A comparative study of scientific and technical output indicators of Mainland China and Taiwan region

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The article compares Mainland China and Taiwan region in terms of two kinds of output indicators, namely scientific output indicators represented by the quantity and the citation of SCI papers, and technical output indicator represented by the number of patents granted by USPTO. Both indicators examined are those of the last decade of the 20th century. The article also examines the growth rate of these indicators. Mainland China and Taiwan region showed different trends in terms of S&T output: the scientific output and technical output of Mainland China grew unevenly, while those of Taiwan region climbed evenly and more quickly. The possible factors causing these differences between Mainland China and Taiwan region, especially those related to S&T policies and their implementation, are discussed.

SINCE 1990, the global scientific and technical developments have made remarkable progress. The economic environment and international trade have experienced increasingly greater and more frequent changes, and national competitiveness is influenced more and more by scientific and technical strength of the respective countries. In addition, achieving the holistic objectives of a nation or a region is more and more related to its S&T policies. In the last decade of the 20th century, Mainland China and Taiwan region, both of which are part of the Chinese nation and are playing great economic roles in the world, have come up with various S&T policies to promote economy and sustainable development. To some extent, these policies are successful by showing that S&T developments do play a significant role in promoting economy. There are two kinds of indicators widely used to appraise S&T output: scientific papers, reflecting the output level of basic scientific research, and patents, reflecting the output level of original invention or technology innovation. This article will compare both sides of the Taiwan straits with the S&T output indicators, and analyse the possible factors causing differences.

Comparison of scientific output on both sides of the Taiwan straits

Science Citation Index (*SCI*) indicators are widely used to appraise scientific output, including: quantitative and qualitative indicators. Quantitative indicators are usually represented by total number of papers recorded in *SCI*, or average number of *SCI* papers published by each individual researcher. Qualitative indicators are often substituted by indexes representing impact of periodical papers, derived from paper citation analysis. Here, we would like to compare Mainland China and Taiwan region with these quantitative and qualitative *SCI* indicators.

Quantitative study

The following phenomena can be seen from Figures 1 and 2.

The Mainland: During the period 1990–2000 the number of *SCI* papers from Mainland China rose by 284%, at an annual growth rate of 13.3%. The curve representing Mainland China in Figure 1 tends to climb quickly during this period, but not evenly. In Figure 2, the curve representing Mainland China went down for the first three years, namely 1990–1992. After an abrupt climb in 1993, the curve goes more smoothly. Mainland China increased its *SCI* papers by 24.6%, and was ranked eighth in the world in 2000, behind the US, Japan, Britain, Germany, France, Italy and Canada.

Taiwan region: This region was ranked thirty-fifth in the number of *SCI* papers in 1986, and twenty-nineth in 1990. *SCI* papers from Taiwan region increased by 327% over this period and grew at an annual rate of 17.3% during the period from 1990 to 2000. As a result, in 2000 Taiwan region ranked eighteenth in the world. In Figure 2, Taiwan region is characterized by distinct growth rates

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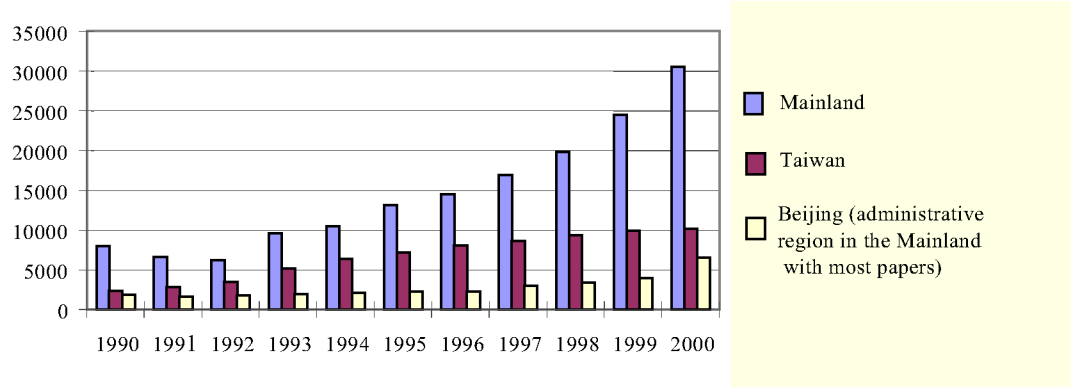

Figure 1. Quantitative comparison of *SCI* papers of Mainland China and Taiwan region 1999–2000. Source: Refs 1 and 2.

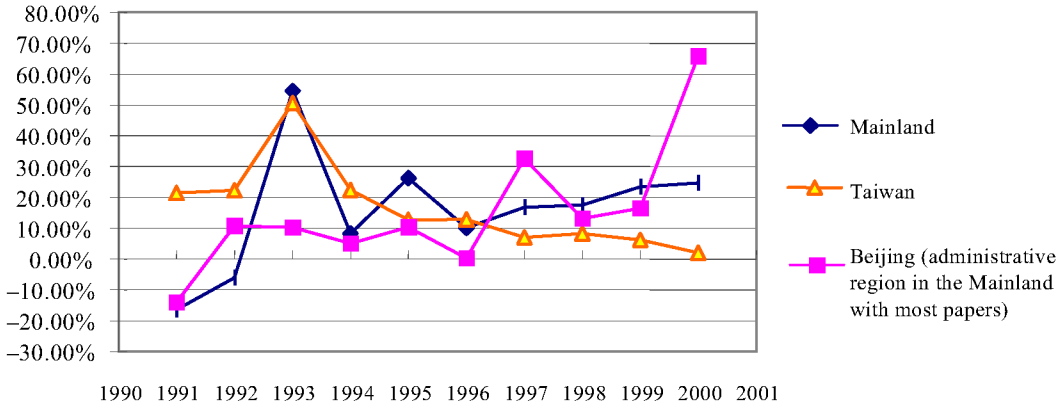

Figure 2. Comparison of growth rate of *SCI* papers of Mainland China and Taiwan region 1990–1999. Source: Refs 1 and 2.

all above 12% before 1996, especially an amazing increase to 50.6% in 1993. The growing pace slowed down after 1997 and it was merely 2.03% in 2000, the lowest since 1990.

The difference in the number of *SCI* papers between Mainland China and Taiwan region had been reducing in the early 1990s. For instance, papers from Taiwan region just accounted for 29.2% of the Mainland in 1990, and in 1994, the ratio reached its highest, 60.9%. However, the ratio went down continuously after 1997, and was 33.1% in 2000.

Comparison between Taiwan region and an administrative region with largest quantity of SCI papers in Mainland China

Historically, Taiwan region has been associated at the provincial level with China. So, it is certainly unfair to compare a region at the provincial level with all the other parts of the country. In other words, it seems more proper to compare regions at the same level. Beijing, also a region at the provincial level, has the most powerful S&T resources in Mainland China, characterized by a strong capacity in basic research, and has been ranked first in terms of *SCI* papers in all the Mainland provinces for a long period. According to statistics of 1998, researchers (scientists and engineers) working in Beijing accounted for 9.37% of the total for Mainland China, and R&D expenditure of Beijing accounted for 20.25% (ref. 5).

Beijing: It can be seen from Figures 1 and 2 that *SCI* papers from Beijing have varied unsteadily since 1990. This number decreases by 14.1% in 1991, and mounts up to nearly 66% in 2000. There are six years, namely 1993–96 and 1998–99 in the last decade of 20th century when Beijing grew more slowly than the whole Mainland. With the exception of 2000, Beijing had just increased its *SCI* papers by 112% from 1990 to 1999, with the annual average growth rate of 8.7%. As a whole, the growth of *SCI* papers in Beijing is much slower than the Taiwan region.

Though at the same provincial level as Taiwan region, Beijing could not compete with Taiwan region in the number of *SCI* papers. For instance, the difference in *SCI* papers between Taiwan region and Beijing was only 446 in 1990, but increased to 5958 in 1999. The difference reduced to 3569 in 2000 because Beijing grew faster and Taiwan region grew slower during the year.

Qualitative study

Qualitative analysis is generally based on impact factor of citation. The impact factor is originally an indicator of

the journal's quality based on the overall citations of the papers published in the journal over a certain time lapse. At the ISI and within the *SCI*, impact factor is defined as the number of times a journal is cited divided by the number of citable articles the journal has published. The impact factor of periodicals is often based on the data of two years. For comparison between regions, five-year windows are used. More precisely, it is given by the ratio of the number (C) of citations of articles of a region over one year (say 2000) to the number (A) of articles published by the same region in the previous five years (i.e. 1995–99).

So, if $C/A \geq 1$, it means that each *SCI* paper from a region during the above-mentioned period is cited at least once on average by *SCI* papers at the counting year. Similarly, if $C/A \leq 1$, it means that each paper is cited less than once that year.

As we know, non-English speaking countries are naturally at a disadvantage compared to English speaking countries in terms of citation. However, Taiwan region and the Mainland, both of which speak Chinese, are comparable in this regard.

As can be seen from Figure 3, the Mainland and Taiwan region are in great disparity with impact factors of *SCI* papers. The curve representing Taiwan region climbs steadily, and gets close to 2 in 2000. That is to say, each *SCI* paper from Taiwan region during 1995 through 1999 is almost cited twice by SCI papers published in 2000, while the curve representing Mainland China hangs around 0.5, way below the Taiwan region curve all along 1990–2000.

Relative citation factor, defined as the ratio of impact factor of a region to the average impact factor of the world, is also used to help represent paper quality. Taiwan region got its greatest ever relative citation factor, namely 0.49 in 2000, which means the impact of *SCI* papers from Taiwan region is even less than half of the world average level. The performance of Mainland China is even poorer.

Comparison of technical output of the Mainland China and Taiwan region

Patents are always used to appraise technical output of a region. Patents are significant indicators to estimate innovative capacity of a country or a region.

American patents

Most people apply for inventive patents in their homeland first. But in order to exploit international markets and acquire monopoly, many corporations apply for and hold patents outside their homeland. The US is the largest market in the world. Currently, the inventive patents granted by USPTO are widely accepted as indicators to appraise the innovative capacity of a country or a region. Figure 4 gives a comparison of the patents granted by USPTO to inventors from Mainland China, Taiwan region and Hong Kong from 1985 to 1998.

Mainland China: There have not been many patents applied overseas since 1985 when the first patent system came into force in Mainland China. For instance, altogether there are only 289 patent applications overseas in 1998. Among all the applications overseas, those for USPTO account for a quarter or so. The USPTO patents to Chinese in 1998, 72 in number, are 72 times that in 1985, when only 1 patent was granted. Besides, Mainland China has made slow progress during 1990 through 1998, far below Taiwan's level. The growth rate over the whole period is just 53.2%, and the annual average growth rate is 5.4%. However, the improvement can be attributed to the very low base.

Taiwan region: In contrast, Taiwan region made rapid progress in acquiring patents granted by USPTO during

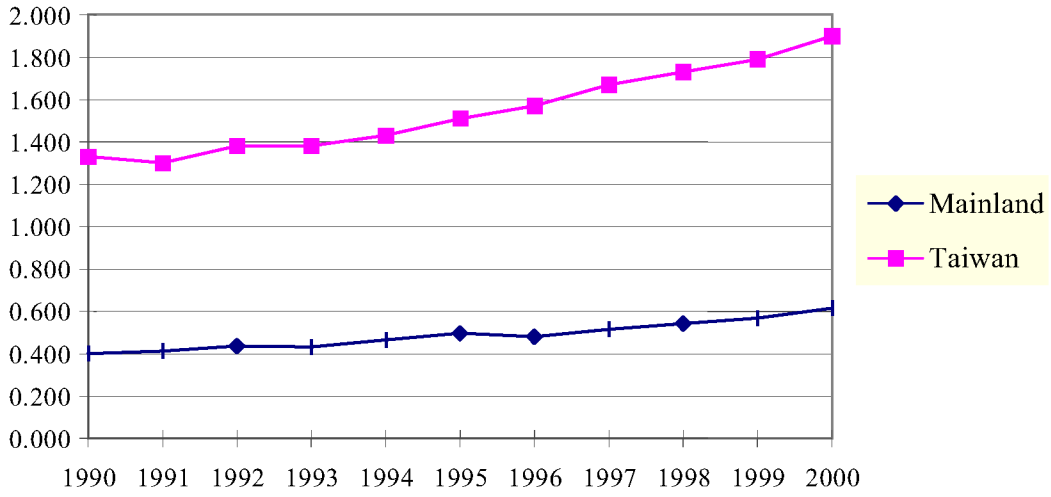

Figure 3. Comparison of quality indicator of *SCI* papers of the Mainland China and Taiwan region 1990–2000. Source: Refs 1–3.

the period 1985–98, especially after 1990. The patents granted increased by 323.5% from 1990 to 1998, and the annual average growth rate is as high as 19.8%. As a result, in 1998 Taiwan region was ranked fourth in the world in USPTO patents, just behind the US, Japan and Germany.

Also, as can be seen from Figure 4, the patents granted by USPTO to Mainland China were amazingly fewer than the Taiwan region. The difference between Mainland China and Taiwan region is so large that it seems difficult to identify the exact number of patents to the Mainland in Figure 4. Besides, the number of US patents from the Mainland grew slowly, and the difference has widened in recent years.

We can also make a point by comparing Mainland China and Hong Kong. In 1990, Hong Kong had only 52 USPTO patents, a little different from Mainland China during that year. However, in 1998, Hong Kong acquired 160 patent grants and the Mainland only 72.

In addition, American patent statistics report shows that Taiwan region owns 173 USPTO patents per million population in 1998. This performance is even better than some industrial countries, such as Germany, France and Canada. In contrast, the number is no more than 0.07 in China (see Table 1).

European patents

As can be seen from Figure 5, European patents to Mainland China were only less than one-third that of the Taiwan region. The difference between Taiwan region and the Mainland has also widened.

The European Patent Office is not widely known in the world. Especially, applications for European patents have not been popular in the Asian region yet. The patents granted to Taiwan region and Mainland China accounted for 0.24 and 0.07% respectively, of the total European patents granted.

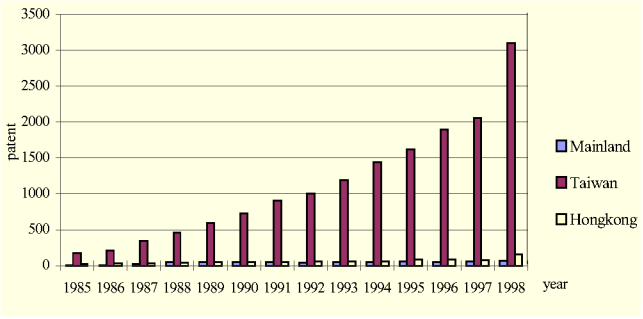

Figure 4. Comparison of American patents from the Mainland and Taiwan region. Source: Ref. 4.

Table 1. Patents granted by USPTO per million population

Region	1993	1994	1995	1996	1997	1998
Mainland China	0.04	0.04	0.05	0.04	0.05	0.07
Taiwan	72.11	85.85	97.98	112.67	119.79	173.51

Comprehensive comparison of papers and patents

In order to contrast the growth of scientific output and technical output at the same time, the period from 1990 to 1998 is selected to calculate the annual average growth rates, because data for both *SCI* papers and USPTO patents are available during this period. As can be seen from Figure 6, great difference between Mainland China and Taiwan region exists in terms of both scientific and technical output growth.

1. The scientific output and the technical output did not go hand in hand in Mainland China unlike in the Taiwan region. During 1990 through 1998, the Mainland increased its *SCI* papers at an average rate much higher than its USPTO patents. In contrast, Taiwan region increased its *SCI* papers and USPTO patents at similar rates. In fact, its USPTO patents grew a little faster than *SCI* papers.
2. S&T output efficiency of Taiwan region is superior to the Mainland. Generally, the efficiency of S&T resources allocation is embodied by S&T output growth. As can obviously be seen from Figure 6, both scientific and technical output in Taiwan region grew faster compared to the Mainland. Thus Taiwan region had higher performance efficiency than the Mainland during this period.

Comments

The Mainland lags far behind Taiwan region in terms of USPTO patents application. Possible reasons for this are as follows

1. Mainland China and Taiwan region are different in market structure. The Mainland's economy has been open to the world for only 20 years or so. It has a large inner market, and up to now, overseas market has been less important than the inner market. In contrast, Taiwan region is small and just has a limited inner market. The people of Taiwan region had realized the limitation in the 1970s and succeeded in developing its economy by exploiting overseas markets through patent strategy. One example is the region's integrated circuit (IC) industry. Now, about 7% of ICs manufactured in the world are made by Taiwan region, and IC industry in the region is developing at the rate of 15% annually.
2. Mainland China and Taiwan region are different in innovative system. Firms are the main sources of innovation in Taiwan region; but this is not the case in the old S&T system of Mainland China. Now, firms have been recognized as the main body of technology innovation in the Mainland after 2000. In the old S&T system of Main-

land China, technology innovation was mainly based on R&D activities of research institutes. For a long time, firms have not built enough R&D capability, and research institutes have no incentives in innovation or applying for patents. For instance, Zhejiang province, one of the richest areas in Mainland China, has 45 research institutes at the provincial level. In 2000, 28 among 45 institutes did not apply for any patent. Among these 28 institutes, 17 had never applied for any patent. In addition, 95% of firms in Zhejiang had never applied for patents. The counties without special administration agency for patent affairs account for 70%.

3. Researchers pay more attention to papers than to patents in Mainland China. Individual researchers from Mainland focus more on papers published than on patents granted, unlike those from Taiwan region.

It has been a common phenomenon that 'researchers emphasize more on papers than on patents' in Mainland China. In 2000, Mainland China ranked eighth in the world in terms of *SCI* papers, and in contrast, was only ranked twenty-third in terms of patents granted by USPTO. The ratio of *SCI* papers to USPTO patents in quantity is 81 to 1.

One example is patent application in Zhejiang University, one of the most famous colleges in Mainland China. The university was granted R&D fund over 600 million RMB in 2000. In 2000, 76 out of 100 applications were granted. Though it is improper to calculate input–output efficiency based on data from the same year, we make a simplistic calculation to get a rough ratio. So we can see that in 2000, Zhejiang University was able to get a patent after expending R&D fund of 6 million RMB. Besides, among all the patent applications, only 8% is inventive patent. However, Zhejiang University does rather good work in comparison with most Chinese colleges for its top rank in patent applications since 1985, when the Chinese Patent Law came into force.

4. Government policies – Mainland China has no technology policies effective in encouraging patent applications. One example is the '863 Programme', namely Chinese National Programme for High Technology Development. To some extent, the programme has been successful. For instance, from 1986 to 2001, the programme totally injected 5.7 billion RMB, and achieved added value of 56 billion RMB. The input–output ratio reached nearly 1 : 10. Besides, indirect economic benefit is estimated to be more

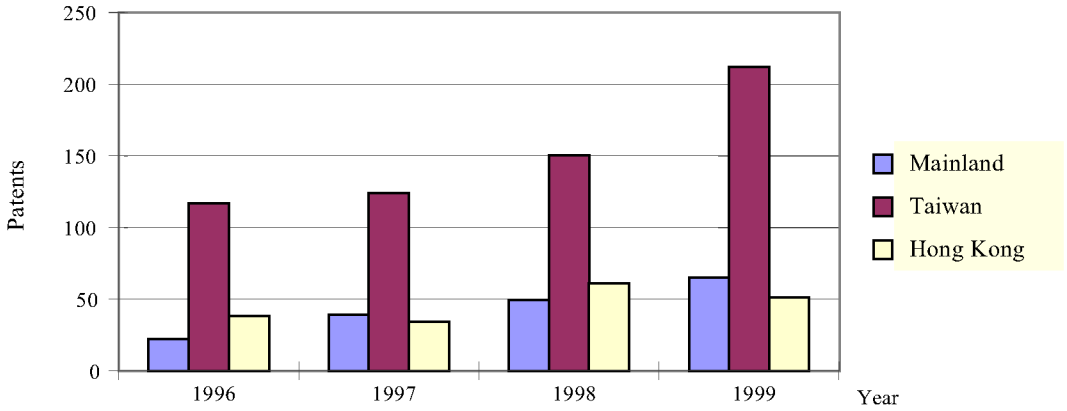

Figure 5. Comparison of European patents from Mainland China and Taiwan region. Source: 1996–2000 data, European Patent Office, http: //www.european-patent-office.org/epo/an_rep/index.htm.

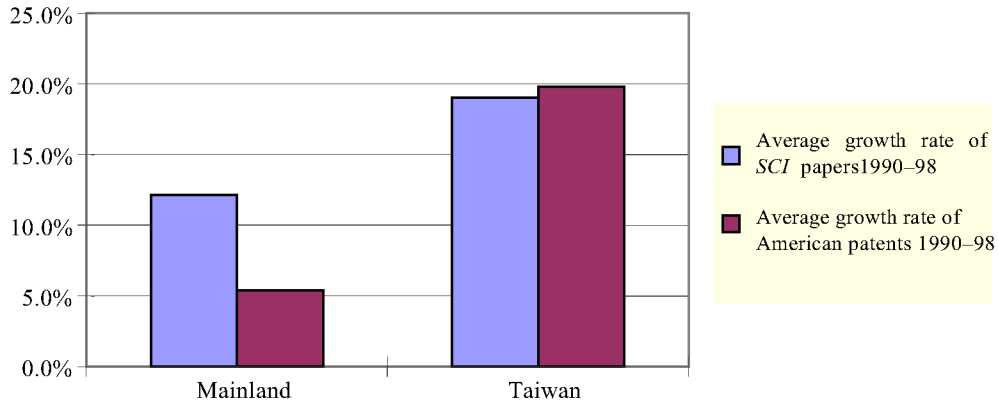

Figure 6. Comprehensive comparison of papers and patents.

than 20 million RMB. However, the programme is poor in patents. The programme had applied for about 2000 patents totally during the above-mentioned 15 years. In contrast, Samsung Group Co of South Korea applied for about 900 patents in Mainland China just in the year of 2000.

5. Intellectual talents – As a result of talent policy and developing economy of Taiwan region, more and more students living abroad get back to Taiwan region. Only 3% of students living abroad came back in 1950, but 63% came back 1989 (ref. 6). These talents have played a great role in improving S&T output of Taiwan region. However, it was in the 1990s that the concept of studying abroad came into great vogue in Mainland China. Students abroad might come back to serve their homeland in the future, but not right away. These students living abroad have not contributed much to S&T output of the Mainland.

Conclusions

Mainland China and Taiwan region showed different trends in terms of S&T output, represented by *SCI* papers and USPTO patents, during 1990 through 2000: the scientific output and technical output of Mainland China grew unevenly; in contrast, indicators of the Taiwan region climbed evenly and more quickly.

Regarding the quality of *SCI* papers, the Mainland is below Taiwan region in terms of impact factor of citation. Both the Mainland and Taiwan regions are below the world average. The rank of citation indicators of *SCI* papers from the Mainland is qualitatively lower than that of quantity. According to statistics in a paper published in *Science* by Robert May, during the period 1981–94, Chinese papers ranked thirteenth in quantity, accounting for 0.9% of the world papers, but only sixty-fifth in quality represented by citation.

Because of limitation of the old S&T system and its special economical condition, Mainland China is not successful with its policies. There have not been enough original technologies by now. Hence China's economy may face difficult times if the potential in economic development to be derived from technology import and capital investment is exhausted.

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