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The trend of concentration in scientific research and technological innovation: A reduction of the predominant role of the U.S. in world research & technology

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ABSTRACT

This study investigates the trend of global concentration in scientific research and technological innovation around the world. It accepts papers and patents as appropriate data for revealing the development and status of science and technology respectively. The performance of these outputs in production and citation impact is taken into consideration in the analysis. The findings suggest that both papers and patents are geographically concentrated on a small number of countries, including the United States, the United Kingdom, Japan, Germany, and France. China has made great progress in paper production and citation impact, and Taiwan and Korea have experienced a rapid growth in patents over the past years. The degree of concentration dramatically decreases when the data from the United States are excluded, indicating the effects of the U.S.'s participation on the concentration. Patents show a higher degree of concentration than papers. With time-varying aspects taken into consideration, the study indicates that the degree of concentration of papers and patents has gradually decreased over time. The concentration of patents has declined more slowly than that of papers. This decrease of the concentration is mainly due to the reduction of the predominant role of the U.S. in world R&D output.

1. Introduction

The political and economic landscape of the world is constantly changing. In 1945 there were 51 member states of the United Nations, and presently the number has increased to 192 countries. The group of major economies has grown from G6 to G8, and then to G8 + 5 in recent decades. It has been announced that the G8 will be superseded by the G20 as the main economic council of wealthy nations. With the growth of world economies, the number of countries enhancing investment in scientific infrastructure and innovation activities has increased accordingly. Many countries have intensive participation in the R&D race and are keen to foster their progress in product of research outputs. Such competition may change the world share of science and ultimately leads the shift of the geographic concentration of scientific research and technological innovation. Certainly it has been shown that the center of gravity of the world system of science and technology shifts with time (Leydesdorff & Zhou, 2005). It is shown that, for example, China demonstrates the world's second largest potential in science and technology. It and other emerging nations like South Korea, Taiwan, Brazil and Turkey are already changing the balance of power as measured by scientific production (Glänzel, Debackere, & Meyer, 2008).

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The production of papers and patents reflects a country's development in scientific research and technological innovation respectively. The performance of papers is related to the status of basic scientific research and the quality of a country's research competence. Patents are often viewed as excellent indicators of technological status, regional or national innovation (Cantwell & Fai, 1999; Zander, 1997), and the capacity for transforming technologies into economically productive output. In studies of geographic concentration of science and technology, papers and patents are often viewed as main data sources and analyzed with respect to different interests in social studies of science.

While there has been an increase of number of countries participating in the R&D market, many researchers indicated that world research output and innovation are concentrated on certain of countries. Sin (2011) analyzed seven LIS Journals from 1980 to 2008 and found that most papers published in high-ranking international journals had been written by authors based in a few nations. Braun et al. also found that in 1980s the production of papers in physics, chemistry, life sciences, engineering, and mathematics was highly concentrated on a small group of countries (Braun, Glanzel, Maczelka, & Schubert, 1994a; Braun, Glanzel, Maczelka, & Schubert, 1994b). King (2004) further pointed out that 31 countries could represent the whole research world in terms of both paper production and citations. Regarding the development of a specific region, Pouris (2009) revealed that science and technology research outputs of Africa are mainly contributed by South Arica and Egypt. Similar findings are obtained in studies focusing on a specific discipline. Golnabi and Mahdieh (2006) indicated that 58.9% of papers and 90.1% of patents in laser technology are from four countries: the United States, Japan, Germany, and China. IFigueira et al. (2007) pointed out that most papers on post-traumatic stress disorder are produced by a small number of countries, although more and more countries have been contributing to studies in this field. With consideration of research population, Kao (2009) demonstrated that authors in operations research were from only a few countries.

In addition to the studies in geographic concentration, research has been conducted to explore the concentration between citations and papers. Guan and Ma (2007) found that citations are concentrated on certain of papers. Similarly, Evans (2008) also indicated that, with regard to online publications, citations are concentrated on only a small number of papers and core journals. Yet Lariviere, Gingras and Archambault (2009) found a decline in the concentration of citations from 1900 to 2007, with consideration of time-varying aspects.

Studies are made to reveal the change of concentration and indicate the trend is toward a gradual dispersal of concentration over the past years (IFigueira et al., 2007; Hullmann, 2007). It seems widely accepted that a growing number of countries participating in science dilutes the concentration of research. However, it is still not clear whether the concentration is shifting in both science and technology, nor how the predominance in R&D changes among countries. Beyond most previous studies, which were inherently limited to certain subject areas, countries, or production of papers, the present study attempts to determine overall trends from both scientific research and technological innovation perspectives.

This study examines the trend of concentration of scientific research and technological innovation. It consolidates data on papers and patents, and illustrates the figures of production and citation impact of papers and patents. Although it is understood that patent concentration is higher than paper concentration, this issue of concentration is seldom addressed in patent analysis. To obtain a comprehensive view of the trend of geographic concentration of R&D output, the present study analyzes the production and citation impact of papers and patents to reveal the concentration and development trends of scientific research and technological innovation. An effort is also made to ascertain which countries have the largest share of papers and patents in the world and how their predominant role changes with time.

2. Methodology

Our study utilizes bibliometric and patentometric methods to explore the concentration of scientific research and technological innovation between 1981 and 2008. It adopts the production and citation impact of papers and patents as indicators of scientific research and technological innovation respectively. Both these measures have been widely used for showing a country's research performance and competitiveness. For example, statistics of paper productivity and impact are very common indicators in university ranking studies (Liu & Cheng, 2005; Marginson, 2009; Quacquarelli, O'Leary, & Ince, 2008), and patent-related measures are largely used by the World Economic Forum, the IMD Business School, and the OECD to evaluate the extents of technological innovations (IMD, 2009; OECD, 2009; WEF, 2009).

Several data sources are compiled into the indicators in the study. Paper-related data are collected from Thomson Reuter's National Science Indicators (NSI), which is developed for investigation of publication output and citation impact at national level. The database contains research articles, notes, and reviews derived from the Web of Science® and have been used in bibliometric studies (Glänzel, Danell, & Persson, 2003). Despite the potential criticism of being a secondary source, it provides us with necessary research-related statistics, including the number of papers and the number of citations. The data of NSI are derived from Web of Science®, which have been widely used in bibliometric studies. Researchers can develop in-depth studies of national-wide scientific trends by using well-established analytical data from over 180 nations around the world. In terms of patents, data are collected from the United States Patent and Trademark Office (USPTO), which provides a wide range of the patents issued since 1976. Despite its focus on U.S.-approved patents and the possibility of a 'home advantage' effect (e.g. Criscuolo, 2006; Li, Lin, Chen, & Roco, 2007; Paci, Sassu, & Usai, 1997), the data source showed a broadest coverage and has been widely adopted in patent analysis (e.g. Gao, Guan, & Rousseau, 2011). Actually this kind of bias is not only present in the USPTO but also in the EPO. It is an inevitable problem that there are some biases, in any appearance, inherent in national or regional patent databases. As the one of the world's primary markets, many patents submitted in other countries are simultaneously submitted for U.S. patents. It is not unreasonable to believe that the USPTO includes most of the world's