An analysis of innovation competitiveness of China through patent analysis

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ABSTRACT

This article assesses the innovation competition characteristics in China through patent analysis. The Chinese patents in US Patent and Trademark Office (USPTO) database from 2004 to 2008 are used for analysis. The findings suggest that the innovation competitiveness of China has increased in recent years. The absolute number of patents has shown the trend of rapid growth, but the share of utility patents is much lower than the global share. Based on analysis of technology fields, two main high innovation technology fields of China are the Electrical and Electronic machinery (E&E) and Computer and Communication (C&C) fields. The main international technology cooperation partner in these two fields is Taiwan. Moreover, Chinese patent output in the US is concentrated on a few large enterprises, and the patent proportions of the top 5, 15 and 30 assignees have increased each year. The top 5 patent assignees demonstrate strong innovation competitiveness in C&C and E&E fields. Among the large assignees are Hong Fu Jin Precision in both E&E and C&C fields, and Fu Zhun Precision and Huawei Technologies in E&E and C&C field respectively.

Keywords: Chinese competitiveness; Innovation; Patent analysis; Patent quality; Essential technological strength; Innovative competitive capability.

INTRODUCTION

Patent represents an important carrier of human being's intellectual properties and plays a central role in promoting scientific and technological progresses as well as in improving a country's innovational ability. Patents have been used as an indicator to measure the competition capabilities of countries and enterprises. International estimates from reports such as the *World Competitiveness Yearbook (*WCY) (IMD 2011) or the *Global Competitiveness Report* (GCR) (World Economic Forum 2011) often regard the patent data as an indicator of competitiveness for a nation. Moreover, the Patent Board (TM) uses patent data to evaluate a company's innovational abilities. The WCY provides an annual report on the competitiveness of countries and analysing the environmental factors that influences the competitiveness of enterprises. The report measures fifty-seven (57) countries on a basis of three hundreds and twenty-nine (329) criteria for evaluations, which includes four (4) indicators related to patents: Patent Applications, the Patents Granted to

Residents, the Number of Patents in force, and the Patent Productivity. The Global Competitiveness Report 2011 – 2012 (World Economic Forum 2011) claimed that the Growth Competitiveness Index (GCI) of China ranked at the 26th position, within one hundred and forty-two (142) major economies. This is the fourth time that China has been ranked within the top thirty (30) countries in the world. Among the indicators incorporated in GCI is the number of utility patents granted in the United States and is considered the most direct and objective measure of a country's innovation capacity (Chen, Lin and Huang 2007).

The Patent Board (TM) (Amato, Christine and Oldach 2009), which specializes in tracking and analysing innovations, movements and business values of patent assets across as many as seventeen (17) global industries, has taken patents of the United States as their data source and produces the yearly Patent Scorecard for main companies and industries, such as Chemicals, Biotechnology and Pharmaceuticals. Furthermore, the United States Patent Counts can also function as an imperative indicator when combined with a series of industry-standard metrics to evaluate the most innovative hi-tech companies around the world.

Generally, studies focusing on topics of both national competitiveness evaluation and company innovation analysis usually use the United States patents to measure the innovational technical forces of an economy or an industry. This study measures China's innovation competitiveness based patents awarded in the USA. It explores innovation competition characteristics of Chinese patents from the perspective of both patent quantities and qualities in the period 2004-2008. The research objectives are as follows:

a) To analyse the development trend of Chinese patents by studying the numbers of annual patent numbers and the share of Chinese utility patents to the world's;
b) To discover main innovation technology fields and international cooperation partners of China;
c) To identify the concentrative characteristic of China's innovation strength by filtering out top Chinese patent assignees based on patent numbers and the fields applied; and
d) To reveal essential patent enterprises in six (6) main innovation technology fields of China and to estimate China's global patent activities of top patent assignees by using patent quality indicators such as patent share and activity index rate.

LITERATURE REVIEW

Patents are useful for competitive analysis to investigate the trend of technological innovation (Abraham and Morita 2001; Huang 2009; Liu and Shyu 1997). Patent analysis has been used for forecasting technology and for evaluating competitiveness of countries and companies. It has been emphasized that the patent data could reflect the pattern of technological developments. The technological entry, exit and survival could be reflected by patent analysis (Malerba and Orsenigo 1999). How patent data can be retrieved and analysed in order to find patterns of developments and innovations in a field of technology was discussed by Yu and Kehoe (2001).

Based on the patent data, scholars have used different technological indicators, such as patent counts, national priorities, patent shares for international presence, and the citation rate (Jacobsson and Philipsson 1996; Lo 2010; Marinova and McAleer 2003). In one study, the patent co-citation approach was used to identify the major R&D fields of a specific

technology (Shen et al. 2010). In another study, the patent classification system under technological sectors and subsectors was constructed to identify the major application areas of technologies, and to forecast their future trends (Bhattacharya and Khan 2001). Moreover, patents may be combined with academic papers to forecast emerging technologies. Daim et al. (2006) studied the forecasts for three emerging technology areas (fuel cell, food safety and optical storage) by integrating the use of bibliometrics and patent analysis into well-known technology forecasting tools such as scenario planning, growth curves and analogies.

Patent data reflect technological activities within a country and have been used to evaluate national competitiveness or innovation abilities. Quite a few scholars have analysed inventive activities and technological changes of some technology fields in single or group of countries (Kutlača 1998; Bhattacharya 2004; Sun et al. 2008). The technological competitive positions of the industrialized nations and the impacts from the patents could be measured by patent analysis (Chakrabarti 1991). Also, industrial structures and innovative abilities of nations could also be compared using patent data (Lin and Lee 2010; da Motta e Albuquerque 2000). Hu and Jaffe (2003) and Maurseth and Verspagen (2002) have used patent data to evaluate international knowledge flow, knowledge spillovers and diffusion.

On the other hand, patent analysis at company level helps reveal the technological strategies of the companies. Patent information serves as an objective and public information to understand core technologies of companies (Wu, Chen and Lee 2010). Companies can use patent information to identify gaps between the perceived and the actual level of information advancement on their competitor's R&D strategies (Schmoch and Schnöring 1994; Ernst 1997). Patent data can point out the technological emphases or trends of companies. Abraham and Moitra (2001) use patent counts to evaluate the advanced technological and innovational abilities for companies in India. Tomita (2003) has used patent analysis to predict the potential longevity and pioneering abilities of companies.

These patent analyses usually resort to patent counts or citation frequencies; nonetheless, these simple statistical numbers are not sufficient for evaluating the whole performance of a nation or a corporation. In this study, the researchers endeavor to set up an indicator system, considering both patent quantity and quality and combining them in order to evaluate the competitiveness of China.

METHODOLOGY

This paper attempts to evaluate the competitiveness of China through patents of China granted by the United States. The patents are categorized into two types, utility and the design patents. The raw data are selected from the patent database of US Patent and Trademark Office (USPTO). China has been chosen in the field of assignee country and the data was searched in April of 2009, with the year of issued dates set during the period of time from 2004 to 2008.

Patent assignees were carefully identified taking into considerations that assignees might use different names when applying patents, such as an abbreviated name, a full name and a name of subsidiary company. Also, to weed out duplicates care was taken to observe for name capitalization differences, spelling mistakes, punctuation differences, enterprise

combinations or renaming.

In order to analyse the technical developments of a country, the patents were also grouped by technology field classification, to evaluate a country's technological activities and identify new trends or in comparing the development of major technology fields (Lin and Lin 2002). Following Chen's et al. (2005) study, this study used the United States Patent Classification (USPC) to convert class numbers to six (6) technology categories: Chemistry, Computer and Communication(C&C), Biotechnology and Pharmaceuticals (B&P), Electrical and Electronic machinery (E&E), Mechanical, and Others.

Patent Indicators

Patents could be used as indicators to measure science and technology innovational skills of technology fields, enterprises, organizations, countries, and regions. For further detailed analysis, this study uses the following indicators: number of patents, Current Impact Index (CII) (Breitzman and Narin 2001), Essential Patent Index (EPI) (Chen, Lin and Huang 2007), Essential Technology Strength (ETS) (Chen, Lin and Huang 2007), Patent Share rate, and Activity Index (Albert, Yoshida and Opatal 2004) to evaluate patent quantity and quality. The formula used to measure innovativeness is shown as follows:

$$CII_{ij} = \frac{C_{ij} / K_{ij}}{\sum_i C_{ij} / \sum_i K_{ij}} \quad \text{(Eq. 1)}$$

C_{ij} represents the cited number of patents in a certain year, and company *i* produced in industry *j* from the previous five years. K_{ij} is the total number of patents, and company *i* produced in industry *j* from the previous five years.

$$EPI_{ij} = \frac{EPN_{ij} \Big/ P_{ij}}{0.5} \quad \text{(Eq. 2)}$$

EPN_{ij} represents the number of the essential patents owned by company *i* in industry *j*. The calculation processes is detailed in Chen, Lin and Huang (2007).

$$ETS_{ij} = \frac{P_{ij}}{M_{ij}} * \sqrt{EPI_{ij} * CII_{ij}} \quad \text{(Eq. 3)}$$

P_{ij}, EPI_{ij}, CII_{ij} represents the number of patents, the EPI and the CII of company *i* in industry *j* respectively, where M_{ij} represents the median value of total patent number.

$$\mathrm{AI}_{ij} = \frac{Com_{ij} \Big/ \sum_j Com_{ij}}{Con_{ij} \Big/ \sum_j Con_{ij}} \quad \text{(Eq. 4)}$$

Com_{ij} represents the utility patent number of company *i* produced in technology field *j*. Moreover, Con_{ij} is the utility patent number of country *i* produce in technology field *j*.

RESULTS

General Status of Chinese Patents

The world top twenty patenting status for the period 2004 to 2008 is indicated in Table 1. The results show that China's patent number and rank have increased from 440 in 2004 (ranked 19) to 1,481 in 2008 (ranked 12). One thing needs to be pointed out is that the number of patents from China here only includes patents from the mainland areas of China, and excludes those from Hong Kong and Taiwan. Table 2 compares China and the world patent output by types of patents (utility and design) for the period 2004 to 2008. There are other types of patents besides these two; as such the number of total patents is larger than the sum of these two kinds. Table 2 shows that the number of utility and design patents from China has increased since 2004. China's share of utility patents was about 65%, but it is much lower than the world utility patent share which has kept up to about 90%. It is generally considered that the utility patents infer higher technology value than the design patents. Therefore, a lower share of utility patents infers that the value of Chinese patents is lower than the world's.

Table 1: The Top Twenty Countries with the Largest Number of Patents during 2004-2008

Country	2008		2007		2006		2005		2004	
	Patent number	Rank	Patent number	Rank	Patent number	Rank	Patent number	Rank	Patent number	Rank
United States	94,750	1	96,110	1	104,444	1	84,598	1	84,823	1
Japan	37,255	2	36,770	2	40,285	2	32,323	2	37,190	2
Germany	9,540	3	9,578	3	10,407	3	9,187	3	10,616	3
Korea	8,944	4	7,462	5	6,570	5	4,622	5	4,521	5
Taiwan	8,482	5	7,998	4	8,521	4	6,260	4	5,446	4
France	3,299	6	3,291	7	3,483	7	2,848	7	3,307	6
Canada	3,240	7	3,337	6	3,610	6	3,005	6	3,030	7
Britain	2,506	8	2,611	8	2,864	8	2,266	8	2,253	9
Netherlands	2,434	9	2,390	9	2,496	9	1,952	9	2,442	8
Switzerland	1,979	10	1,852	10	1,946	10	1,531	10	1,788	10
Italy	1,546	11	1,482	11	1,519	11	1,243	12	1,438	12
China	1,481	12	1,012	15	702	16	501	16	440	19
Sweden	1,434	13	1,437	12	1,519	11	1,315	11	1,444	11
Australia	1,430	14	1,390	13	1,377	13	917	14	814	14
Finland	1,168	15	1,200	14	1,241	14	928	13	1,180	13
Israel	904	16	858	16	944	15	724	15	757	15
Singapore	643	17	705	17	513	18	259	20	284	20
Hong Kong	602	18	684	18	577	17	459	17	475	16
Denmark	507	19	452	20	478	20	437	18	453	17
Belgium	405	20	495	19	505	19	382	19	445	18

Note: From *US Patent and Trademark Office (USPTO)*.

The annual number of utility patents from China from 2004 to 2008 in the six (6) technology fields is shown in Figure 1. Patents in E&E field were the largest every year from 2004 to 2008, followed by C&C field. The patents of these two technology fields outnumber the patents in other technology fields in 2008, with the annual increase reaching 67.5% and 79.8% respectively. It indicates that E&E and C&C fields are becoming the main technology fields that have higher innovation competitiveness in China. The number of utility patents in Chemistry, B&P, and the Mechanical and Other fields were comparatively lower indicating lower innovativeness.

Table 2: China and the World's Share of Utility and Design Patents, 2004-2008

	China			World		
	Utility patent	Design patent	Total	Utility patent	Design patent	Total
2004	286 (65%)	153 (35%)	440 (100%)	164,254 (91%)	15,692 (9%)	180,264 (100%)
2005	329 (66%)	172 (34%)	501 (100%)	143,806 (92%)	12,951 (8%)	157,025 (100%)
2006	444 (63%)	258 (37%)	702 (100%)	173,772 (89%)	20,965 (11%)	195,288 (100%)
2007	645 (64%)	367 (36%)	1012 (100%)	157,282 (87%)	24,062 (13%)	181,881 (100%)
2008	967 (65%)	513 (35%)	1481 (100%)	157,772 (86%)	25,565 (14%)	184,004 (100%)

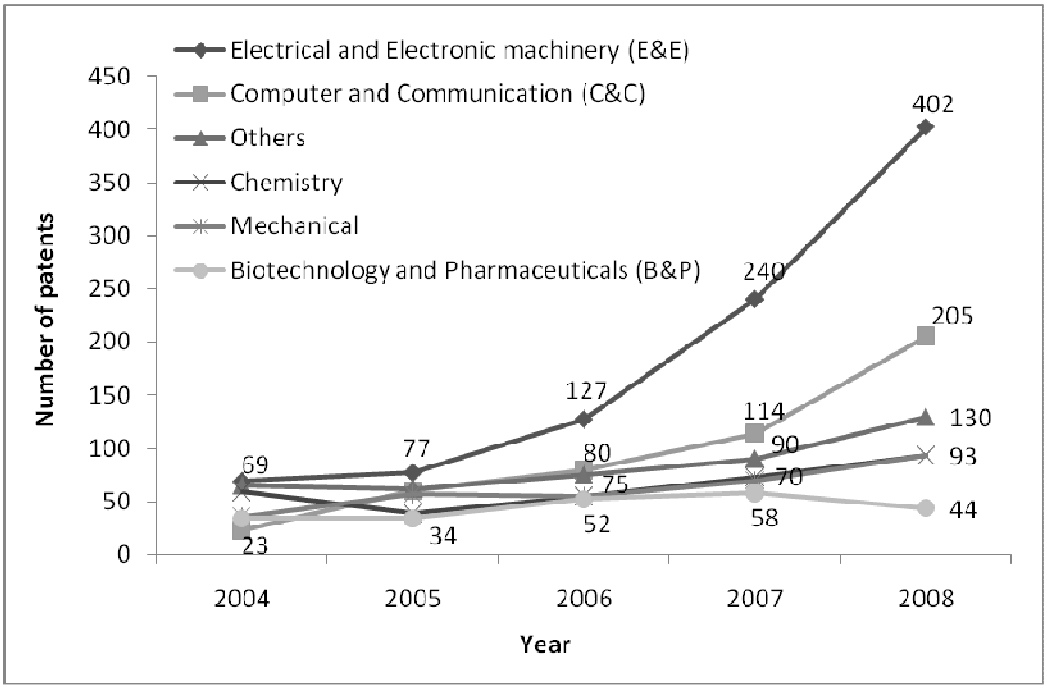

Figure 1: Chinese Patent Trends in Technology Fields between 2004 and 2008

The study also analysed patent assignees in accordance to the country or regions and trend lines indicated the cooperation relations of mainland areas of China with other countries and regions in E&E, C&C and Mechanical fields (Figures 2, 3 and 4). Since the cooperation patents of the other three technology fields are so few that no clear cooperation relationship can be found.

Figures 2, 3 and 4 show that the assignees located in the mainland area of China collaborate mainly with Taiwan in these three (3) technology fields and the cooperation increased every year, especially in the E&E field where there were 223 patents collaborated in 2008, far larger than other two (2) fields. Taiwan and the USA are also the main cooperation partners of China in C&C field (Figure 3). Besides Taiwan, patent assignees in the Mechanical field also frequently cooperate with the Virgin (British) Islands, US and Japan. The cooperation with US and Japan became less in the last two years, whereas the cooperation with Virgin (British) Islands increased.

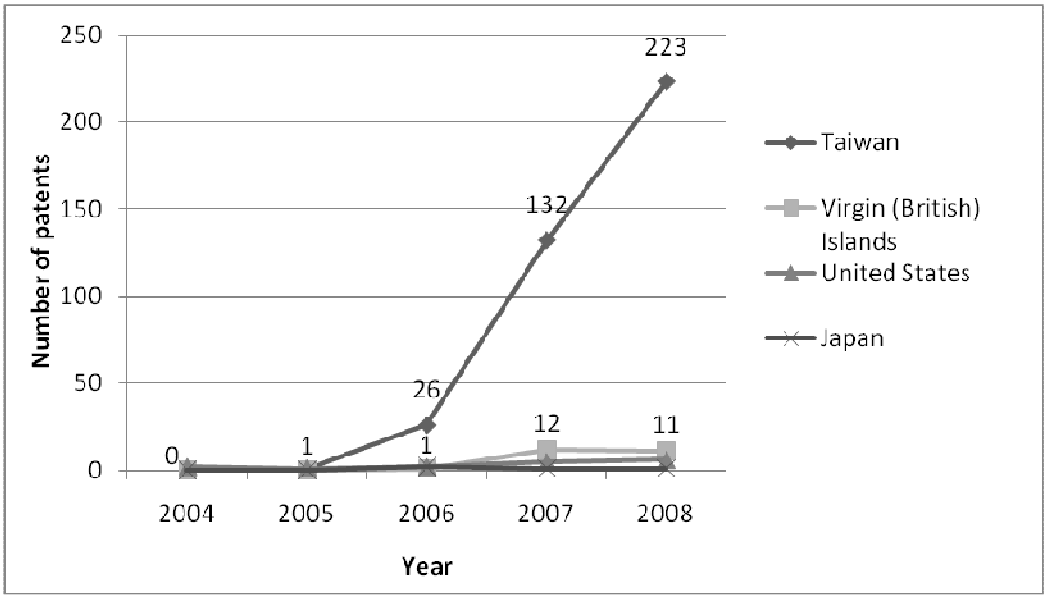

Figure 2: The Multinational Cooperation in E&E Fields

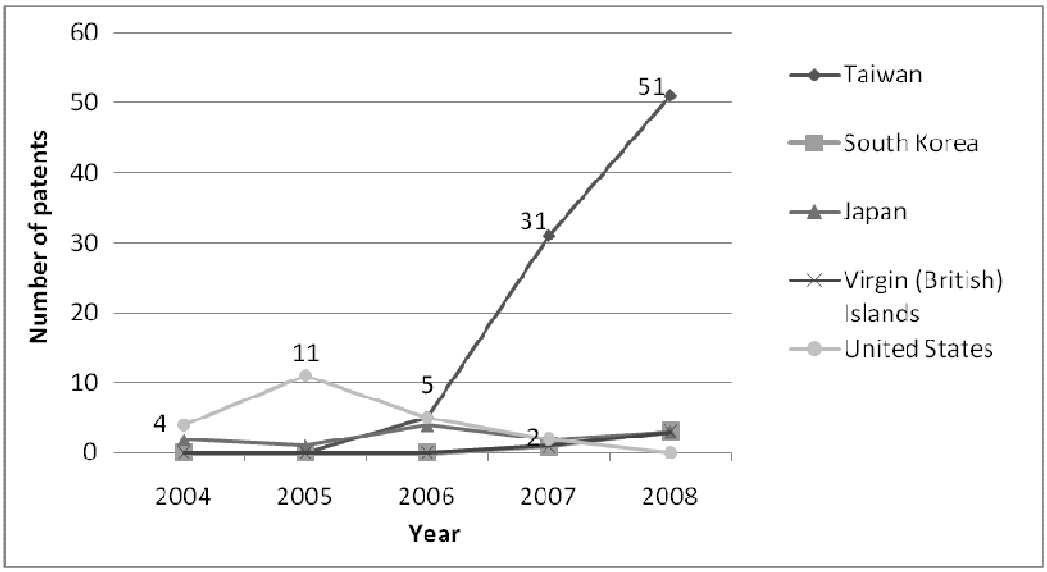

Figure 3: The Multinational Cooperation in C&C Field

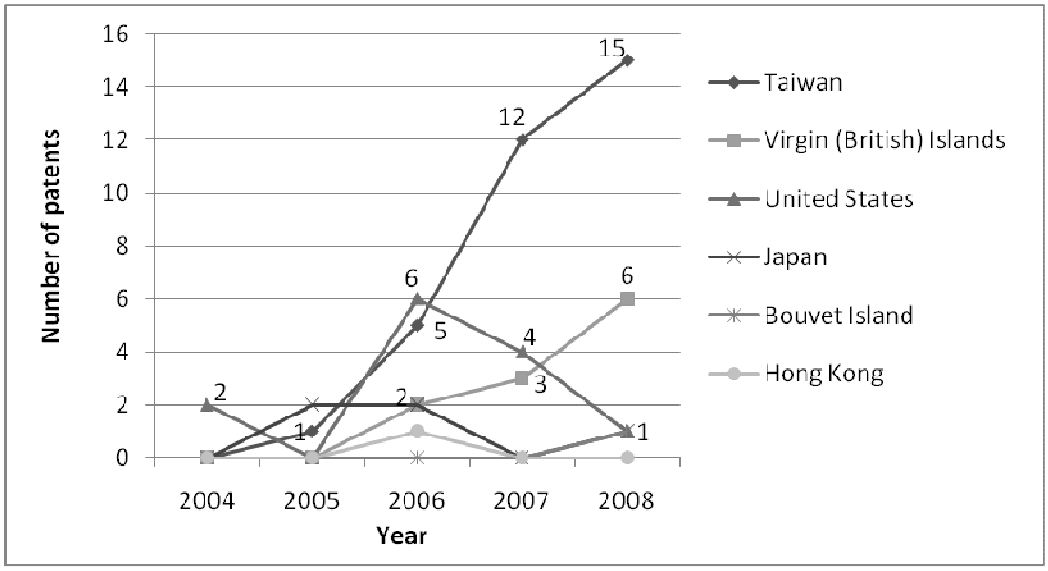

Figure 4: The Multinational Cooperation in Mechanical Field

Patent Assignee Analysis

The patent numbers of the top 5, 15 and 30 assignees in China are shown in Table 3. The results show that the number of patents had increased continually from 2004 to 2008 and the proportions to total have become larger each year. The patent share of the top 5 was only 11% in 2004, and it increased to 30% in 2008, the same proportion as that in the top 30 assignees in 2004. The patent number and proportions of the top 15 and 30 have also been increasing year by year, and reached as high as 43% and 51% in 2008 respectively. This trend indicates that Chinese patent output in the US is concentrated among a few strong enterprises and research institutes.

Table 3: The Patent Number of the Top 5, 15 and 30 Assignees

Year	Patent number (proportion)			
	TOP 5	TOP 15	TOP 30	Total
2004	46 (11%)	90 (20%)	130 (30%)	440 (100%)
2005	94 (19%)	142 (28%)	225 (45%)	501 (100%)
2006	100 (14%)	231 (33%)	261 (37%)	702 (100%)
2007	245 (24%)	405 (40%)	478 (47%)	1012 (100%)
2008	439 (30%)	641 (43%)	754 (51%)	1481 (100%)

In Figure 5, patent assignees are classified into three (3) categories, the top 5, 6-30, and others, in order to calculate their statistics of patents in different technology fields in 2008. The patent number of the top 5 patent assignees group in 2008 were 200 and 94 in E&E field and C&C field respectively and as high as 50 percent and 46 percent in their respective fields. This numbers indicate that the innovation competitiveness of these two technology fields mainly came from the top 5 patent assignees, especially for E&E field. The top 6-30 patent assignees group has the highest patent number in Chemistry field, whereas the

"other" assignees group has the highest patent number in "Others" field. Patents in the B&P field mainly came from the "other" assignees, indicating that the patent output in this field is much dispersed.

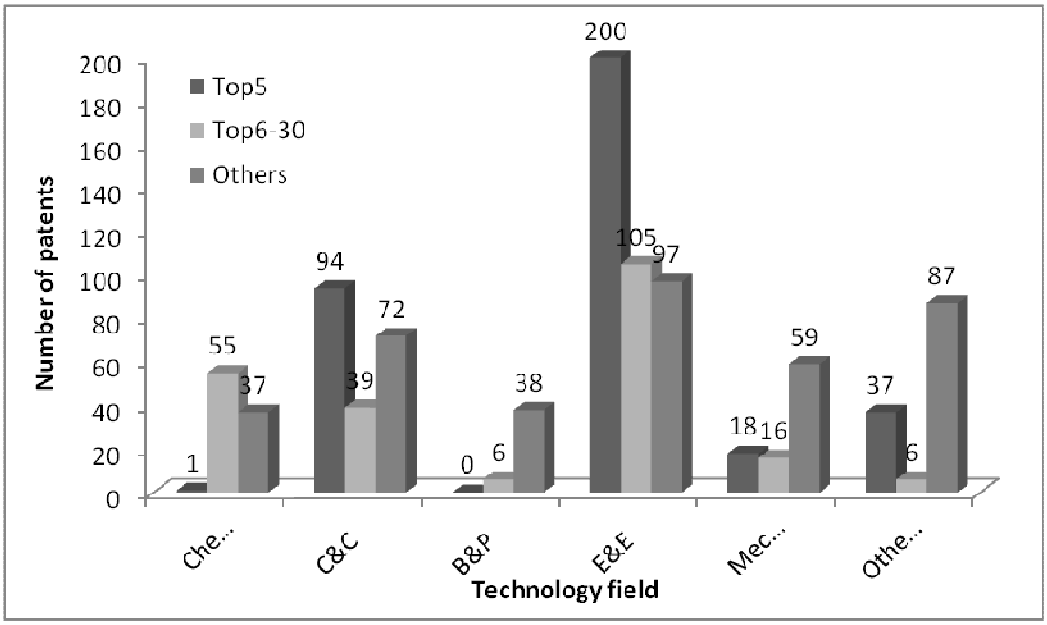

Figure 5: Total Patents of the Top 5, 6-30, and Other Assignees in Six Fields in 2008

Observations by type of assignees, which has 10 or more patents, indicate that the main assignees are enterprises, while one is a university, the TsingHua University. TsingHua University ranked sixth with 39 patents in 2008, and all its patents are utility patents. Hong Fu Jin Precision ranks first with 182 utility patents in 2008, which exceeded the number from other companies. Furthermore, the high number utility patents imply higher R&D abilities.

Table 4: The Main Chinese Patent Assignees in 2008

Patent Assignee	2008			2003-2007	
	Patent Number		Utility Patent Number	Average Number	Rank
	Rank	Count			
Hong Fu Jin Precision	1	182	182	23.8	1
Beifa Group	2	87	0	5.6	10
Fu Zhun Precision	3	77	76	15.6	2
Huawei Technologies	4	50	48	10.8	6
Futaihong Precision	5	43	26	4.4	12
TsingHua University	6	39	39	12.8	3
Sae Magnetics (H.K.)	7	25	25	12.2	5
China Petroleum & Chemical	8	24	24	12.4	4
Semiconductor Manufacturing Int.	9	23	23	7.4	7
Innocom Technology	10	20	20	1.4	19
Dong Guan Bright Yin Huey Lighting	11	15	0	6.2	8
Nuctech Company	12	10	10	2.0	18
Great Wall Motor	12	10	0	0	--

Among the main assignees, the Beifa Group and the Futaihong Precision indicated the highest accelerated increase. Their ranks from 2003 to 2007 are 10th and 12th respectively, which climbed up to number 2 and 5 respectively in 2008. For the Beifa Group, despite their patent number was the second highest, the number of utility patents is identified to be zero, which probably indicates that these patents are patents with low values. Dong Guan Bright Yin Huey Lighting and Great Wall Motor were in a similar situation, indicating zero utility patents in 2008.

Essential Patent Assignees

To further evaluate the competitiveness of patent assignees in the two main technology fields (E&E and C&C), the integrated indicators in measuring quantity and quality are used. These indicators include a company's or an institute's aptitude for executing research projects and developments, their competition capabilities, and the number of utility patents. The retrieved and calculated source data for the total number of utility patents in 2008 and the average number of utility patents for the period of time from 2003 to 2007 are examined by various indicators, such as the ETS, the CII, and the EPI. The essential patent assignees of these two technology fields are chosen from the main assignees shown in Table 4, based on three principles. First, the utility patent number of the chosen assignees in 2008 should be greater than the average utility patent number of the chosen assignees for the period 2003 to 2007 in that technology field. Secondly, the average utility patent number of the chosen assignees for the period 2003 to 2007 should be greater than the average utility patent number of all assignees in that technology field. Thirdly, the count of ETS in the technology field should not be zero. For instance, neither the utility patent number, nor, CII nor EPI could be zero. In other word, the basic principle of selecting essential patent assignees is that the quantity of utility patents must achieve a certain level, so that the patent quality can be credible.

a) The Electrical and Electronic Machinery (E&E) Field

The analysis of patent performance in the E&E field reveals that Fu Zhun Precision has the highest ETS value of 13.07, and it had 63 utility patents published in 2008, which is far larger than the average number of 13, in the period 2003 to 2007; its CII value and EPI value are both higher than the expectation value, 1.0. This means that the company's high ETS value not only depends on patent quantity, but also on quality (Table 5). Coming in second with an ETS value of 9.21 was Hong Fu Jin Precision, which has the largest number of utility patents, 122 in 2008, but its CII value of 0.83 and EPI value of 0.69 are all lower than the expectation value. This means that the company's high ETS value mainly depends on patent quantity, not on quality. TsingHua University comes in third with an ETS value of 3.78, and has a larger number of utility patents, 32 patents in 2008, which is far more than the average number of 4 during the period 2003 to 2007; yet its CII value and EPI value are only slightly higher than the expectation value. Nuctech Company ranked fourth with a higher CII value of 2.31 and a higher EPI value of 2.67. Semiconductor Manufacturing International and Huawei Technologies are also essential patent assignees in this field, but their ETS values are lower than that of the other essential assignees.

In general, there are six (6) main patent assignees chosen in E&E field. Hong Fu Jin Precision, Fu Zhun Precision and TsingHua University have accumulated more utility patents in 2008, which were all far higher than the average number from 2003 to 2007. One thing needs to be pointed out is that Hong Fu Jin Precision has the highest utility patent number both in E&E field and in China (Table 4), but the quality of its patents is not the best in E&E field. Fu Zhun Precision has the highest ETS value, that is, the best quality in E&E field.

Table 5: Essential Patent Assignees in E&E Field

	Rank 2008	ETS 2008	CII 2008	EPI 2008	Utility patent number 2008	Avg. utility patent number 2003-2007
Fu Zhun Precision	1	13.07	2.71	1.59	63	13
Hong Fu Jin Precision	2	9.21	0.83	0.69	122	15
TsingHua University	3	3.78	1.1	1.27	32	4
Nuctech Company	4	2.23	2.31	2.67	9	1
Semiconductor Manufacturing Int.	5	1	0.32	0.86	19	5
Huawei Technologies	6	0.27	0.61	1.33	3	0

b) The Computer & Communication (C&C) Field

The analysis of patent performance in the C&C field reveals that Huawei Technologies scored the highest ETS value of 12.43, much larger than the other patent assignees. Concurrently, it has fulfilled the largest number of utility patents of 43 in 2008, which is much larger than the average number of 9 during the period from 2003 to 2007. Its CII value (0.91) and EPI value (0.83) are lower than that of most the other essential assignees, and are even below the expectation value, 1.0. This means that Huawei Technologies high ETS value mainly depends on patent quantity, rather than the quality (Table 6). Hong Fu Jin Precision came second with an ETS value of 4.93, its CII value (0.79) and EPI value (0.12) are lower than the expectation value, but its utility patent number (48) is the largest in this field. Semiconductor Manufacturing International ranked third with a higher CII value of 1.26 and a higher EPI value of 2, but its utility patent number in 2008 was only 3. In the fourth position, TsingHua University has a higher CII and EPI values but small utility patent number in 2008. This means that the high ETS value of TsingHua University mainly depends on the higher patent impact and better patent quality in this field.

Table 6: Essential Patent Assignees in C&C Field

	Rank 2008	ETS 2008	CII 2008	EPI 2008	Utility patent number 2008	Avg. utility patent number 2003-2007
Huawei Technologies	1	12.43	0.91	0.83	43	9
Hong Fu Jin Precision	2	4.93	0.79	0.12	48	6
Semiconductor Manufacturing Int.	3	1.59	1.26	2	3	1
TsingHua University	4	1	1.49	1.5	2	1

In general, there are four main patent assignees chosen in C&C field. Hong Fu Jin Precision had the largest utility patent number in 2008, followed by Huawei Technologies and these two assignees had a higher average utility patent number in the period 2003 to 2007. Semiconductor Manufacturing International and TsingHua University have small patent numbers, but they obtained better EPI and CII values. Also, it can be noticed that Hong Fu Jin Precision has the highest utility patent number both in C&C field and in China (Table 6), but its performance is ranked second in both C&C and E&E fields. Huawei Technologies has the highest ETS value, which means it has the best quality of patents in the C&C field.

Patent Share of Main Assignees

In order to find the proportion of utility patents between main patent assignees listed in Table 4 and the total utility patents in each technology field, patent shares of main assignees was calculated. Based on the analysis of this study, Hong Fu Jin Precision had the

highest Patent Share rate in E&E field (30.4%) and C&C field (21.9%) in 2008, much higher than the average proportion from 2003 to 2007. Also, the patent share rates of Hong Fu Jin Precision were high in Mechanical field and "Others" field in 2008, indicating that this company is indeed a strong technological company in China. The patent share rates of Fu Zhun Precision are high in E&E field and "Others" field. Huawei Technologies is recognised as being prominent in C&C field. TsingHua University has a high patent share rate in E&E field. Sae Magnetics (H. K.) has a high patent share rate in C&C and Mechanical fields. Futaihong Precision has a high patent share rate in Mechanical field and China Petroleum & Chemical has the highest patent share rate in Chemistry field, which were 23.7% in 2008 and 22.8% for the period from 2003 to2007. Table 7 presents these findings.

Table 7: Patent Shares of Main Assignees in Six Technology Fields

	Chemistry		C&C		B&P		E&E		Mechanical		Others	
	2008	2003-2007 Avg.	2008	2003-2007 Avg.	2008	2003-2007 Avg.	2008	2003-2007 Avg.	2008	2003-2007 Avg.	2008	2003-2007 Avg.
Hong Fu Jin Precision*	0	0	21.9%**	10.9%	0	0	30.4%	13.6%	7.5%	3.1%	9.4%	2.3%
Fu Zhun Precision	0	2%	0	0	0	0	14.6%	0	4.3%	0	11.8%	0
Huawei Technologies	0	0	21.4%	16.3%	0	0	0.8%	0.6%	0	0.4%	1.6%	0
Futaihong Precision	0	0	1.5%	0.3%	0	0	3.1%	2.4%	7.5%	2.6%	3.1%	0
TsingHua University	1.1%	3.6%	1.0%	2.7%	0	3.4%	7.9%	4.1%	5.4%	4.8%	0	2.3%
Sae Magnetics (H.K.)	0	0.8%	7.5%	12.6%	0	0	0.8%	0.9%	7.5%	7.5%	0	0
China Petroleum & Chemical	23.7%	22.8%	0	0.7%	0	0	0	0	1.1%	0	0.8%	0.7%

* Main assignees are selected from Table 4 by excluding the assignees that have the count zero in most of the six technology fields.

**The numbers with underline mean the Patent Share rates are higher than 5% and the numbers in gray area mean that the rates are higher than 10%.

Activity Index of Main Assignees

The activity index of the main assignees shown in Table 3 are calculated and shown in Table 8. China Petroleum & Chemical was very active in Chemistry field, and its average Activity Index value from 2003 to 2007 (17.2%) was much higher than the value in 2008 (9.3%). It shows that the patent output of this company in Chemistry field decreased sharply in 2008. Huawei Technologies is the most active company in C&C field, and its Activity Index value in 2008 is lower than the average Activity Index value from 2003 to 2007. Hong Fu Jin Precision is active in E&E field and C&C field. Fu Zhun Precision is active in E&E field and "Others" field in 2008.

Table 8: Activity Index of Main Assignees in Six Technology Fields

	Chemistry		C&C		B&P		E&E		Mechanical		Others	
	2008	2003-2007 Avg.	2008	2003-2007 Avg.	2008	2003-2007 Avg.	2008	2003-2007 Avg.	2008	2003-2007 Avg.	2008	2003-2007 Avg.
Hong Fu Jin Precision*	0	0	1.1%	1.1%	0	0	1.6%	1.4%	0.4%	0.3%	0.5%	0.2%
Fu Zhun Precision	0	0.5%	0	0	0	0	1.8%	0	0.5%	0	1.5%	0
Huawei Technologies	0	0	4.2%**	6.2%	0	0	0.2%	0.2%	0	0.2%	0.3%	0
China Petroleum &Chemical	9.3%	17.2%	0	0.5%	0	0	0	0	0.4%	0	0.3%	0.5%

*Main assignees are selected from Table 4 by excluding the assignees that have the count zero in most of the six technology fields.

** The numbers in gray area mean the Activity Index values are higher than 3%.

DISCUSSION AND CONCLUSION

Patent data represent a valuable source of information relating to the technology development and innovation ability of a country. This study used Chinese patent data in USPTO database to study innovation competition characteristics in China. The development trend of Chinese patents is explored and main patent assignees are analysed using integrated indicators of patent quantity and quality. The research herein has drawn the following conclusion:

a) Quantity of Chinese Patents: 2004-2008

The number of patents from China in USPTO has increased from 440 in 2004 to 1,481 in 2008. China's ranks in patent numbers have arisen from 19th to 12th place, revealing that China has become a country with strong competitiveness. The increasing trend of patent quantity benefits from China's patent policy and strategy implemented in 2002. Moreover, patent application has been used as one of the main evaluating indicators in a few national science and technology programmes. The number of utility and design patents from China had been increasing every year, but the share of utility patents, which was about 65%, is lower than the global utility patent share which was about 90%. It is generally considered that utility patents contain important technology information and construct a higher value than the design patents. From the share of utility patents, it can be assumed that the value of Chinese patents is lower than the world's. Chinese government tries to address this situation by adopting a policy that promotes the application of utility patents, such as providing application fee allowance, programme support and product preferential of enterprise income tax.

b) Patents in the E&E and C&C Fields in China

According to the classification analyses of the six (6) technology fields, the number of utility patents in E&E and C&C fields had both increased extensively from 2004 to 2008 and were higher than that of other technology fields in 2008, indicating these two (2) technology fields have higher innovation competitiveness in China and are becoming two main innovation technology fields in China. In order to indentify the multinational cooperation partners of China, patent assignees are analysed. The results find that three (3) technology fields (E&E, C&C, and Mechanical fields) have clearly shown multinational cooperation relations, and the most important partners of China in these three (3) fields was Taiwan,

especially in E&E and C&C fields. The cooperation with other countries was less and this aspects need to be encouraged.

c) Top Chinese Patent Assignees

The patent number of the top 5, 15 and 30 assignees had increased continually from 2004 to 2008, and their proportions have become larger each year which indicates Chinese patent output in the US is concentrated on a few large enterprises and research institutes. The patent share of the top 5 was only 11% in 2004, and it increased to 30% in 2008. The majority of patents were in E&E and C&C fields. The patent number of the top 5 patent assignees group in 2008 were 200 in E&E field and 94 in C&C field respectively, as high as 50% and 46% in their respective fields. It indicates that the innovation competitiveness of these two (2) technology fields mainly concentrate on the top 5 patent assignees, especially for E&E field. Chinese government put forward the idea of "developing an independent innovative capacity, to build a country based on innovation" in 2005, and has made a good effect. The enterprise is the most important entity of innovation and has become an important issue for China.

d) The Top Chinese Enterprises in Patent Output

Hong Fu Jin Precision had the largest patent number (182), among all Chinese assignees in 2008, and these are all utility patents. This number was higher than the other assignees showing its leading position among Chinese companies. When integrated indicators were used to evaluate innovational ability of these main companies and institutes, the results show that Hong Fu Jin Precision is one of the strongest as well as the highest utility patent number in E&E and C&C fields, and the patent share rates of this company are the largest in E&E and C&C. TsingHua University is the only university in the top 10 patent assignees, and is one of the essential patent assignees in E&E and C&C fields.

Although this study attempts to set up an integrative indicator system to evaluate the competitiveness of China through analysing patent data, there are still other indicators that need to be considered such as the citing and cited patterns, the legal statuses, and the technology classifications. Also, another possible solution is to use a combination of indicators such as article, economic, and product data, and combine this information with patent data to establish a more reliable evaluation system.

REFERENCES

Abraham, B. and Morita, S. 2001. Innovation assessment through patent analysis, *Technovation*, Vol. 21, no. 4: 245-252.

Albert, M., Yoshida, P. and Opatal, D. 2004. *The New Innovators: Global patenting trends in five sectors, U. S. Department of Commerce*. Office of Technology Policy. Available at http://www.technology.gov/Reports/09111998.pdf.

Amato ,T., Christine,W. and Oldach, S. 2009. *Patent Scorecard Leaders.* Industry, Intellectual Property Today. Available at http://www.iptoday.com/articles/2009-2-oldach.asp.

Bhattacharya, S. 2004. Mapping inventive activity and technological change through patent analysis: A case study of India and China. *Scientometrics*, Vol. 61, no. 3: 361-381.

Bhattacharya,S. and Khan, M. 2001. Monitoring technology trends through patent analysis: A case study of thin film. *Research Evaluation*, Vol. 10, no. 1: 33-45.

Breitzman, A. and Narin, F. 2001. Method and apparatus for choosing a stock portfolio, based on patent indicators. *US Patent 6175824* filed July 14, 2011 and issued January 16, 2011.

Chakrabarti, A. 1991. Competition in high technology: analysis of patents of US, Japan, UK, France, West Germany, and Canada. *IEEE Transactions on Engineering Management*, Vol. 38, no. 1: 78-84.

Chen, D., Chang, H., Huang, M. and Fu, F. 2005. Core technologies and key industries in Taiwan from 1978 to 2002: A perspective from patent analysis. *Scientometrics*, Vol. 64, no. 1: pp. 31-53.

Chen, D., Lin, W. and Huang, M. 2007. Using Essential Patent Index and Essential Technological Strength to evaluate industrial technological innovation competitiveness. *Scientometrics*, Vol. 71, no. 1: 101-116.

Daim, T., Rueda, G., Martin, H. and Gerdsri, P. 2006. Forecasting emerging technologies: Use of bibliometrics and patent analysis. *Technological Forecasting and Social Change*, Vol. 73 no. 8: 981-1012.

Ernst, H. 1997. The patent portfolio for strategic R&D planning. *Innovation in Technology management – the key to global leadership, PICMET '97,* Portland Oregon*,* 27-31 Jul 1997: 491-496.

Hu, A. and Jaffe, A. 2003. Patent citations and international knowledge flow: The cases of Korea and Taiwan. *National Bureau of Economic Research Working Paper Series*, Massachusetts, October 2003: working paper No. 8528.

Huang, Y. 2009. An investigation of the interaction between science and technology from literatures of giant magnetoresistance. *Journal of Library and Information Studies*, Vol. 7, no. 1-2: 53-76.

IMD (Institute for Management Development) 2011. *2011 Results: World Competitiveness Yearbook*. IMD World Competitiveness Yearbook. Available at http://www.imd.org/research/publications/wcy/World-Competitiveness-Yearbook-Results/#/.

Jacobsson, S. and Philipsson, J. 1996. Sweden's technological profile what can R&D and patents tell and what do they fail to tell us?, *Technovation*, Vol. 16, no. 5: 245-253.

Kutlača, Đ.G. 1998. Patent-related activities in Serbia from 1921 to 1995, *Scientometrics.* Vol. 42, no. 2: 171-193.

Lin, H. and Lin, H. 2002. From imitation to innovation: the study of patents from Taiwan. *Taiwan economic research monthly*, Vol. 25, no. 5: 23-35.

Lin, J. and Lee, C. 2010. Industrial structure and innovation: comparison of innovative performance between South Korea and Taiwan using patent data derived from NBER. *International Journal of Technology Management*, Vol. 49, no. 1/2/3: 174 - 195.

Liu, S. and Shyu, J. 1997. Strategic planning for technology development with patent analysis. *International Journal of Technology Management*, Vol. 13, no. 5/6: 661-680.

Lo, S. 2010. A comparative study of linkage indexes: Co-assignee, reciprocal citation, patent coupling and co-patent. *Journal of Library and Information Studies*, Vol. 8, no.1: 11-27.

Malerba, F. and Orsenigo, L. 1999. Technological entry, exit and survival: an empirical analysis of patent data. *Research Policy*, Vol. 28, no. 6: 643-660.

Marinova, D. and McAleer, M. 2003. Nanotechnology strength indicators: international rankings based on US patents. *Nanotechnology*, Vol. 14, no.1: R1-R7.

Maurseth, P. and Verspagen, B. 2002. Knowledge spillovers in Europe: A patent citations analysis. *Scandinavian Journal of Economics*, Vol. 104, no. 4: 531-45.

da Motta e Albuquerque, E. 2000. Domestic patents and developing countries: arguments for their study and data from Brazil (1980-1995). *Research Policy*, Vol. 29, no.9: 1047-1060.

Schmoch, U. and Schnöring, T. 1994. Technological strategies of telecommunications equipment manufacturers: A patent analysis. *Telecommunications Policy*, Vol.18, no.5: 397-413.

Shen, Y., Chang, S., Lin, T. and Yu, H. 2010. A hybrid selection model for emerging technology. *Technological Forecasting and Social Change*, Vol. 77, no.1: 151-166.

Sun, Y., Lu, Y., Wang, T., Ma, H. and He, G. 2008. Pattern of patent-based environmental technology innovation in China. *Technological Forecasting and Social Change*, Vol.75, no. 7: 1032-1042.

Tomita, T. 2003. An heuristic analysis of long-life leading companies in orders of patent applications. In *Modsim 2003: International congress on modelling and simulation,* Queensland, Australia, 14-17 July 2003: 1206-1210.

World Economic Forum 2011. *The Global Competitiveness Report 2011 – 2012.* World Economic Forum - Geneva Switzerland 2011. Available at http://www.weforum.org/reports/global-competitiveness-report-2011-2012.

Wu, H., Chen, H. and Lee, K. 2010. Unveiling the core technology structure for companies through patent information. *Technological Forecasting and Social Change*, Vol.77, no.7: 1167-1178.

Yu, X. and Kehoe, C. 2001. Patent data for technology assessment, Part II: Using U.S. patent data to examine trends in GPS technology. *Science and Technology Libraries*, Vol. 22, no.1-2: 117-135.