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Industry evolution and key technologies in China based on patent analysis

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Abstract Patents are the manifestation of the industry's research and development (R&D) endeavor; therefore, this paper studies the industry evolution of and key technologies in China from the perspective of patent analysis. Patents in six types of industries, including Chemical (excluding Drugs), Computers and Communications, Drugs and Medical, Electrical and Electronics (E&E), Mechanical, and Others are analyzed in this study. Findings from the analysis show a steady increase of US granted utility patents in China as well as percentage of these patents in the world over the period between 2003 and 2008. All the above industries in China have been growing rapidly during this period, which is very different from the global industry development. Despite the rapid development, the citation rates of these patents have been low, reflecting a need for improvement in the quality of patents and R&D performance for these six industries in China in order to exert more influence in the industry world. The analysis on patents also reveals China's industry distribution to be similar to the global industry distribution, with the exception of E&E industry which weights over one third of the total patents in technologies. The E&E industry is also the field with largest economic growth which rises more rapidly after 2006 with a sudden increase of patents in USPC 361. Detailed tracking of the key technology evolution reveals that 90% of the newly issued patents in USPC 361 after 2006 are owned by Foxconn Technology Co., Ltd, pointing to an unbalanced R&D environment in China's E&E industry sector. By providing the insight into the evolution of China's industrial and technological development through the perspective of patent analysis, this paper hopes to provide an objective statistic reference for future policy directions and academic researches.

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Introduction

With the development of science and technology, global economy has become extremely competitive. A country's competitiveness depends on its overall national strength, and one of the keys is its science and technology development. The importance countries place on science and technology development can be seen in China as an example. In order to enhance its global competitiveness and maintain national or regional security in recent years, China has started to place more emphasis on technology research and development (R&D) as well as the emerging industries in recent years. It is also playing a more active role in the world's R&D.

Because of the ever-growing importance of science and technology, intellectual property rights become an important strategic resource for countries and regions. The quantity and quality of original invention patents are very significant for a country's long-term development and economic security. Patents summarize the achievements of science and technology, and they can reflect the latest technological inventions as well as the innovative capability of a nation. Accordingly, patents provide a reliable indicator of measuring technology development (Chen et al. 2006). Although patent indicators come with various limitations, they remain a unique resource for the analysis of technology progress. Consequently, more and more countries are paying special attention to patent analysis and applying the corresponding results for policy references. Numerous world-renowned institutes are devoting efforts to patent analysis, hoping to evaluate technology development and identify industry trends for the future. Following Schmookler's studies on the relation between technical inventions and economic growth in 1960s (Schmookler 1966), several researchers have focused on the assessment of technological performance by implementing patent indicators. Pavitt and Patel (1988) analyze the country's relative competence through patent data and have constructed "Reveal Technology Advantage (RTA) index". Ramani and De Looze (Ramani and Looze 2002) compare the "knowledge base" in three European countries from patent applications. Guan et al. (Guan and Ying 2007) explore the Chinese science-technology linkages by means of quantitative analysis on patents in China granted by the United States Patent and Trademark Office (USPTO).

In analysis of industrial and technological development, patent classification, which organizes complex technical information into logical and understandable statistics, is one of the important evaluation sources. Mendonca works on discovering how the organizations specializing in traditional businesses have developed cutting-edge knowledge by analyzing statistics of patent classes (Mendonca 2009). Meyer examines converging technology phenomena in nanotechnology field through co-occurrence analysis of patent classes (Meyer 2007). Since a patent's class number serves to group similar technologies together and objectively reflects the patent's technical subject(s), "technological change" can be traced by the changes in the patent quantity of different classes. Additionally, patent classes can be further aggregated at the industrial sector level, according to their applications. Consequently, "industrial transformation" can be identified in terms of patent counts within each industry. In a word, patent classification analysis not only represents the transformation of a country's technologies, but also evaluates and identifies the trend of a specific or rising industry. Lacasa et al. (2003) provide a precise analysis of chemical technology transformation in Germany, based on the calculation of patents in chemistry

field as well as its subfields. Chen et al. (2005) study the transformation of core technologies and key industries in Taiwan, through the quantitative analysis of patents in different technology areas and industry sectors.

The United States Patent and Trademark Office (USPTO) is the federal agency for granting patents and registering trademarks. Founded in 1802, the USPTO has granted more than 4,000,000 patents since 1976. Over the years, the USPTO has developed a highly elaborate classification system primarily based on 'proximate function' principle, in which similar processes or structures that achieve similar results are considered to have the same fundamental utility and are grouped together. Other rationales, 'industry or use', 'effect or product' and 'structure' have also been utilized in the US patent classification system ("Examiner's handbook chapter one: Organization of" 2010). Patents granted by the USPTO provide a relatively accurate picture of the world's technology distribution: Approximately half of the inventions of US patents are foreign-owned, and numbers of US-granted invention patents in each country are roughly proportional to their country's gross domestic product (GDP) (Narin 1991). Taking the quality factors into considerations, the USPTO-granted patents have higher technological value than foreign patents and, to some extent, can indicate the high quality of the invention (Hinze and Schmoch 2004; Soete and Wyatt 1983).

Thus, in order to examine China's industrial and technological development in recent years, this study has retrieved and compiled patents in China that have been granted by the US from 2003 to 2008. The research first reviews the history of the selected patents, and then studies the overall developments of industries and technologies. Finally, the research moves into discussion of the transformations of industries and technologies year by year. Overall, this paper provides an objective statistical reference for future policy directions and academic researches through the study of technological and industrial development.

Methodology

The data

The patent data for this study has been retrieved from the USPTO database and downloaded online (http://www.uspto.gov) on April 19th, 2009, which includes all the US issued patents from 2003 to 2008.

Patents of a country can be identified by two ways in the USPTO database: assignee country patents and inventor country patents (Bhattacharya 2004). Usually, people use inventor country patents (i.e. patents attributed to a country based on address of any of the inventor belonging to it), because it can reveal the inventive/innovative activity in a country. While, analysis based on assignee country patents (nationally assigned patents) is able to the delineate patents that in a legal sense belongs to a country. It can reveal a country's technological development emphasis, and reflect technological competitiveness and industrial development potential that a country possessed. Thus, the present study uses 'assignee country' patents to explore China's technology and industry transformation.

Among various types of patents (e.g. utility patents, design patents, and plant patents), utility patents can best reflect a country's R&D and innovation capability. Therefore, for the purpose of this study, only utility patents are selected to explore the evolution of technologies and industries.

Patent classification and statistical method

Over the years, the USPTO has developed a highly elaborate classification system for the patented inventions. This system, United States Patent Classification (USPC), primarily based on the 'proximate function' classification rationale, consists of about 400 (3-digit) patent classes with over 120,000 patent sub-classes. The analysis on technology herein is carried out first by resorting to USPC main class, and each target patent is categorized into one specific technology field to avoid overlapping. Accordingly, the study compiles and ranks the technologies by the order of utility patent counts to understand the distribution and evolution of technologies. As for enterprises in certain technology eras, the present study ranks them by the order of the number of utility patents, for disclosing the distribution of technologies in these enterprises.

The US patent classification system clusters patents according to 'proximate function' principle, as well as 'industry or use', 'effect or product' and 'structure' principles. Though it takes the use and manufacturing factors into consideration, patents are not classified according to their application in industries in the US patent system ("Examiner's handbook chapter one: Organization of" 2010). Thus, US patent classification may not be very suitable for industry sector research. However, considering US is major market of China, the US granted patents are quite representative of the world's technology. Moreover, each country's invention patents in the US are roughly proportional to their country's GDP. Thus, we have selected US patents to study China's industry development in the present study.

However, even 400 classes are far too numerous for most industries. Hence, a higher level reclassification (classes aggregated at the industrial sector level) is needed for the analysis of industries. The present research utilizes the patent classification method developed by the National Bureau of Economic Research (NBER), in which the 400 USPC classes are aggregated into 36 two-digit technological sub-categories, and those in turn are further aggregated into six industry sectors, including Chemical (excluding Drugs), Computers and Communications (C&C), Drugs and Medical (D&M), Electrical and Electronics (E&E), Mechanical, and Others (Hall et al. 2001). According to NBER's classification, Chemical (excluding drugs), Mechanical and Others industries are regarded as traditional industries, while C&C, D&M, and E&E are considered to be emerging industries (Hall et al. 2001). In order to track and understand the development and transformation of industries, the present study converts USPC main class numbers into six industries based on NBER classification method, and calculates the actual utility patents in six industry sectors as well as 36 technological sub-categories. Then, the study ranks the major technology categories by the number of utility patents, in 6 years or year by year. Due to the fact that there is always an element of arbitrariness in devising an aggregation system and in assigning the patent classes into various industry sectors, this study examines the industry evolution to some extent by employing NBER's patent classification.

Patent indicators

Activity index (*AI*): AI is the ratio of the percentage of a country's patents in a particular industry to the percentage of all US patents in the industry. An indicator which provides a way to gauge a country's relative technological emphasis, AI is defined as the percentage of a country's US patents in an industry, divided by the percentage of all US patents in that industry. The industry with an AI of more than 1.0 is regarded as a country's key industry and development focus. The formula is as follows.

$$\mathrm{AI_{ij}} = \frac{Nij \Big/ \sum_{j=1} Nij}{\sum_{i=1} Nij \Big/ \sum_{i=1,j=1} Nij}$$

i: country; j: industry.

N_{ij}: the number of patents in industry j of country i.

Citations per patent (*CPP*): CPP is the number of citations per patent within a certain period. It is defined as the sum of citations happening within a certain period, divided by the number of all the patents from 1976 to this period. CPP value is mainly used to measure the impact of each patent, and it displays the influence of patents on the scientific and technical progress in that year. It can reflect patent quality and R&D level to some extent. When number of patents increases very rapidly, CPP tends to be lower than the true long-term citation rates, as most of the patents being very recent and therefore have not had much time to accumulate citations over any given citation window.

$$\mathrm{CPP} = \frac{NC}{N}$$

NC: the sum of citations within a certain period, N: the total number of patents from 1976 to this period, CPP: the number of citations per patent within a certain period.

Results and discussion

China-held US-granted utility patents

The total number of US granted utility patents in China over the past 6 years is 2,759. Table 1 shows the number of these patents by year, revealing the increasing growth rate of China-held US patents. The increase in the number of patents are relatively small for the period 2003–2004, where the number has grown from 183 to 218, with a growth rate of about 19%. After the year of 2005, the number of patents rises more rapidly, with an annual growth rate of more than 30%.

Table 1 The number of US granted utility patents by year

Year	US (annual growth rate)	Foreign (annual growth rate)		Total (annual growth rate)
		China	Others	
2003	87,893	183	80,947	169,023
2004	84,270 (−4.1%)	218 (19.1%)	79,802 (−1.4%)	164,290 (−2.8%)
2005	74,637 (−11.4%)	329 (50.9%)	68,840 (−13.7%)	143,806 (−12.5%)
2006	89,823 (20.3%)	442 (34.3%)	83,507 (21.3%)	173,772 (20.8%)
2007	79,526 (−11.5%)	639 (44.6%)	77,117 (−7.7%)	157,282 (−9.5%)
2008	77,501 (2.6%)	948 (48.4%)	79,323 (2.9%)	157,772 (0.3%)
Total	493,650	2,759	469,536	965,945

Data compiled by authors for this study

Starting in 2006, the USPTO takes new measures to improve the efficiency and effectiveness of the patent application and examination process, including hiring sufficient numbers of new patent examiners, delivering effective training, sharing work with other patent offices, out-sourcing, leveraging advances in information technology, streamlining procedures, and working with the applicant community to provide products that meet their needs while efficiently utilizing the office's resources ("Fiscal Year 2006: A record-breaking year for the USPTO" 2010; "Patent performance for the year 2006" 2010). These changes have been useful in accelerating the patent examination process: 332,000 patent applications have been completed in 2006 ("Fiscal Year 2006: A record-breaking year for the USPTO" 2010), and the number of patents issued by USPTO exhibits an obvious increase in the same year.

The above measures notwithstanding, the growth in number of patents by China after 2005 is still very impressive, with growth rate as high as 34.3% in 2006 that is distinctly higher than the patents counts by US and other foreign countries. Same phenomenon occurs in 2007 and 2008. This might be resulted from China's heavy emphasis on R&D expenditure and desire to protect intellectual property rights overseas to create more value for industries. According to OECD statistics, since 2005, R&D investment in China has increased by more than 20%, and China has become the world's second largest country in R&D investment.

On the other hand, there is no significant increase in the number of total US granted utility patents, whether in the US or other foreign countries ("Patents by country, state, and year—utility patents" 2008). The total number of patents maintains at around 160,000. Neither the number of patents in the US nor in foreign-other countries (excluding China) exhibits any significant increase. In the 3 years of 2004, 2005, and 2007, the patents in the US and in foreign-other countries even show negative growth, with the annual growth rate of less than zero, as shown in Table 1.

Figure 1 illustrates the numbers graphically. As China's R&D has grown along the way, the number of US granted utility patents in China continues to climb up for the period 2003–2008, growing from less than 200 to more than 900. Furthermore, the growth rate of China-held US patents gradually becomes faster. While the number of patents in the US and in foreign-other countries (excluding China) shows no obvious change, both of them maintain at around 80,000. With the constantly increasing number of patents in China, it can be foreseen China will become more important in the global technology R&D and innovation activities.

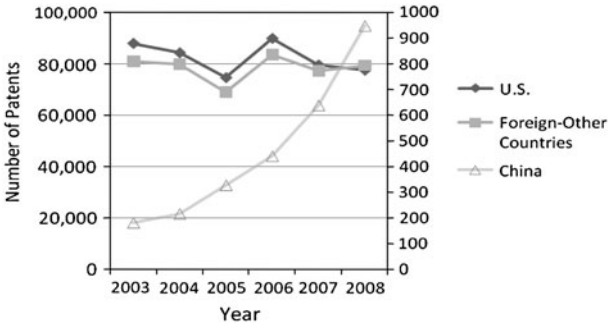

Fig. 1 The US granted utility patents in China, US and foreign-other countries by Year

Overview of industry type and key technologies

In the period from 2003 to 2008, the distribution of six industry types in the world is depicted in Fig. 2 ("Patents counts by class by year" 2010), where emerging industries, C&C industry and E&E industry, ranked the first and second, with the ratio of 28% and 23%, respectively. The shares of three traditional industries [Chemical (excluding Drugs), Mechanical, and others] had been all between 10 and 20%. The proportion of D&M industry was the smallest, less than 10%. Overall, the industry type distribution was rather diversified. Emerging industries, which accounted for 60% of the total, had taken a slightly larger share than traditional industries. This illustrates that from a global perspective, more technology R&D and innovation activities were concentrated on emerging industries.

The China's industry type distribution was similar to the global distribution in that the emerging industries had accounted for 60% in both two cases, as shown in Fig. 3. However, the internal ratio is not exactly the same. E&E industry weights over one third of the total, taking the leading position. This reflects the more important role E&E industry plays in China's R&D and innovation. Since 2000, Chinese government has introduced relevant policies to promote E&E industry development and made timely adjustment in export tax rebate rate in some key electronic products. As a result, the R&D in China's E&E industry has shown rapid growth, and the industry scale in the national economy remains the leader. The share of electronic products in China's total foreign trade reaches 37% in 2008. The statistics clearly indicates that E&E industry has become the first pillar industry to promote China's economic and social development. The shares of Chemical (excluding Drugs), Mechanical, and others range between 10 and 20% with no obvious differences among the proportions of the three, similar to the world situation.

The more important role the E&E industry plays in China's R&D and innovation can also be reflected by the patent AI analysis. AI is defined as the percentage of China's US patents in an industry, divided by the percentage of all US patents in that industry. Thus, it is an effective method to gauge a country's relative innovation emphasis, more intuitive than the weight analysis above. AI value in China's E&E industry during the past 6 years is 1.5, as shown in Table 2, higher than the other five types of industries. This also illustrates that China has paid more attention to the innovation activities of E&E industry, and E&E

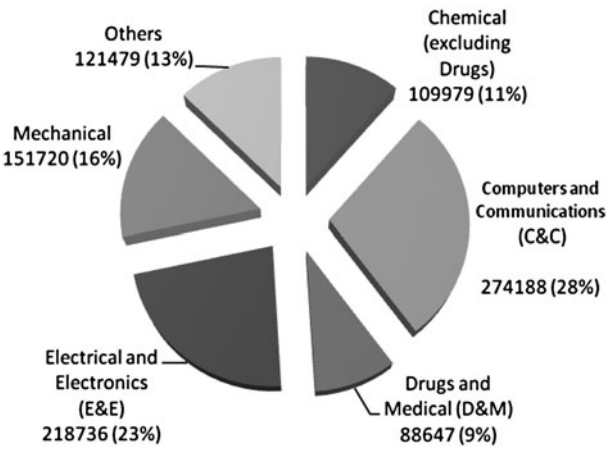

Fig. 2 The shares of six industry types in the world

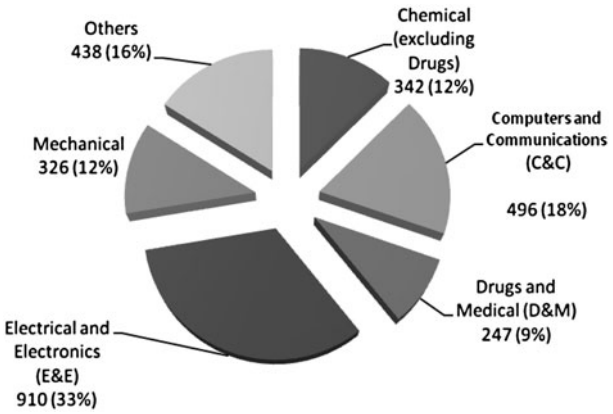

Fig. 3 The shares of six industry types in China

industry has been R&D focus in China during the recent years. Regarding to the citations per patent, the CPP values in China's six types of industries were between 0.6 and 0.8, less than 1.0. There is much room for the growth in CPP in all the six types of industries. The innovation capabilities and R&D levels in China's industries need further improvement to expand their influences across the world.

As mentioned above, E&E industry has been the innovation focus in China during the recent years. In search of R&D emphasis in E&E industry, the study ranks the key technologies in E&E industry according to the number of utility patents in each USPC main class of E&E field. The technologies that have more issued patents are believed to be the R&D focus and can represent China's superior technologies in E&E sector. As described in Table 3, the top 5 key technologies in E&E industry are Electricity: electrical systems and devices, Electrical connectors, Semiconductor device manufacturing process, Illumination, and Active solid-state devices, such as transistors and solid-state diodes.

Among the top 5 key technologies, the one with the highest number of utility patents is Electricity: electrical systems and devices (class no. 361), which accounts for 26.9% of the patents in E&E industry, 8.88% of the total patents in six industries of China, a percentage that far exceeds the other technologies. A closer look into the patent assignees in Table 4 reveals that approximately 87.8% patents belonged to Foxconn Technology Co., Ltd. As one of the world's top 500 corporations, Foxconn Technology Co., Ltd is the world's largest electronics factory, specializing in computer, communications, consumer electronics, digital content, auto parts, access roads and other industries. This reflects only a

Table 2 The patent activity index (AI) and citations per patent (CPP) in six industry sectors in China

Industry	AI	CPP
Chemical (excluding Drugs)	1.1	0.62
Computers and Communications (C&C)	0.6	0.74
Drugs and Medical (D&M)	1.0	0.62
Electrical and Electronics (E&E)	1.5	0.71
Mechanical	0.7	0.78
Others	1.3	0.62

Data compiled by authors for this study

Table 3 Top 5 Key Technologies in E&E in China

Rank	Class no.	Patent number (%)	Definition
1	361	245 (26.9)	Electricity: electrical systems and devices
2	439	72 (7.91)	Electrical connectors
3	438	66 (7.25)	Semiconductor device manufacturing: process
4	362	64 (7.03)	Illumination
5	257	51 (5.60)	Active solid-state devices (e.g., transistors, solid-state diodes)
Total in E&E		910 (100)	

Data compiled by authors for this study

very small number of companies have mastered advanced technologies in E&E industry, and the overall R&D level in China is not so balanced.

Although Foxconn Technology Co., Ltd. Has set up factories in China as early as 1988, the first two utility patents in Electricity: electrical systems and devices (class no. 361) have been issued in 2005. And after that, the number of issued patents has grown rapidly, increasing from 4 in 2006, 83 in 2007, to 126 in 2008. This suggests that only until recent years has Foxconn Technology Co., Ltd begun to pay more attention to technology innovation and recognized the importance of intellectual properties for the economic interests. This is also consistent with the situation that China has made more efforts to promote R&D activities and innovations in E&E industry ever since 2005.

Industry evolution and key technologies

The data in Table 5 shows that C&C industry is the only one that continues to climb up in the number of patents in the world, increasing from 37,617 in 2003 to 52,832 in 2008, with the growth rate of 40%. With the exception of C&C industry, the other five types of industries all exhibited slight declining trends, as shown in Fig. 4 ("Patent Performance for the Year 2006" 2010). It illustrates that from the global perspective, the emphasis for R&D and innovation in these five types of industries have gradually declined in the past 6 years. Technology R&D and innovation activities have become so focused on C&C industry that C&C industry is bound to maintain its leading position in the global R&D structure and plays a more active role in the economic growth all over the world in the future.

Statistics show, the situation in China is distinctly different from that in the world. The number of patents has kept rising along the period, as depicted in Table 6. The largest growth of the patents in China appears in E&E industry, with the number of patents increasing from 48 in 2003 to 391 in 2008. And the growth rate grows faster after 2006.

Table 4 Patent assignees in USPC class no. 361

Rank	Assignees	No. of patents (%)
1	Foxconn Technology. Co., Ltd.	215 (87.8)
2	Shenzhen Futaihong Precision Ind. Co., Ltd.	6 (2.45)
3	Huang, Huadao	5 (2.04)
4	Inventec Electronics	3 (1.22)
5	Wenzhou Sansheng Electrical Co., Ltd.	2 (0.82)

Data compiled by authors for this study

Table 5 The number of patens in six types of industries in the world by year

Industry	2003	2004	2005	2006	2007	2008	Total
Chemical (excluding Drugs)	22119	20224	16132	17932	16787	16785	109979
Computers and Communications (C&C)	37617	41300	38968	54399	49072	52832	274188
Drugs and Medical (D&M)	18813	14852	12506	15376	14261	12839	88647
Electrical and Electronics (E&E)	36758	37732	33315	38765	35978	36188	218736
Mechanical	28492	26796	23264	26985	23661	22522	151720
Others	25199	23160	19262	19962	17388	16508	121479

Data compiled by authors for this study

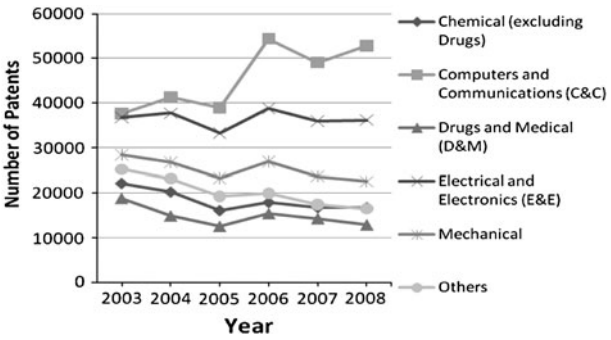

Fig. 4 The changes of six types of industries in the world by year

Table 6 The number of patents in six types of industries in China by year

Industry	2003	2004	2005	2006	2007	2008	Total
Chemical (excluding Drugs)	32	53	39	55	70	93	342
Computers and Communications (C&C)	19	22	58	81	114	202	496
Drugs and Medical (D&M)	30	30	34	52	58	43	247
Electrical and Electronics (E&E)	48	47	76	114	234	391	910
Mechanical	20	26	58	56	73	93	326
Others	34	40	64	84	90	126	438

Data compiled by authors for this study

Although the USPTO has improved patent examination efficiency since 2006 and the total patent approval number rises drastically as the result ("Patents counts by class by year" 2010; Ramani and Looze 2002), the rapid growth rate after 2006 for E&E industry is still very impressive, consistent with the rapid growth in China's electronic products export which increased from 65.02 billion US dollars in 2001 to 459.5 billion US dollars in 2007, with an average annual growth rate as high as 38.5%. And from 2001 to 2007, the value-added in E&E industry reaches an annual growth rate of 24.9%, showing good momentum of development.

As mentioned above, technological advancement in every industry sector in China has been in continuous progress, which is different from innovative activities all over the world, as shown in Fig. 5. Although global C&C industry is also increasing, the growth of

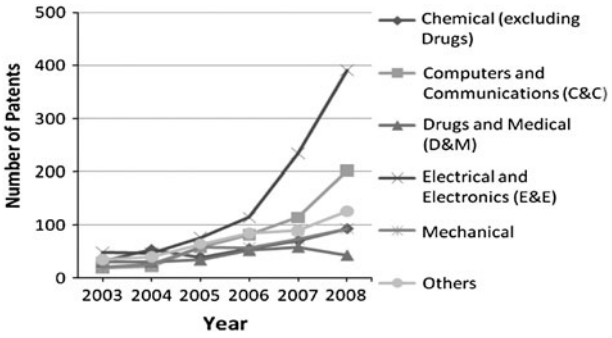

Fig. 5 The changes of six types of industries in China by year

it in China for over 900% is 22 times of that in the world for 40%. Furthermore, with the slight decrease of the other five types of industries in the world, China will play an increasingly important role in the global R&D and innovation.

An important note to take here is that as the number of patents in China's six types of industries grows, the number of citations has not increased as quickly as the patent quantity—the CPP in all the six industries maintains at a relatively low level, roughly from 0.2 to 0.8, and even declines in the past 6 years, as shown in Table 7. This reflects the impact of the R&D achievements of the six types of industries in China on the global industries has not been significant enough. The patent quality of China's industries has not been improved, in spite of the rapid increase in the number of patents; the innovation capabilities and R&D level are still at low level and need further improvement.

Meanwhile, although the number of patents in China's E&E industry has grown most rapidly during the past 6 years, its performance in CPP values has not been outstanding, comparing to the other five types of industries. The CPP values of China's E&E industry from 2003 to 2008 keep at between 0.4 and 0.5, as low as the other five types of industries. The patent quality and innovation capabilities of China's E&E industry are also behind the world average, in need of further improvement. While, another point should be mentioned is that when number of patents increases very rapidly, the CPP value tends to be lower, and most of the patents are very recent and therefore have not had much time to accumulate citations over any given citation window; therefore, as the patents in China's E&E industry increases so rapidly, the CPP values counts for E&E industry may be somewhat lower than the true long-term citation rates will be.

Additionally, as mentioned above, the growth rate of the number of patents in China's E&E industry has been relatively small before 2006, yet it has become much faster hereafter. A further study in key technology evolution in Fig. 6 demonstrates that the

Table 7 The citations per patent (CPP) in six types of industries in China by year

Industry	2003	2004	2005	2006	2007	2008
Chemical (excluding Drugs)	0.42	0.36	0.38	0.40	0.41	0.31
Computers and Communications (C&C)	0.80	0.69	0.41	0.61	0.41	0.42
Drugs and Medical (D&M)	0.68	0.37	0.36	0.39	0.36	0.26
Electrical and Electronics (E&E)	0.57	0.55	0.50	0.49	0.48	0.43
Mechanical	0.42	0.32	0.27	0.29	0.33	0.31
Others	0.46	0.40	0.38	0.46	0.38	0.40

Data compiled by authors for this study

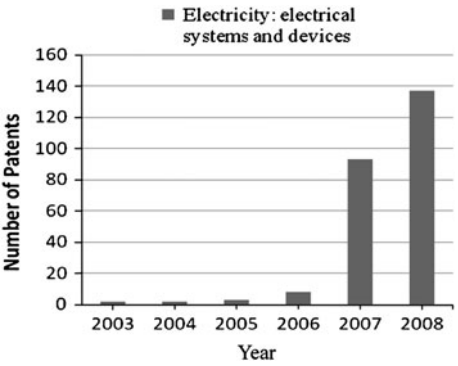

Fig. 6 The number of patents in USPC 361 in China by year

Table 8 The number of patents in USPC 361 in different assignees in 2007 and 2008

Assignees	Number of patents	
	2007	2008
Foxconn Technology Co., Ltd.	83	126
Huang, Huadao	3	2
Shenzhen Futaihong Precision Ind. Co., Ltd.	3	1
Wenzhou Sansheng Electrical Co., Ltd.	1	1
Shanghai Sansi Technology Co. Ltd.	1	0
Sun; Liang	1	0
Suzhou Songbao Electric Co., Ltd.	1	0
Huawei Technologies Co., Ltd.	0	1
Innocom Technology (Shenzhen) Co., Ltd., Innolux Display Corp.	0	1
New Focus Lighting and Power Technology (Shanghai) Co., Ltd.	0	1
Sung; Chien-Min	0	1
Wenzhou Yongtai Electric Co., Ltd.	0	1
Xi_an Kong Hong New Materials Sci-tech Co., Ltd.	0	1
CE Lighting Ltd., Landlite Light Fixtures Mfg. Co., Ltd.	0	1

Data compiled by authors for this study

growth rate in E&E industry has risen rapidly due to a sudden increase of patents in Electricity: electrical systems and devices (class no. 361) between 2007 and 2008.

However, a closer look into the assignees in Table 8 reveals that 90% of the issued patents in Electricity: electrical systems and devices (class no. 361) from 2007 to 2008 have been owned by one single corporation—Foxconn Technology Co., Ltd. So, the large growth in E&E industry does not reflect the advancement of overall R&D capacity of China's E&E industry. Actually, Foxconn Technology Co., Ltd has so enormous impact on the R&D and innovations of E&E industry in China that it's not safe for the long-term development of China.

Conclusion

The technology information in patent documents makes patents an effective tool to study a country's key technology and industry-type development. Through analysis of patent

classification from US granted utility patents in China from 2003 to 2008, the research herein has drawn the following conclusions:

China is playing an increasingly important role in the global R&D and innovation; The patent quality and R&D level of China's six types of industries stand at a low level across the world, and still need further improvement

As China's R&D have grown along the way, the US granted utility patents continue to increase in number during these years. After the year 2005, the number of patents has climbed up more rapidly. It reflects China's emphasis on the value of patents and desire to protect intellectual property rights to create more values for industries in recent years. Meanwhile, there has not been an obvious increase in the total number of US granted utility patents. Yet, the total share of utility patents in China continues to increase, signifying that China has become more important in the global technology R&D and innovation activities.

Except for C&C industry, the other five types of industries in the world all exhibit declining trends over the past 6 years. Technology R&D and innovation have become more focused on C&C industry, suggesting that C&C industry is bound to maintain its leading position in the global industry structure in the future. As presented in the above discussion, China's situation is rather different that all the six types of industries are in continuous progress. Accordingly, China shall play an increasingly important role in the global R&D and innovation.

Although the number of patents in China's six types of industries has increased rapidly, the CPP have maintain at a rather low level and keeps declining in the past 6 years. Thus, the patent quality and R&D level of China's six types of industries still need further improvement to enlarge their influences all over the world.

E&E Industry accounts for a larger share in China than in the world; China's E&E Industry might need to be improved further

From 2003 to 2008, the global industry type distribution had been diversified, and emerging industries had been slightly more flourishing than traditional industries. China's industry type distribution at this time is quite similar to the global distribution, except for E&E industry holding a larger share with relatively high patent activity index. The R&D focus in E&E industry is Electricity: electrical systems and devices (class no. 361), which accounts for 8.88% of total utility patents and far exceeded the other technologies. However, nearly 88% patents in USPC 361 belonged to Foxconn Technology Co., Ltd., implying that few companies mastered advanced technologies in E&E industry. The overall R&D level in China was not balanced and might need to be improved.

Among the six types of industries, E&E has shown the largest growth. After 2006, the number of patents has been growing more quickly. The faster growth is largely due to a sudden increase of patents in Electricity: electrical systems and devices (class no. 361), in the years of 2007 and 2008. However, since 90% of the issued patents in USPC 361 between 2007 and 2008 have been owned by Foxconn Technology Co., Ltd., Foxconn has enormous impact on the R&D and innovations of E&E industry in China, which is not helpful for long-term development of China. Furthermore, the CPP of China's E&E industry maintain at a low level, in spite of the rapid increase in the number of patents. Thus, the innovation capabilities in E&E industry all over the country should achieve more improvement.

In conclusion, the development of key technologies and industry types has been explored through the analysis of patent class, in hope of providing an objective statistic

reference for future policy directions and academic researches. Since the study herein limits the time period from 2003 to 2008, a longer period will provide more information and more evident trends. Also, NBER's patent classification method may be adjusted to be more suitable for the research of China. Additionally, analysis of patent data together with other outputs, such as percentage contribution made by certain industry toward China's GDP would be an effective compliment for evaluating the development of industry types and key technologies in China. Those above-mentioned points will be added in future studies.

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