Co-inventor Analysis on China’s international technology collaboration in US patent activities: 1976-2010

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Abstract

Since 1978, China’s economy and science & technology boom and it has shown great power and immense potential to the world. This prosperity is inseparable from China’s international collaboration. This paper is focused on China’s international technology collaboration activities based on the USPTO patent data from 1976 to 2010. By using of patent statistics analysis and association analysis method, we analyze the US patent data on co-inventor level. The analysis showed that the number of joint patent got a leap and increasing at a high speed at the beginning of 1997. The cooperation scope is gradually expanded and the innovation capacity improved significantly. Most of the co-inventors are from the United States, Taiwan province, Hong Kong and Japan. In the areas of cooperation research field, the joint patents mainly distribute in G06, H01 and H05.

1. Introduction

Since the implementation of “reform and opening-up” policy in 1978, China has achieved great improvement on economics and technology and gives expectations on becoming the world’s innovation center. To enhance the national innovation capacity, we must make full use of the favorable conditions of opening up. International technology collaboration plays a crucial role in the development of technology and economics in our country. Research on the current status of China’s technology collaboration can not only help us explore the development of China’s technology innovation capacity since “reform and opening-up” and understand China’s strategic role in technology innovation, but also provide guidance for our future international technology cooperation study.

Patent information is a standardized data which directly related to science and technology development and new technology; it often acts as the most important index to the evaluation of technological innovation activities. This paper chooses the patent data applied by Chinese inventor in the United States Patent and Trademark Office (USPTO) to study the international technology cooperation of P.R. China (In this paper, without special instructions, China refers to the mainland of China.). The article starts with...
co-inventor viewing angles: in view of the overall situation and technical field respectively. The article will unfold as follows. In section 2 we review previous analysis work on technology collaboration. Section 3 is mainly about describing the framework of the article and giving a briefly explanation of the preprocess process and the specific content of the patent analysis. After that, in section 4, the author lists the main methods of the paper. And the fifth section describes the specific analysis process and the corresponding results. At last, section 6 tells the conclusions of the whole paper.

2. Literature Review

Over the past decades, technological innovations have become more and more important for a country’s economic growth and competitiveness in the period of global knowledge economy. In order to make better use of the advantage of the various resources, they gradually focus to the technical cooperation. A recent study based on the academic papers statistical analysis found that at the beginning of the twentieth century co-authorships accounted for less than 10 percent of all publications, while at the end of the twentieth century, the percentage had gone up to account for over 50 percent.

Lots of scholars suggest that international collaboration in science should be considered as a communications network which is different from national systems and have its own internal dynamics. Archibugi and Michelle put forward “Techno-globalism” in 1995, this concept describes the deep interaction between technology and globalization that induces firms to bring about radical change both in their own organization structures and in inter-firm relations. There are varied ways of technology cooperation such as research and development cooperation, joint design, produce together, etc. Cooperation can effectively improve the efficiency of scientific research, the capacity of the corporation, and the competitive ability of the regions. Facing the increasingly grim international competition, Archibugi and Grupp both pointed that the upcoming of increased technological globalization or techno-globalism is inevitable.

In order to cope with the challenge of globalization better and grasp the development trend of science and technology, scholars have done a lot of research in the field of technology collaboration from different angles in recent years. In general, their researches are mainly from three angles: the first one is the technology collaboration between different countries/regions or different enterprises. This is the main research field in cooperation study. Federico Cavaggio studied the situation of the foreign patent applications in Japan with the JPO patent data, evaluated the factors that can cause great influence on the growth of the number of patent application, and Japan’s international cooperation status. Chun-Yao Tseng studied the technological innovation and knowledge network in Asia with the data of USPTO, choosing information and communication technologies as an evidence and selecting South Korea, Taiwan, Singapore, Hong Kong, P. R. China and India as represent. Anna Bergek analyzed the role of multiple inventors from different countries in international R&D development cooperation. The second one is the university-industry collaboration. R.M. Davies pointed out that university-industry collaborations would become the main form of cooperation. Marghetita Balconi did a case study of microelectronics to learn the interaction influence between university and corporation. Reinhoide analyzed which firm and industry characteristics are conducive to cooperation with universities using community innovation survey data for Belgium. The third angle is the technological cooperation among different universities. This kind of collaboration has been a phenomenon of growing importance for scientists, research organizations and policy makers. For instance, Jonathon N. Cummings has focused on the coordination costs and project outcomes in multi-university collaborations.

This paper mainly studies the cooperation between different countries and regions. Data of this kind of research is always from the literature, projects and patent, meanwhile the last one is the most common one. In this field, the majority research objects are a certain or a selected number of countries or regions within
an especial scope and most of the research method is patent statistical analysis\cite{1,15-16}. The purpose of the paper is to explore China’s effort in international technology collaboration from 1976 to 2010. In addition to using the patent statistical analysis, the article also adopts some other data mining methods such as the association analysis to make further explore China’s international technology collaboration situation.

3. Analysis Framework

The paper is focused on the international technology cooperation between China’s inventors and other countries or regions’ inventors using the USPTO patent data. The framework is shown in figure 1. In this article we make more detailed analysis from two angles: Overall Analysis and IPC analysis. The whole research surrounds the theme--“international technology collaboration” closely and the main methods are patent statistics and association analysis.

3.1. Data Retrieving and Preprocess

The main purpose of this paper is to analyze the international technology collaboration between China’s inventors and other countries or regions’ inventors. Using the retrieval words “ICN/CN AND APD/19760101->20101231)”, we can get 18777 patents from USPTO. Among the all 18777 patents which applied by China’s inventors, there are 12121 patents applied by more than one inventors, which is 65% of the total patent application. And 50% of the 12121 patents are applied by both China’s inventors and the other countries or regions’ inventors. The research is mainly based on the 6118 valid multi-application patents. However, because the design patents do not have any IPC information, we select the 4850 patents to complete the IPC analysis.

3.2. Data Analysis

In order to exhibit the result more clearly, we define “co-inventor” as the cooperator whose country/region code is not “CN” among all the inventors of a patent in this paper. It is the most direct international collaboration way that inventors from different countries or regions work together and
jointly apply for patents. Ma and Lee\cite{21} think that the presence of multiple inventors is a clear indicator of collaborative inventive activities. The co-inventor analysis involves two parts: macro overall situation and micro IPC analysis.

**Overall Analysis:** The overall analysis means describing the general situation of the patents from USPTO, which applied by the multiple inventors including both China’s inventors and other countries or regions’ inventors during 1976-2010. This part examines the distributions of the patent application, the main technology collaboration field, and etc.

**IPC Analysis:** In this part, we will classify different patents by IPC code and analyze the technology trend by years. Based on various attributions of the co-inventors, this part will show some more detailed conclusions of different research fields, such as leading producer of one special field or the different countries or regions’ research key-point.

4. **Method and Methodology**

Patent data has been treated as the most important output indicator in technology collaboration research\cite{15-17, 21}. Based on the patent data, there are three main methods of international technology collaboration analysis: Patent statistics analysis, patent association analysis and patent citation analysis. Patent data itself contains many different attributions such as inventors; apply year, application number, assignee and IPC code. Patent statistics analysis is to compare these different attributions and explore its internal rules by a series of means such as frequency statistics and regression analysis. Patent association analysis is always used for judging the cooperation and competition relationship between different categories, finding the technology’s focus and development direction and deserving according to the topics of patents. But patent association analysis has a limited application in patent analysis because its algorithm is very complicated. Different from the first two methods, patent citation analysis explores the internal relationship by studying the citation information\cite{22}. We can get more information by patent association analysis and patent citation analysis than only by patent statistics analysis. In order to study China’s international technological innovation collaboration efforts in about 30 years, we’ll use both patent statistics analysis and patent association analysis to reflect the international technology cooperation situation of P. R. China.

5. **Results and Discussion**

5.1. **Overall analysis**

The 6118 cooperative patents involving 11758 person times of inventors (If one inventor applied more than one patents, it will be counted as two or more times) from 39 countries or regions (including P. R. China). Fig.2 exhibits the inventions of residents of the major collaborative countries or regions.

Fig.2 shows that the joint inventions between China and USA appear to be the largest and the ones with Taiwan are the second largest. These two main partners of China occupy 4817 patents (71.7% of the joint inventions) totally. Hong Kong, Japan, Canada and Germany are the next. However, except these 6 ones, co-inventors from the rest 32 foreign countries only applied 667 patents (11.9% of the joint inventions). This phenomenon suggests that though there are a lot of countries and regions participate in the international technology collaboration with China over the years, only minority of them have a close relationship with China. If China wants further international technology collaboration, on one hand, it should enlarge its cooperative partners; on the other hand, it should increase its research efforts and make use of the foreign intelligence to promote technological innovation.
Fig. 2 Joint inventions between residents of China and other countries or regions

Fig. 3 Patent application of six major countries and regions: 1978-2010

Fig. 3 illuminates the annually patent applications applied by the co-inventors from different countries or regions. The line chart only presents the most active countries and regions mentioned previously whose patent applications are far more than the rest countries or regions’ --United States, Taiwan Province, Hong Kong, Japan, Canada and Germany. We can distinguish from the figure that in the first nearly 20 years since the implementation “Reform and opening-up” policy, China performed poorly in the international technology collaboration in joint patent application. Apart from the United States, most of the countries and regions’ patent co-application are very small (less than 5). This situation has improved significantly since 1997. The number of joint inventions applied has made a leap, especially Taiwan’s. We can figure from fig. 3 clearly that besides the rapid growth of the joint inventions cooperated by China and USA, Taiwan has made a great contribution to China’s technology innovation and its joint inventions with China even outnumbered the USA in 2008. Meanwhile, other countries and regions have also cut a figure in international technology collaboration with China; their patent application keeps stably.

We find the earliest one who applied patent in USPTO together with China is the USA. Although Taiwan province is geographically adjacent with Chinese mainland, their cooperation is not frequently at first. Not until 1998 did the number of joint inventions between them begin to increase and had a great leap in 2004, the cross-strait relations have been obviously improved. Taiwan province has already become the most important co-partner of China. This is not only because the strong similarity between China and Taiwan Province in cultures and traditions, more to the point, it is due to China’s unremitting efforts to integrate Taiwan Province into the China’s mainland economic circle.

Fig. 4 exhibits a topic-based association map about the relationship of 20 main co-partner countries and regions. The map also illustrates that the United States, Taiwan province, Hong Kong, Japan, Canada and Germany are the top six co-countries/regions. In the collaboration activities, USA is in the domain position. On the other hand, the number of patent application of Taiwan province whose collaboration direction is relatively independent from the other countries’ or regions’ is almost as much as the United States. Meanwhile, the number of the joint inventions applied by co-inventors from the United States, Canada, Japan, Hong Kong and Singapore is not less than Taiwan, but their technology collaboration field is very similar and the relationship between them is closer. We can also figure out that the co-inventors have formed a core countries centered in the US. Relationships on topic between the inventors from the US and that from Canada, Japan and Hong Kong are quite close, while which is a little weaker between Taiwan province and the core countries, and almost no relation between Germany and them. As for the rest countries, such as France, Finland and France, it is more deviating from the core.
Fig. 5 is an apply year-topic-based association map, which not only shows the topic-based relationship with different apply years, but also flags three top high-yield countries or regions of each apply year. From Fig. 5 we can find out that the international technology collaboration activities between China and other countries and regions from 1976 to 2010 can be divided into five stages, and the US is always the most important partner on international technology collaboration with China in the past 25 years. The cooperation activities between China and Taiwan are gradually moving beyond the US in recent years.

The five stages are shown as follows: (1) the first stage (1976-1988): Lack of international technology collaboration. (2) the second stage (1989-1996): The main co-partners are the US, Italy and India, however their research topics are separated. (3) the third stage (1997-2002): The main co-partners transferred into the US, Taiwan and Hong Kong, and the cooperative research topics were gradually becoming clustered. (4) the fourth stage (2003-2007): The main co-partners are changed into Taiwan, the US and Japan. Meanwhile, the research topics are relatively concentrated. The quantity of patent applications keeps increasing at a fairly high rate, especially in 2006. This might due to the implementation of International S&T Cooperation Program of China in 2001. (5) the fifth stage (2008-2010): The main co-partners are the US and Taiwan. The research topics appear to be decentralized and got a small turning point, which implies that China’s international technology collaboration direction is changing into a different road; we will discuss it in detail in the next section.

5.2. Research field analysis

In this section, we judge different technology fields mainly by the IPC code. Generally, a utility patent performs better in explaining the technology innovation capacity than the design patent. Meanwhile there is a negative impact on retrieving the topic words yet the design patents are lack of abstract information. Furthermore, the design patents always do not have any specific IPC code. Therefore, in order to highlight the technology innovation potential and increase the topic words’ integrity and accuracy, the article only analyzes the 4850 utility patents.

According to the data, G06F (Electric Digital data processing) appears the most in all 4850 patents, 554 patents; followed by H01R (Electrically-conductive connections; Structural associations of a plurality of mutually-insulated electrical connecting elements; Coupling devices; Current collectors) 321 patents; H05K (Printed circuits; casings or constructional detail of electric apparatus; Manufacture of assemblages
of electrical components) 305 patents; H01L (Semiconductor devices; Electric solid state devices not otherwise provided for) 235 patents and G06K (Recognition of data; Presentation of data; Record carriers; Handling record carriers) 174 patents.

Fig.6 displays the relationship of the co-inventors’ countries and regions based on different IPC code. On the bias of different research fields, the main co-inventors’ countries and regions can be divided into three clusters: one is centered with the United States, surrounding by Taiwan province, Canada, Hong Kong, Japan and Singapore. The number of patents in this cluster is large and the research emphasis is similarity. The other two clusters are Finland and Korea; and Switzerland, the United Kingdom and Belgium respectively. These two clusters, on the other hand, cover little patents, and the relationship inner-cluster is weak. From the IPC code, we can find out that due to the differences of each country or region’s innovation capability and technological orientation, their main technology cooperation points are also varied. For instance, the cooperation with the United States is focused on G06 (Computing; Calculating; Counting), Taiwan province is H05 (Electric techniques not otherwise provided for) and H01 (Basic electric elements), and Germany is C07 (Organic Chemistry).

Apart from the analysis of the total utility patents, we also choose one particular field to release more detail, the one who occupies the most joint inventions, G06F. We can draw a map describing the relationship of the G06F patents co-inventors’ countries and regions via association analysis (see Fig.7). The map shows clearly that in the major technology collaboration research field G06F, most of the co-inventors are from the United States and Taiwan, but there are subtle differences in their research key points. In this research field, most of the co-partner countries and regions are US-centric, but Taiwan just exists as a supporter. Meanwhile, even though HongKong, Israel and Finland are not the main international technology collaboration areas in this field, their research subjects are centered with the US closely. On the other hand, co-partner countries such as Japan, Germany, Great Britain and Canada’s cooperate research subject, in a sense, are quite different from the US.

There are 2223 (45.8%) patents applied by co-inventors (act as the second inventors) from the United States and 1449 (30.0%) patents from Taiwan. We compare the differences on joint research points between the United States and Taiwan (see table 1-a, b), who have closer relationship with China in technology cooperation activities than others, in order to draw some more detailed conclusions.
Table 1 exhibits the two most important cooperative partners of China; their research fields are comparably different. Most joint patents of the US are about G06F and Taiwan’s are about H05K, H01R and G06F.

| Rank | IPC       | US Application | Taiwan Application | Rank |
|------|-----------|----------------|--------------------|------|
| 1    | G06F      | 257            | 222                | 3    |
| 2    | G06K      | 140            | 15                 | 12   |
| 3    | H01L      | 108            | 68                 | 4    |
| 4    | A61K      | 84             | 1                  | 104  |
| 5    | H01R      | 67             | 232                | 2    |
| 6    | G11B      | 49             | 15                 | 13   |
| 7    | C07D      | 47             | 1                  | 123  |
| 8    | H04N      | 47             | 9                  | 32   |
| 9    | G02B      | 45             | 14                 | 15   |
| 10   | H04L      | 41             | 13                 | 21   |

6. Conclusions

This paper analyzes the patents in USPTO applied by China’s inventors from 1976 to 2010 by patent statistics and association analysis method. The paper has made detailed and complete explanations to China’s international technology collaboration effort based on co-inventor level. We draw some conclusions as follows:

(1) During the first nearly 20 years (1978-1997) since the “Reform and Opening up” policy set up, apart from seldom cooperation activities between China and the United States, merely few countries collaborated with China. But after 1997, this situation changed significantly. The number of joint patent got a leap and increasing at a high speed. The cooperation scope is gradually expanded and the innovation capacity improved significantly.

(2) Though China has established good international technology collaboration relationships with 38 countries and regions, only the cooperation with the US and Taiwan is deep and wide. There is broad space for the expansion of the international technology collaboration between China and the rest countries, and the government should pay more attention on promoting the international technology collaboration both in depth and breadth.

(3) In the areas of cooperation research field, the joint patents mainly distribute in G06, H01 and H05. The cooperation with the Western developed countries represented by the US is mainly concentrated in G06 while that with the Asian countries or regions represented by Taiwan province is more about H01 and H05. Besides these two technology clusters, P. R. China cooperates with many countries and regions in varied research fields as well.

Overall, although China is playing as a manufacturing power in the global economic system, with the increasing of globalization, China’s emphasis of technology innovation development and the national booming on economic strength and comprehensive national strength, China has gained more and more influence all over the world, its cooperation activities with the foreign countries and regions are increasingly frequency and its innovation capacity keeps improving.
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