to find out which sectors that each country have performed better and with vigorous innovative capability.

Our major findings are the followings: both Taiwan and South Korea have gained impressive records in attaining patents from USPTO since the early 1990s, even overtaking the traditional advanced industrialized countries, except the US, Japan and Germany. Both countries have performed very well in the electrical and electronics category. However, secondly, in terms of ownership of patents, individuals and SMEs still play an important role in the Taiwanese cases, which is different form the Korean counterpart where big firms owned most of the patents.

II, national model and path dependence

Technological learning and innovation are crucial for economic development. The major characteristic of a catch-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 catch-up economy has a clear objective to pursue, namely, to close the technological gap between itself and the advanced countries. In contrast to the catch-up paradigm, the innovation-based economy aims at creating and searching for frontier technologies that do not yet exist in the market. Innovation here indicates new and improved products and processes, or as Edquist (1997:18) 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.' In this broader definition, innovation not only indicates new products, but also new process. It may denote abrupt product innovations, but it may also imply incremental process innovations. In any kind, innovation is a process involved searching and exploring the unknown areas with the result is uncertain. Uncertainty is the keyword of innovation (Nelson and Winter, 1977).

Technological learning and innovation occurs at the level of the firm, however any 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). The ways in which national institutions are arranged tend to evolve historically into an idiosyncratic social configuration (Hollingswroth, 1998; 2000) or called a 'national model' and therefore in a large degree influence how technologies are transferred and learned. In other words, a national model is a result of long term historical evolution which combined various coupling or complementary institutions that are favourable for some industries than otherwise to emerge and to become prosperous (Amble 2000: 655). It is therefore not a single and isolated institution, but a set of inter-connected and complementary institutions that constitute the basic support for a certain kind of industrial development (Amble 2000; Hall and Saskice 2001). In the same vein, for the late industrializing country, economic learning occurs not only because of individual firms' effort, but also due to the support of the system of institutions. As Mathews and Cho (2000:21) observe, economic learning in a successful catch up economy "is accomplished not by firms working individually or even in isolated collaborative networks such as private consortia but in 'industrial systems' that provide structure and process between firms and the market, or between firms and the state." Economic learning in this economy takes place in a coordinated or orchestrated fashion, "a manner that approximates the capacity of a company management to coordinate the operations of the different divisions of a company."

Moreover, since institutions enable and constrain individual behaviour by defining the incentive framework in which agents take 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 mainly results from the fixed cost of the institutional architecture and the increasing returns of adoption. As a result, this creates the path dependence or the lock-in effect, which hence explains the phenomenon in which existing institutions tend to persist and become the growth trajectories that are followed by nations.

Following the above institutionalist perspective, we propose that the industrial system or institutional arrangement of a late industrializing country in facilitating technological learning will continue to play a major role in a country's transitioning toward an innovation-based economy. The existing socially-embedded institutional arrangements which support a late industrializing country's technological catching up may create enabling and constraining conditions for the economy to adjust to the transition toward innovation. In addition, the existing institutional arrangements may favor some but not all industries to become competitive in the world market. It is because the institutional structure of a particular political economy may provide firms with advantages than otherwise for engaging in specific types of activities and allow them to produce some kinds of goods more efficiently than others, due to the fact that " the institutions relevant to these activities are not distributed evenly across nations" (Hall and Soskice 2001:37). This confirms what Porter (1990:7) argues, "no nation can be competitive in everything".

There are two different views regarding who will be the agent that generates innovation. The first stresses the importance of the economies of scale for technological innovation. In Schumpeter's (1950) view, large firms have a superior ability to generate technological and organisational innovation, due to their abundant resources. This view was amplified in Chandler's (1991) work so as to demonstrate the central role of the large, oligopolistic firm in technical progress since the 1880s. Following this reasoning, Amsden and Chu (2003) have recently proposed "the second mover's advantage" thesis and argued that organizational scale is essential for latecomer firms to upgrade their technology level. Because latecomer firms tend to enter the mature or mid-level technology industries, whose typical feature is that the return on profit has been declining, the strategy that latecomer firms have to adopt therefore is to ‘ramp-up’ their organizational scale and improve their organizational capability so as to upgrade the level of technology and sustain the profit rate.

Secondly, there is a neo-Marshallian view that highlights the importance of the industrial cluster in which dense interactions among a large number of competing and cooperating firms create an external economy favouring technological innovation and learning (Amin and Thrift, 1993). This view especially stresses the importance of ‘collective efficiency’ (Schmitz, 1995) and ‘trust’ that can amend the resource disadvantage of SMEs. Various studies on the ‘flexible specialisation’ regions (Piore and Sable, 1984) and further research on ‘industrial clusters’ (Saxenian, 1994) suggest that dense production networks among small firms may create an environment that can facilitate the flow of knowledge, ideas, learning and innovation.

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 technological catching up. In the Korean case, because of its economies of scale in economic development, it tends to follow a neo-Shumpeterian approach in transitioning towards technological innovation. Whereas in the Taiwanese case, due to its SME-based economy, it is keen to the neo-Marshallian approach in which industrial clusters play an important role in generating innovation.

III, Methodology

Despite the fact that the application of a patent in different countries involves different procedures with different rates of entry, patent is still regarded as the most representative indicator of innovation. In order to level off the differences, the most common method in doing innovation analysis is to use the United Stated Patent and Trademark Office (USPTO) patent data for comparative research.

Some scholars have criticized that there are drawbacks by using patent as indicator of innovation. For example, first, not all innovations are technically patentable, such as manufacturing processes and operations. Second, not all innovations would be applied for patents by the owners due to the consideration of possible technology leakage. Lastly, owing to the cost and market penetration reasons, innovators may consider file patents in domestic market rather than in the U.S. Keep these drawbacks in mind, we still think that the patent data of USPTO can fulfill our research purpose of comparison. It is because the United Stated is the biggest market in the world that holds the most frontier technologies, therefore most inventors in the world tend to apply patents in the U.S. in order to secure their interests. Thus, patents in USPTO can provide us adequate information -- such as country origin of innovator, grant year, technological class, and ownership status[1] of the innovator, etc.. They can also indicate clearly a country's competitive specialization and the trajectory of its technological development (Patel and Pavitt 1994, Jaffe and Trajtenberg 2002; Mahmood and Singh 2003; Hu and Mathews 2005).

We will employ NBER database to compare a variety of technological patterns, such as knowledge spillover among countries (Jaffe and Trajtenberg 2002). The advantages of NBER methodologies lie in its clear technological classification in term of six main categories—such as Chemical, Computers, Mechanical and Electronics, etc., instead of complicated 417 technological classes (i.e. Current US Classification, CCL) by USPTO without clarification.

[1] USTPO offers independent inventor (s) name(s) and/or assignee name(s)—the later could be individual person(s), firm(s), and institution(s), regardless of domestic or foreign.

Our data will mainly base on the USPTO online patents statistics ranging from 2000 to 2004. The reason in selecting these typical years is that many scholars have done studies in comparing innovation discrepancy between Taiwan and South Korea (Hu and Jaffe, 2001;Chung, Tsai, and Wang, 2004; Hu and Mathews, 2005; Park and Lee, 2006), we will not repeat these similar studies. Particularly, most of the existing studies are based on the NBER database which spans from 1963 to 1999, which encourage us to see the continuity in the following years. Therefore, we combine the useful NBER main category- CCL conversion hierarchy and ownership principles[2], by searching the USPTO online patent data with determined timeframe, selective CCL, and ownership criteria to collect Taiwan and South Korea patents distribution accordingly. The computing results are the followings.

IV: Findings

4. 1 From technological catching up to innovation

Taiwan and South Korea have made impressive progress in obtaining patents from 1990. As Fig.1 shows, the patents of both countries in 1997 reached the level which was similar to Italy and Switzerland, but still lagged far behind Canada, French and United Kingdom. However, they leaped over the above three developed countries after 1997. Currently, Taiwan and South Korea are the fourth and fifth largest patent recipients, after only the U.S., Japan, Germany, of USPTO. The achievement indicates that both Taiwan and South Korea had successfully acquired and assimilated existing technologies developed in advanced industrial economies (Hobday, 1995), and kept improving them that had gone “beyond imitation towards innovation” (Kim, 1997), as demonstrated by the impressive patenting soar.

[2] For simply patent ownership distinction, we denote an unassigned invention belonged to individual (IND); while an assigned invention belonged to organization (ORG).

***Fig 1 here

In terms of approved patents number, Taiwan has led South Korea straight since 1990, except 1998, till 2004. But they excel in different categories. The decomposition of 2000~2004 data file (Fig. 2 or Table 2) shows that both Taiwan and South Korea have performed excellently in category 4 (electrical and electronics). This shows the fruitful result of both countries' enormous effort in developing the industries of this category. Nevertheless, they have excelled differently in the second and third largest granted patent categories. The second and third categories in Taiwan were categories 5 (mechanical), and 6 (Other[3]); whereas in South Korea, they were categories 2 (computers and communications), and 1 (chemical) respectively. Moreover, both countries show not very impressive records on the category of drug and medicine, this also indicates the latecomer status of their biotechnology and pharmaceutical industry.

***Fig 2 here

4.2 The high concentration sector: the ICT industries

The Taiwanese and Korean states' development strategies in promoting the electronics industry have yielded their fruits. If we combine categories 2 (computer and communications) and 4 (electrical and electronics) into the ICT (information and communications technology) industries as to observe the weight of

[3] The industries of category 6 can be regarded as traditional industries, because the subcategories in this category include: 61- agriculture, husbandry, and food; 62-amusement device; 63-apparel and textile; 64- earth working and wells; 65- furniture, house fixtures, 66- heating; 67- pipes & joints; 68-receptacles; 69-miscellaneous-others.

the ICT industries of the whole approved patents, the result (see Table 1) shows that both countries' patents heavily concentrated on the ICT sector. The figure in Korea reaches as high as 60% whereas in Taiwan, 51%. The high concentration of patents in the ICT industries reconfirms what Patel and Pavitt (1994) had observed in their earlier paper on East Asia which claimed that both Taiwan and South Korea had performed well in technological development and catching up, especially on the ICT industries.

Yet, though excel in the ICT sector, there're some variations between these two countries: Taiwan performed better than South Korea in category 4, especially for subcategory 46, which is semiconductor devices. This may indicate that Taiwan possesses better competitive advantages in the semiconductor manufacturing industry, and which may be due to the fact that Taiwan has two of the most advanced IC foundry firms in the world, TSMC and UMC, that posses the most advanced process technology in manufacturing semiconductor. However, South Korea outperforms Taiwan in category 2, particular on subcategory 21 (communications) and 24 (information storage). Because Korean chaebols are famous by their volume production on DRAM and CDMA cell phone, we can reasonably guess that these firms are leapfrogging toward innovations on these industries (Kim, 1997; Lee and Lim, 2001). Surprisingly, though Taiwan has been one of the world major producers on desktop PC, notebook PC and other peripherals, i.e. Taiwanese firms produced over 80% of notebook PC on the global market (MIC, 2006), Taiwan's share of patents on this subcategories (i.e. subcategories 22 and 23) still lag behind that of Korea. We conjecture that this is highly associated with Taiwanese firms' original equipment manufacturing (OEMs) method in producing these goods, which means that Taiwanese firms produce products following the design offered by the buyers without having their own brands labeled on the products. This offset the motivation of Taiwanese hardware firms to conduct intensive R&D (Wu and Hsu, 2001). On the contrary, because Korea chaebols tend to sell their products by their own brands, such as Samsung and LG, they have the motivation to internalize R&D effort in order to support its' worldwide presence.

***table 1 here

4.3 Mechanical and other industries

Besides the similar phenomenon of high patent concentration on the ICT sector in both Taiwan and South Korea, they nevertheless differ on the second, third and fourth largest approved patent categories. Taiwan's second largest approved patent category was 'Others', which are in the areas such as toys, shoes and apparel, chairs and seats, locks, heat exchange, special receptacle or package, and tent, canopy, umbrella, or cane, etc. This indicates that Taiwan is still very innovative in these traditional industries, which also outnumbers that of Korea.

Taiwan's third most innovative industrial category was the mechanical sector, which has 6,274 pieces of patent. The same category in South Korea was ranked as the fourth that gained 3,062 approved patents, which was about half of Taiwan's. Moreover, in terms of the top 10 largest patented subcategory (table2 and table 3) in Taiwan, there are three subcategories that are belonged to the mechanical category: they are tools, land vehicles and exercise devices respectively. Although the majority of the top 10 subcategories are in the electrical and electronics category, the mechanical industries still play important role in Taiwan's innovation system. The significance of the mechanical category has also been noticed by many researchers (Hu and Mathews, 2005; Mahmood and Singh 2003; Park and Lee, 2006) who consistently found that Taiwan's technological catching up from 1970s to 1980s had been particularly specialized on mechanical associated industries, such motorcycle, bicycle, and machine tools. It was only from the 1990s that the ICT sector began to take off as the main contributor of patents and began to occupy the top position in innovative activities.

In contrast to Taiwan's pattern, all but the fourth (chemical) subcategory of South Korea's top 10 approved patents belongs to the electrical and electronics sector. Even the fourth one (liquid crystal cell) is highly associated with the production of TFT-LCD. None of mechanical subcategories are positioned in the top 10 patent gainers.

*** table 2 here

****table 3 here

****table 4 here

4.4 *Distribution by ownership*

Since Taiwan's industrial structure has long been dominated by SMEs, we are very interested to know whether this type of industrial system affect its transition toward innovation. According to the existing researches (Choung 1998; Jaffe and Trajtenberg 2002), the ownership of patents in South Korea from 1976 to 1998 had been highly concentrated in organization; the chaebols owned 89.7% of the patents. In contrast, Taiwan's patent ownership had been more dispersed. Due to the SME dominated economy, the individual ownership of patent reached as high as 64%. We continue to search USPTO data (2000-2004) along with the findings of the above studies, the results are moderate different. Our results show that, for South Korea, the ownership ratio of assigned organizations remains stably high at 90%. For Taiwan, the ownership ratio of individuals declines from 64% to 37% (table 5). This seems to indicate that Taiwan's innovation system has been changing, organizations currently play more important role than in the past in innovation activities. As shown in Fig. 3, Taiwan long-term trend seems to change in the direction in which the share of individuals is decreasing while the share of organizations is increasing.

*** table 5 here

*** Fig 3 here

4.5 Patent ownership in the ICT sector

Now, we analyze the ownership of both countries in the six main categories. First of all, in the ICT sector (category 2 plus category 4), organizations contribute 80% of the patents in Taiwan, while in South Korea, it is 95%. This shows the similarity of the ICT sector in both countries in pursing for patents, this also indicates that the Chanderlian firms emerge in these two countries to pursue for the economics of scales and scope (Amsden and Chu, 2003).

In order to further analyze the distribution of ownership (big firms and SMEs) in different categories of industries, we analyze the top 10 organizations of both countries that own the granted patents during 2000 and 2004. The result show that the top 10 organizations in Taiwan are either belonged to the ICT sector or the state-sponsored R&D institutes (table 6). They consist of the IC foundry, IC IDM firms, IC design, and PC OEMs and peripheral firms. The state-sponsored R&D institutes, ITRI and the National Science Council (NSC), are positioned at the fourth and tenth in the list, which shows the fact that the state still plays an important role in Taiwan's innovation system.

Nevertheless, although the top 10 patent-granted organizations in Taiwan contribute 7,988 items of the patents during the period, they only share 42% of the patents in the ICT industry. As discussed above, the share of the ICT industry in the total granted patents is about 50%, thus we can reasonably calculate that these top 10 organizations contribute about 20% of the total patents, the rest 80% of innovations are distributed among multiply enterprises, including that many of them are SMEs.

South Korea's patents show different pattern of ownership (table 7). The top 10 organizations are all chaebol or related associates. Among them the Samsung group occupies the first, eighth and tenth positions; LG group occupies the second, fourth and ninth positions; the Hyundai, third, fifth and sixth. In other words, 9 of the top 10 organizations are belonged to the top three chaebols. In terms of the share of the top 10 in the total, these organizations contribute 13,301 items; they also supply as high as 86% of patents in the ICT sector. Or, if we compute that the ICT sector contribute 60% of the patents in the total, then this means that the top 10 organizations have about 50% of the share of the total Korean patents. The high concentration rate in the South Korean patents can also be shown in the following figure: the summation of patents of the Samsung groups in the top 10 reaches as high as 57% (7413/13301).

4.6 Ownership Variations: Mechanical and other industries

The above analysis shows that albeit the importance of individuals and SMEs have been in decline in Taiwan's innovation system, compared with that of South Korea, there exists some significant differences. This is especially indicated by the share of patents in the categories of 'others[4]' and 'mechanical', in which the share of individuals continues to maintain at as high as 63% and 57% respectively. The still-important phenomenon of SMEs in gaining patents has rarely been seen in the South Korean innovation system in which SMEs and individuals have played very minor role. Indeed, in the South Korean case, the same categories are still dominated by organizations, in the mechanical category, 87.6%, in Others, 70% (table 5).

****table 6 here

****table 7 here

V, National models and their evolution

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

(1) In terms of the centrality of innovation, Taiwan is more dispersed than South Korea. Although the electrical and electronics category is the one that has most of the patents in both countries, the composition of the top 10 subcategories are different. In the case of South Korea, all the top 10 belong to the ICT sector; however in Taiwan, the top 10 subcategories are dispersed into the mechanical category, such as mechanics, tools, land vehicle, exercise devices, etc.

(2) In terms of ownership of the patents, both countries also show different patterns. In the six major categories of innovation, about 63% of the patents are owned by organizations in Taiwan, but this figure reaches as high as 90% in South Korea. In the ICT sector, this figure was 95% in South Korea, whereas in Taiwan,

[4] Choung (2002) conjectures that most of unassigned individual inventors are owners of SMEs, and we follow this assumption especially for category 5 and 6.

this was 80%. These figures show that innovation in South Korea are high concentrated in the Chaebols, whereas in Taiwan, a considerable amount of innovations were still held by SMEs. This is especially seen in the predominant status of the Sumsung group in the electrical and electronics category. Although one of the state-sponsored R&D institute, the Electronics and Telecommunications Research Institute, was listed in the top 10 status in Korea's approved patents, it held only a small portion as compared with the Samsung electronics Inc. The former constituted only 7％（473/6793）of the latter's patents. On the contrary, Taiwan's case is much less concentrated. Even in the most concentrated electrical and electronics category, there are 58% of patents owned by non-top 10 organizations. Moreover, the top ten owners of patents in Taiwan include two state-sponsored R&D institutes, ITRI and NSC. In which the ITRI constituted as one of the most important contributors of the whole patents. The patents it owns reaches as high as 46% (1030/2239) of the top 1 firm's (TSMC). This shows the importance of the state-sponsored R&D institute in Taiwan as compared with the no-so-significant status of the Korea's counterpart.

The above findings indicate that Taiwan and South Korea have transitioning into innovation-based economies following very divergent routes and which have largely related to the former catching up production systems. Korean case seems to follow clearly the former scale economies and transforming into chaebol-led innovation model. This model can be described as the neo-Schumpeterian one in which big firms play the dominant role in innovation. On the contrary, Taiwanese case is mixed with big firms and SMEs, therefore not as clear as the Korean neo-Schumpeterian model. On the contrary, Taiwanese model is keen to the Neo-Marshallian model in which industrial clusters can generate innovative activities due to intensive interaction and networking. We can further elaborate this in the following.

In the top 10 most innovative industries (table 3) of Taiwan, the most active innovators are the fourth category, including semiconductor device manufacturing process, electrical connectors, active-solid-state devices, electrical systems and illumination. The second active innovators are in the fifth category, which mainly composed of traditional sectors such as tools, land vehicle, exercise devices. These two categories of industries in Taiwan are products of industrial clusters.

It is well known that the semiconductor industry in Taiwan has been created and nurtured by the state (Mathews and Cho 2000; Chen 2003). It is because of the state's construction of the Hsin-chu Science Industrial Park (HSIP) and provision of other very generous tax incentives that attracted many of the electronics-related firms in the park which consequentially created an industrial cluster. In the late 1980s, it was because the establishment of IC foundry firms, TSMC and UMC, in HSIP that attracted most of the semiconductor related firms, especially the IC design firms, into the science park. This in consequence has brought HSIP to become one of the most innovative IC design regions in the world in the 1990s (Chen 2003；Hsu 2000；Wang and Gao 1999). Moreover, in the 1990s, the IC design industry has upgraded into the SoC (system-on-chip) level in which many of the blocks of IC design can be bought and sold (called the intellectual properties or IPs) and recombined into a new IC. Plus the progress of process technology into the nano level of the ICs, the rules of IC design become so complex that call for the necessity of intensive interactions between process engineers and IC designers in order to ensure the yield level. This especially occurs between foundry engineers, who are responsible for IC manufacturing that have deeper knowledge about the process technology and the rules of production, and the IC designers who create new knowledge on IC design but still have to follow the design rule set up and constrained by the process technology of the foundry manufactures (Chen 2003l Wang and Chen 2006). Indeed, the foundry manufactures has brought about the emergence of the IC design industry in HSIP, which in due course also deepen the regional integration because of the necessity of firms' interaction due to the progress of process technology. The regional innovation system has been created and the industrial cluster also enhances HSIP's competitiveness in the world market.

Different from HSIP, Taiwan's mechanics and machine tools industry is not the creation of the state. Currently Taiwan is the world 5th largest producer of the machine tools industry, and most of the machine tools manufactures have clustered in the central region of Taiwan (Wang and Gao 1999; Hsu and Cheng 2001; Liu 1999). Also, it has two of the world top bicycle producers, Giant and Merrida, in the region that have created their inter-connected production networks within it. Again, in contrast with HSIP, the emergence of this region has been a social evolution of the mechanics industry, the state has done very little to the formation of this region. Different from the electronics industry where big firms have become dominated in the 1990s, the mechanics and machine tools industry are overwhelmingly dominated by SMEs. Moreover, the regional intensive networks and trust built by long term cooperation among the SMEs have brought about high degree of flexibility and productivity of the region. From the early 1990s on, the state has suddenly 'found' the existence of the mechanics region, therefore new resources have been pooled into this region, including the state-sponsored R&D institute ITRI, to set up regional R&D office in the area. Currently, the ITRI, local SMEs, and regional production networks have transformed itself into an innovation network, producing new essential components, of which many are the patent products, to integrate into the tools machine. The central region has become an innovation cluster of the mechanics industry in Taiwan.

There are some salient similarities between Taiwan's semiconductor and mechanics industries: vertical disintegration, regional cluster, production networks and flexibility. These features are typical elements of a neo-Marshallian innovation system. Although both industries have their own historical origins and developed with different routes, they finally converged into similar pattern and shown alike characteristics. The neo-Marshallian innovation system seems to become the salient feature characteristics of Taiwan's new national model of innovation and this has largely transformed from the former technological catching up era in which the SME-based production system and the external economies are the main features.

The similar path dependence effect also occurs in the route of South Korean's transformation. As discussed above, all the top 10 items of patents belong to the electrical and electronics industry and they also mainly owned by Chaebols. These Chaebols used most of the R&D expenditures and created most of the patents. These of course are the bright-side products of Korean state's big push industrial policy, and which also has created brand-named, world-class big companies such as Samsung, LG, and Hyundai that have been listed in the world top 100 companies. Due to their abundant financial resources, these Chaebols continue to buy and assimilate technologies from abroad, and finally create their own new technologies in the frontier. This especially shows in the semiconductor, memory chips and TFT-LCD industries. Currently, Korean chaebols are leading firms in the above areas, they tend to make strategic alliances with world leading firms, such as Intel, IBM, Sony, Phillips, Texas Instruments, Toshiba, Sharp, Quacomm, etc,. to develop new products for next generations（Cho and Lee 2003. These chaebols now are no longer technology receivers, but have the capability to become knowledge creators. Currently, Samsung has successfully established its leading status on the areas such as cell phone, memory chip, TFT-LCD in the world market.

The Korean way of transition from technological catching up to innovation has been following the model of scale economies. The Korean state and Chaebols have invested enormous capital and resources in technological learning and in moving up the ladder to technological innovation. This path is akin to the neo-Shumpeterian pattern of innovation: it has the characteristics of scale economies, in which vertically integrated big firms are the agents of innovation. The neo-liberalist economic liberalization in Korea after the 1997 financial crisis seems to have reinforced the neo-Schumpeterian tendency (Pirie 2005;Kong 2000) through which chaebols are easier to find new financial resources to expand their global market share and strategic alliances.

VI: Discussion and 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 analyze the innovation patterns and the ratio of individual/organization ownership of these two countries. We have found that both Taiwan and Korea have followed strongly of their catching up routes and shown strong path dependent effect. Taiwan's pattern can be called a neo-Marshallian model, with characteristics such as industrial clusters, production networks and vertically distintegrated industrial structure. Whereas the Korean pattern has become akin to the neo-Schumpeterian model, with the characteristics of economies of scale and vertically integrated industrial structure.

By presenting the differences between Taiwan and Korean patterns of transformation into innovation based economies, one cannot help but to ask an intriguing question: whether we can discern the difference and find out which route of transition is better to economic development? This is a difficult question to answer for the following reasons.

First of all, if we differentiate technological innovations into radical, incremental, architectural and modular types (Henderson & Clark 1990), then bigger firms have more resources to invest research into areas that can fundamentally change the architecture of the industry, whereas the smaller firms tend to follow the architecture set up by bigger firms and invest research into areas such as modular and incremental or process innovations. In Taiwan's case, most of the firms in both the electrical/electronics and mechanics industries have been engaged manufacturing industrial goods for the world leading firms through the OEM method, they therefore tend to follow the existing design architecture to produce goods for others. If they engage in technological upgrading and innovation, they tend to do modular and process innovations in order to increase the yield rate and decrease the cost (Ernst 2000; Sturgeon 2002). Taiwanese firms do not want and need to invest into areas with high risk, such as radical innovation, due to limited financial resources and market environment. This also becomes the competitiveness of Taiwanese firms in the world market: modular innovation with low cost and flexibility. On the contrary, the Korean firms tend to develop architectural innovation because of their own brand-named products which have to compete head to head with other brand-name products in the world market. It is also because of the abundant financial resources that have made chaebols' enormous investments into the architectural innovation possible. The best example of this case is Korean chaebol's leapfrogging into the CDMA cell-phone production and now lead the world in the 3G communications（Lee and Lim 2001. In this perspective, Korean firms have produced products with higher level of technological complexity (cf. Mahmood and Singh 2003).

Nevertheless, secondly, there is no significant difference between Taiwan and South Korea in terms of technological trade. According to OECD (2005), the value of both countries' technology import in 2003 was the same, which was 0.53% of GDP. In terms of the value of technology export as proportion of GDP in the same year, Taiwan was 0.15% as compared to Korea's 0.13%. These figures indicate that both countries were deficit in technological trade. However, Taiwan seems to export more than that of Korea, though the figure was not very significant in statistical terms. This seems to indicate that we are not able to explicitly argue that Korean model is better than that of Taiwan's. Moreover, the patent dada can only tell partial story of industrial innovation, because innovation can have various forms. For example, Italy's industrial products are famous by their design, but it has not performed impressively in the patent data. The Italian industrial system is similar to Taiwan's, which also has the characteristics of neo-Marshallian model- flexibility, trust, production networks and clusters (Piore and Sable 1984). From this perspective, Taiwanese production system and innovation model is not necessarily less innovative than the Korean one.

Finally, there is a tendency that deserves to be observed in the future. That is whether there will be a convergence between Taiwan and South Korea in terms of technological innovation. Whether the big firms will play the leading role and replace the SMEs and industrial clusters? We have seen the tendency in which both countries have developed divergent routes. However, we have also observed that the proportion of individuals in Taiwan in obtaining patents has reduced in due course. The bigger firms seem to increase their share in the patent data. Is this indicating the future demise of the industrial cluster model? We think not, as we have observed that there exists the institutional path dependence effect for both countries.

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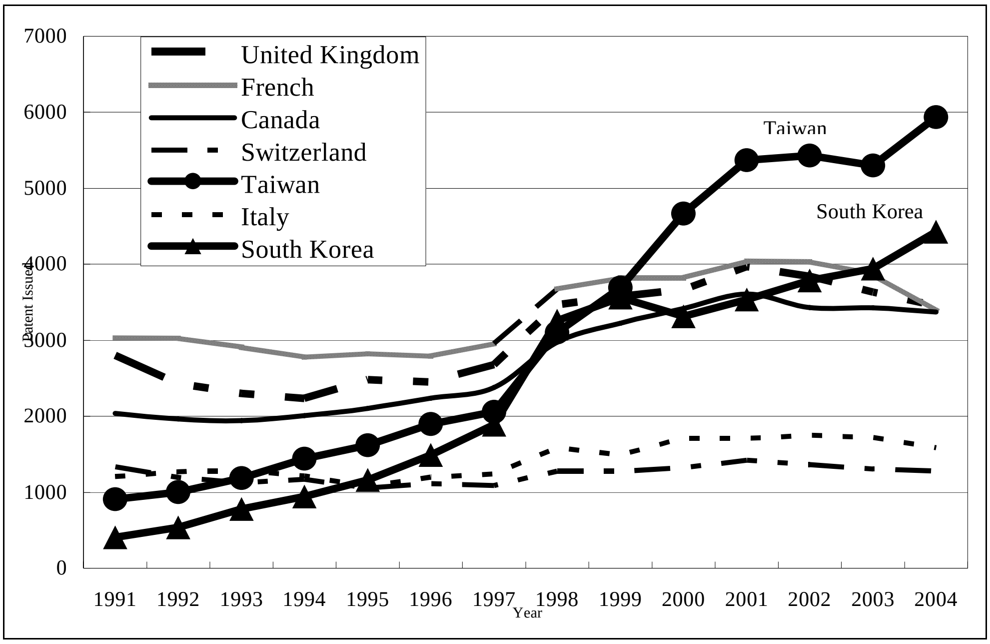

Figure 1 Granted U.S. patents , Top 4 to10 Countries

Source: USPTO (2006)

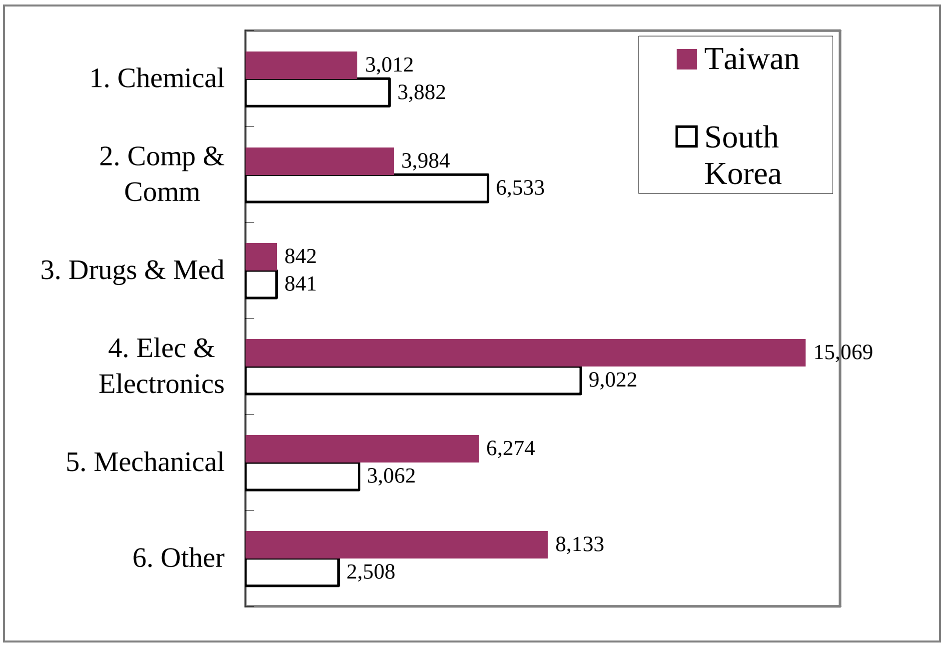

Figure 2 Taiwan and South Korea Patent Distribution

Table 1 Comparison of Patents Distribution in ICT Industry

NBER Category code and name	NBER Sub-Category code and name	Taiwan	South Korea
2 Computers and Communications	21 Communications	1,460	2,256
	22 Computer Hardware & Software	1,115	1,533
	23 Computer Peripherals	664	845
	24 Information Storage	745	1,899
4 Electronical and Electronic	41 Electrical Devices	3,258	1,019
	42 Electrical Lighting	1,242	1,089
	43 Measuring & Testing	599	441
	44 Nuclear & X-rays	243	220
	45 Power Systems	2,272	1,009
	46 Semiconductor Devices	6,764	3,975
	49 Miscellaneous-Elec	691	1,269
Subtotal (Percentage to Total)		**19,053** (51%)	**15,555** (60%)

Source: adapted from USPTO (2006)

Table 2 Patent Distribution by Category

NBER Main Category	Taiwan		South Korea	
	Counts	%	Counts	%
1. Chemical	3,012	8	3,882	15
2. Computers and Communications	3,984	11	6,533	25
3. Drugs and Medicine	842	2	841	3
4. Electric and Electronics	15,069	40	9,022	35
5. Mechanical	6,274	17	3,062	12
6. Other	8,133	22	2,508	10
Total	**37,314**	**100**	**25,848**	**100**

Source: Adapted from USPTO (2006)

Table 3 Taiwan's Top 10 Patents, Rank by Class

Rank	Category	Class and Technology	Counts
1	4	438 Semiconductor Device Manufacturing: Process	4,086
2	4	439 Electrical Connectors	1,567
3	4	257 Active Solid-State Devices, e.g., Transistors, Solid-State Diodes	1,353
4	4	361 Electricity: Electrical Systems and Devices	924
5	4	362 Illumination	628
6	5	081 Tools	408
7	5	280 Land Vehicles	389
8	2	365 Static Information Storage and Retrieval	345
9	5	482 Exercise Devices	334
10	1	430 Radiation Imagery Chemistry: Process, Composition, or Product Thereof	313

Source: USPTO (2006)

Table 4 South Korea's Top 10 Patents, Rank by Class

Rank	Category	Class and Technology	Counts
1	4	438 Semiconductor Device Manufacturing: Process	2,248
2	2	365 Static Information Storage and Retrieval	1,008
3	4	257 Active Solid-State Devices, e.g., Transistors, Solid-State Diodes	984
4	1	349 Liquid Crystal Cells, Elements and Systems	664
5	4	313 Electric Lamp and Discharge Devices	457
6	2	370 Multiplex Communications	433
7	2	345 Computer Graphics Processing and Selective Visual Display Systems	424
8	4	327 Miscellaneous Active Electrical Nonlinear Devices, Circuits, and Systems	402
9	2	455 Telecommunications	393
10	2	369 Dynamic Information Storage or Retrieval	367

Source: USPTO (2006)

Table 5 Taiwan and South Korea Patent Distribution by Ownership, 2000-2004

NBER Main Category (unit, %)	Taiwan		South Korea	
	ORG	IND	ORG	IND
1. Chemical	68.8	31.2	89.3	10.7
2. Computers and Communications	82.9	17.1	95.9	4.1
3. Drugs and Medicine	41.0	59.0	68.4	31.6
4. Electronical and Electronic	80.1	19.9	94.4	5.6
5. Mechanical	43.3	56.7	87.6	12.4
6. Others	36.9	63.1	70.2	29.8
Average	**63.0**	**37.0**	**90.0**	**10.0**

Source: adapted from USPTO (2006)

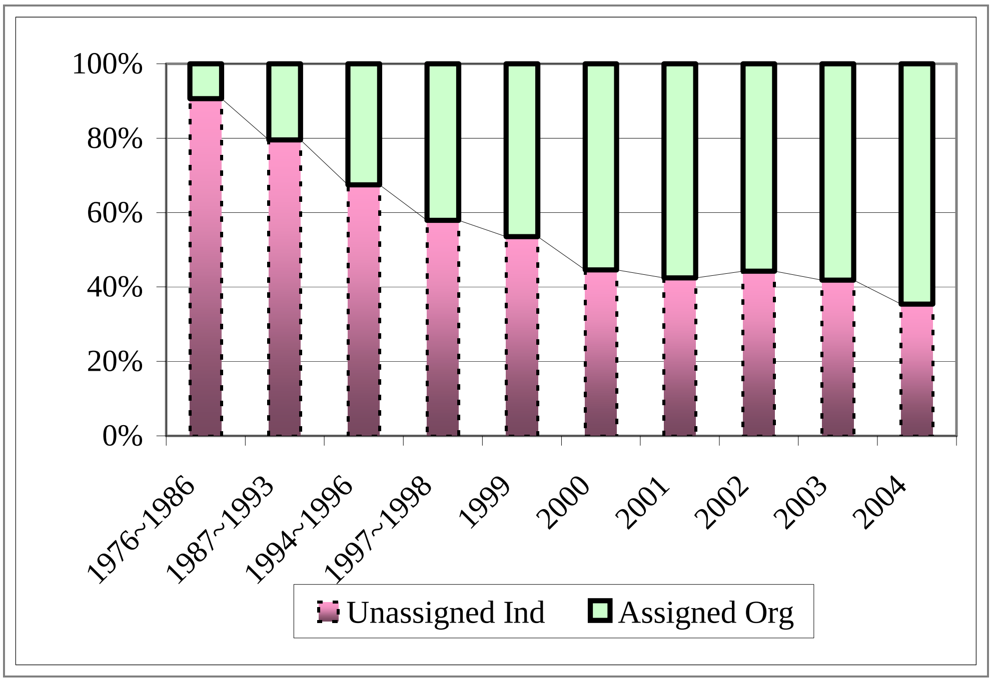

Figure 3 Ownership of Taiwan's Patents, 1976-2004

Source: adapted from USPTO (2006)

Table 6 Taiwan's Top 10 Patented Organization

Rank	Inventor Name	Counts
1	Taiwan Semiconductor Manufacturing Co., Ltd.	2,239
2	United Microelectronics Corporation	1,526
3	Hon Hai Precision Ind. Co., Ltd.	1,175
4	Industrial Technology Research Institute, Taiwan	1,030
5	Macronix International Co., Ltd	529
6	Winbond Electronics Corp.	454
7	Vanguard International Semiconductor Corporation	322
8	VIA Technologies, Inc.	239
9	Delta Electronics Inc.	238
10	National Science Council	236

Source: USPTO (2006)

Table 7 South Korea's Top 10 Patented Organization

Rank	Inventor Name	Counts
1	Samsung Electronics Co., Ltd.	6,793
2	LG Electronics Inc.	1,674
3	Hyundai Electronics Industries Co., Ltd.	1,501
4	LG. Philips LCD Co., Ltd.	712
5	Hynix Semiconductor Inc.	674
6	Hyundai Motor Co., Ltd.	519
7	Electronics And Telecommunications Research Institute	473
8	Samsung SDI Co., Ltd.	374
9	LG SEMICON Co., Ltd.	335
10	Samsung Electro-Mechanics Co., Ltd.	246

Source: USPTO (2006)