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A bibliometric study of China's semiconductor literature compared with other major asian countries

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In this paper we compare the scientific research in the semiconductor-related field in China with some other major nations in Asia. It is based on the bibliometric information from SCI–Expanded database during the time period of 1995–2004. We show that China has been developing fast in semiconductor research, and become the second productive country in Asia as reflected by the publication profile. The evidences indicate a significant increasing trend in the research efforts and readership among Asian countries. Similar to the scientists in Japan and South Korea, Chinese scientists were more inclined to work in larger groups, typically 4 or more authors. The assessment of research quality is further conducted based on citation-based measures. As benchmarks, two western countries, namely USA and Germany, have been compared in the citation analysis. It is revealed that the impacts of research outputs in the Asian countries, except for Japan, have been badly incommensurate with their devoted research efforts compared with USA and Germany. Like most of other Asian countries the research results of Chinese scientists in semiconductor have a low international visibility despite their strong research efforts and increasingly large domestic readership. The application of Leimkuhler curve illustrates vividly the inequality of citation times among the compared countries. Furthermore, the Gini Indices of each country and each pair of countries are calculated which illustrates again the inequality of informetric productivities.

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Introduction

Science and technology development in China

Marking a major step in openness to the world for the Chinese scientific communities, Chinese National Conference of Science at 1978 had a focus to rebuild Chinese science and technology system. Since then a series of significant events took place, e.g. the establishing of National Natural Science Foundation of China (NSFC) at 1986, the improvement and consolidation in operation system of education and science & technology, etc. With the fast development of national economy, large progresses have been achieved in science and technology. According to the Chinese Statistics Yearbook 2004, the number of scientific publications authored by Chinese scientists in 2003 have ranked the 5th in the world and accounted for 5% of the global publications in three major international indexes (SCI,[1] EI[2] and ISTP[3]).

In this context, it is our intention to show the growing trends and features of research activities in an important scientific discipline in order to take a deeper look at the developing steps and trends in the progress of S&T in this country.

Disciplinary overview

Semiconductor is one of the key materials for information industry. According to the reports by SEMI,[4] Japan has been the largest market of the semiconductor equipments, while South Korea is a large user of semiconductor equipments with annual increase of 91% in 2003. There is also large increases in the market of semiconductor equipments for both mainland China and Taiwan, expanding by as high as 146.1% and 124.0% in 2004. Asia has reached the highest growth rate on the manufacturing of semiconductor equipments in the world in 2004, which is the reason we analyze this area in this paper.

The semiconductor industry is highly dependent upon scientific breakthroughs (LIM, 2004), which is evident in the progressing of U.S. semiconductor industry. For this

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[1] *Science Citation Index* (*SCI*) provides access to current and retrospective bibliographic information, author abstracts, and cited references found in 3,700 of the world's leading scholarly science and technical journals covering more than 100 disciplines. http://scientific.thomson.com/products/sci/

[2] *Engineering Index* (EI) also known as Compendex is the most comprehensive interdisciplinary engineering database in the world. It contains over 8 million records and references over 5,000 international engineering sources including journal, conference, and trade publications. http://www.engineeringvillage2.org.cn/

[3] *Index to Science & Technology Proceedings* (ISTP) provides comprehensive, multidisciplinary coverage of proceedings papers delivered at prestigious international scientific and technology conferences. http://scientific.thomson.com/products/istp/

[4] Semiconductor Equipment and Materials Institute (SEMI) is a global industry association providing members with superior customer service at the local level. http://www.semi.org

reason, it would be necessary for us to explore the progress of scientific research in semiconductor field as reflected by semiconductor literatures.

As indicated by HAWKINS (1976), the semiconductor research and development began in the late 1940's. In the recent decades, research and development of semiconductor has grown very rapidly and become increasingly important for the economic growth of many developed and developing countries. The semiconductor research, as well as other sub-disciplines of information science and technology, as identified by the NSFC in China, is one of the areas of high priority in China (WANG & GUAN, 2005; GUAN & HE, 2005).

Bibliometric analysis – A powerful tool for evaluation

The bibliometric study involves the statistical analysis of quantitative aspects of scientific publications (MOED, 2002). It adopted quantitative performance indicators to get over the disadvantage of subjectivity in peer review and expert judgments (VAN RAAN, 2004), and has been used to assess research performance in an increasing amount and variety of studies (RINIA, et al, 1998).

The principal assumption underlying the applications of bibliometric indicators is that the production of scientific literatures can reflect important stages of scientific activity. The reason lies in the fact that scientific progress is achieved by scientists who work together to study specific research areas (PRICE, 1963). In order to keep each other informed on the scientific results, the scientists would like to publish them for evaluation by other professional colleagues (MERTON, 1972). In these publications, researchers refer to the previous work of others in the same field. Consequently, scientific literatures are a reflection of scientific activity. The progress of science can be studied through quantitative analysis of documentations (GARFIELD, 1979).

More specifically, the number of publications is considered to be one of the indications of scientific activities. The citation analysis provides indicators of publications of international scientific influence and impact (NARIN, 1976; GARFIELD, 1979; MARTIN & IRVINE, 1983; MOED et al., 1985; MOED et al., 2002; GARG, 2002; VAN RAAN & VAN LEEUWEN, 2002).

The present study attempts to evaluate the growing trends and performance level of semiconductor research of China, using bibliometric indicators of statistics analysis of international scientific literatures. HAWKINS (1976) firstly surveyed the semiconductor journals by analyzing bibliographic data of semiconductor from 1970 to April 1975 on the DIALOG[5] system. Tsay and his several collaborators made a series of studies (TSAY et al., 2000; TSAY & MA, 2002; TSAY et al., 2003) on semiconductor literatures during

[5] DIALOG system is the world's first online information retrieval system to be used globally with materially significant databases. It offers organizations the ability to precisely retrieve data from more than 1.4 billion unique records in such fields as business, science, engineering, finance and law. http://www.dialog.com/about/

the time period of 1978–1997 using the INSPEC[6] database. LIM (2004) measured the research activities in semiconductor industry using the ISI databases.

Objectives

The objectives of the present research are:

1. To quantify the volume and relative proportions of publications of China in the field of semiconductor on the SCI-Expanded database during 1995-2004, compared with some other selected Asian countries.
2. To identify the publication and communication characteristics, including the number of authors and country of publication.
3. To explore the impact of China's semiconductor research in both Asia and worldwide using citation-based indicators.
4. To illustrate the distribution characteristics of citations by applying Leimkuhler Curve and Gini Index to different nations during the time period studied.

Data collection and methodology

The present study was restricted to the on-line edition of the SCI-Expanded database. The ISI databases are used for measuring research performance from international perspectives. It has been approved by MOED (2002) that the bibliometric analysis based on the ISI databases can provide internationally recognized useful and valid information of Chinese research activities.

In this paper we use publication information indexed in the SCI-Expanded during 1995 and 2004. All the bibliographic data containing "semiconduct*" in the "TOPIC" field has been searched for the selected countries and region, including China, India, Japan, South Korea, Taiwan, Germany and USA. The wildcard of asterisk (*) represents additional expanded characters. Therefore, the search "semiconduct*" would retrieve items with "semiconduct" as its etyma. Thus, the search results include broad descriptive terms, such as "semiconductor", "semiconductors", "semiconductivity" and "semiconducting" in titles, abstracts, key words and subject categories. Hence, the present study would retrieve most of the papers in the field of semiconductors. Similar searching techniques were also used by GARG (2002) and TSAY et al. (2000).

[6] INSPEC is the leading English-language bibliographic information service providing access to the world's scientific and technical literature in physics, electrical engineering, electronics, communications, control engineering, computers and computing, information technology, production, manufacturing and mechanical engineering. It is published by the Institution of Electrical Engineers (IEE) since 1898. http://scientific.thomson.com/products/inspec/

In the literature search, we use one or more authors' address as the region of research. The document type was limited to articles, reviews letters and notes. No more limitations in language or any other attributes have been applied. Authors' names were taken as recorded in the database. All the bibliographic data which had been filtered before were then downloaded and saved. Our analysis is first focused on the bibliometric information of the five Asian countries and Asian region. Then Germany and USA are included later for comparison.

Based on the data obtained, we have calculated a range of bibliometric indicators, counting the number of articles, the number of authors for each article and the number of times these articles were cited, as well as recording articles' country of publication. In addition to the simple sums, some composite indexes have also been calculated. In order to analyze trends, indicators were calculated either annually or aggregated for the whole period.

As to the impact indicators based on citation counts, we have adopted the most frequently used "the average number of citations per article published in a country", namely *CPP*. The measurement "uncitedness" was calculated by dividing the number of papers which had never been cited by the total number of papers published in a country. The percentage of highly cited papers was also calculated to indicate their impact. We have also investigated the distribution characteristics between the citation counts and the number of publications. In informetrics, a graphical representation is the Leimkuhler curve, which illustrates the concentration or diversion of citations within a population of articles.

Result and discussions

Trends

As previously indicated, the number of publications is one of the indications of scientific activities. The number and growth tendency of semiconductor literatures in the five Asian countries and region during 1995–2004 have been illustrated in Figure 1.

It has been observed in Figure 1 that Japan is the most active country based on publication counts, which takes the leading position among the five Asian countries (region), with a little decrease in 2003 and 2004. As for the trends, China is the fastest increasing one because its semiconductor publications covered in ISI-databases increases from less than 200 in 1995 to 900 in 2004. And the rate is even higher in the last three years. South Korea and Taiwan both keep a steady pace, while India has almost remained the same for the 10 years.

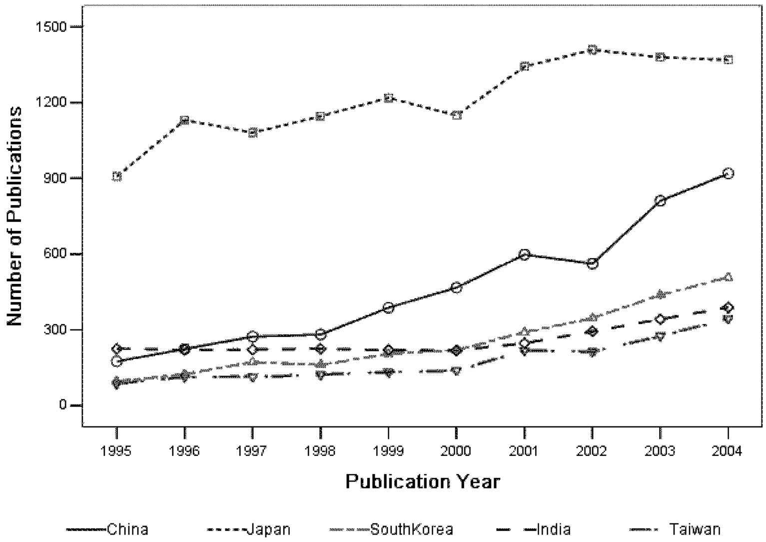

Figure 1. Chronological distribution of semiconductor literature in 5 Asian countries and region

Incidentally, the rapid development in information science in China, including the semiconductor research, took place since the field was listed as one of the top priority projects of the NSFC (GUAN & HE, 2005). This may indicate that a fast growing developing country can earn some comparative advantages during their catch-up scientific activities in some new emerging science discipline.

Publication characteristics of semiconductor literature

The modern science is highly internationalized. Many scientists prefer to publish their results internationally, as it would improve the impact of research results and stimulate research activities as well.

In this sub-section, the distribution profiles of "country of publication" of semiconductor literatures will be analyzed. The distribution of publications from 1995 to 2004 is shown in Table 1.

Where the proportions of literatures in the countries can be seen. To see the extend of the influence of these publications internationally, the statistical results indicate that a majority of semiconductor literatures indexed by SCI have been published in the developed countries.

Table 1. Summary of the countries of publication

Authors' affiliation / Country of Publication	Japan	China	South Korea	India	Taiwan
1995					
Domestic	*27.34*	*13.71*	*21.88*	*16.89*	*3.45*
USA	34.62	25.14	27.08	22.22	43.68
England	16.54	30.29	27.08	28.44	21.84
Netherlands	8.49	12.57	7.29	11.11	8.05
Switzerland	10.36	8.57	10.42	13.33	5.75
Others	2.64	9.71	6.25	8.00	17.24
Total	100	100	100	100	100
2004					
Domestic	*20.89*	*19.80*	*18.50*	*9.51*	*0.29*
USA	33.24	26.88	31.69	21.85	47.09
England	13.59	14.91	12.01	21.85	16.57
Netherlands	20.53	24.81	14.76	28.02	16.57
Switzerland	6.65	5.55	8.07	10.03	5.52
Others	5.12	8.06	14.96	8.74	13.94
Total	100	100	100	100	100

It is indicated by the distribution of "country of publication", the research in semiconductor in China has closely followed the trends in Asia with considerable number of papers published in USA, England, Netherlands and Switzerland. There are also indications that the proportions of domestically publishing papers in four Asian countries and region were decreasing except for China. For China, the share of papers published domestically accounted for about 14% in 1995. In 2004 the share is increased to nearly 20%. The ratio of publications in Chinese language also increased from less than 3% in 1995 to 11% in 2004.

It is also noted that increased Chinese language journals were incorporated in the ISI databases. As most people in the would do not understand the Chinese language the growing proportion of literatures in Chinese language may not be advantageous in connecting researchers internationally. In this regard, the Chinese scientists should be more encouraged to write in English and contribute to international journals.

Collaboration pattern

The old adage "strength in numbers" holds generally for research (CRONIN et al., 2003). Advancements in science are results of collective efforts. "Academic work increasingly is teamwork, just like industrial production" (POSNER, 2001). In this regard, it is necessary to study collaboration patterns of authors. In the following context, we present the collaboration profiles of the five Asian countries and region measured by the indicator of Co-authorship Index.

Co-authorship Index has been firstly elaborated by SCHUBERT & BRAUN (1986), and is obtained by calculating proportionally the publications by single, two, multi- and mega-authored papers for different nations or for different sub-disciplines. This methodology is similar to the Activity Index suggested by FRAME (1977).

The Co-authorship Index is calculated as follows:

$$CAI = \{(N_{ij}/N_{io})/(N_{oj}/N_{oo})\}\times 100$$

where:

N_{ij} denotes the number of papers co-authored by j authors in the i-th country,
N_{io} denotes the total number of papers in the i-th country,
N_{oj} denotes the number of papers co-authored by j authors in all countries,
N_{oo} denotes the total number of papers in all countries.
CAI=100 indicates that the number of publications corresponds to the average within a co-authorship pattern. CAI>100 reflects higher than the average, and CAI<100 indicates lower than the average.

Here, the papers have been firstly divided into four categories according to number of authors. They are: single-author, two-author, multiple-author papers with three to four authors, and mega-author papers with five or more authors. And the profiles of *CAI* for the compared countries have been illustrated in Figure 2.

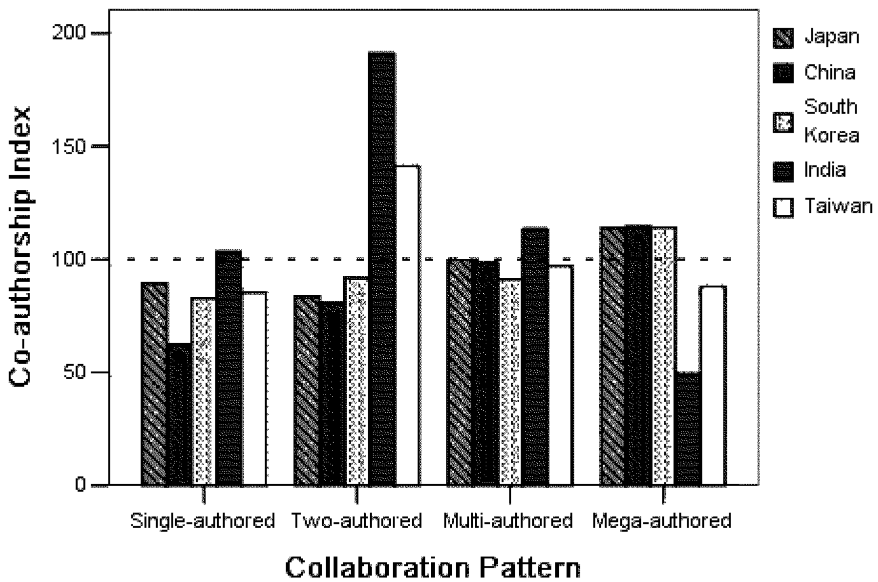

Figure 2. Sketch map of collaboration patterns reflected by CAI

It is clearly indicated in Figure 2 that *CAI* of mega-author papers in Japan, China and South Korea is more than the average. In other words, papers published by scientists in these three countries preferred to work in large groups. As for China, where researchers have becoming more and more aware of the importance of collaboration (GUAN & MA, 2004). This is reflected by the relative higher Co-authorship Index of mega-authored papers. The *CAI*s for India and Taiwan are apparently diverged from others. They work in relative small groups.

Citation-based analysis

The citation analysis is an effective way of comparing research productivity and impact within different aggregations – the individuals, institutions, or nations (NARIN, 1976; CRONIN, 1984; BORGMAN, 1990). In several earlier informetric studies, citation analysis offered insightful information about research performance and scientific influence (MOED, 2002; VAN RAAN, 2002. The citation analysis is considered to be more factual than peer review (COLE et al., 1978).

In this sub-section, the citation data of Germany and USA have been included, since they are both very active in semiconductor research. They could be considered as benchmarks to compare the research impact and international visibility of the Asian countries and region.

Table 2. Citation-based indicators for evaluating the research quality

Citation-based indicators	Symbol
The number of papers (articles, letters, notes and reviews) published in the database of on-line edition of SCI–EXPANDED	*P*
The number of citation recorded in SCI journals to all publications considered	*C*
The average number of citations per publication (Self-citations not excluded)	*CPP*
Percentage of papers not cited during the time period considered	*%Pnc*
Percentage of highly cited papers during the time period considered	*%Phc*
Publication Efficiency Index	*PEI*

CPP – This indicator is an average number of citations per publication. Due to a limitation of the databases, self-citations were not excluded from the total citation counts, which could to some extent result in bias in the measurement for the impact because some authors may over-cite their own work. However, the large number of papers in the bibliometric study should smooth out the distortions by self-citations (KING, 2004).

%Pnc – It is obtained by calculating the percentage of papers not being cited during the time period considered (RINIA, et al., 1998). It indicates lower international visibility. In our study, we have found that among all the papers in the databases the

average citation time of a paper is equal to 8.995298. Therefore papers having received citations of more than 9 times are considered as highly cited papers.

Publication Efficiency Index (*PEI*) – This is another derivative of the above mentioned Activity Index introduced by PRICE (1981), and was used by GARG (2002) and GUAN & MA (2004) in their studies as a measure of research quality. It indicates whether the impact of publications in a country in a research field is compatible with the research efforts. The value of *PEI* >1 for a country indicates that the impact of publications is more than the research effort devoted to it for that particular country and vice versa. In the present study, it is obtained through dividing the percentage of citations (*TNC%*) by the percentage of publications (*TNP%*):

$$PEI = \frac{TNC_i / TNC_t}{TNP_i / TNP_t}$$

where

TNC_i denotes the total number of citations of country i;
TNC_t denotes the total number of citations of all countries;
TNP_i denotes the total number of papers of country i;
TNP_t denotes the total number of papers of all countries.

The values of different surrogate measures used for comparing the impact of research results for the seven countries are showed in Table 3.

Table 3. Summary of research impact for different countries

Countries \ Indicators	*P*	*C*	*CPP*	*%Pnc*	*%Phc*	*PEI*
Japan	12,134	86,516	7.13	26.77	20.32	0.75
China	4,698	19,027	4.05	36.25	12.62	0.42
South Korea	2,560	10,134	3.96	37.81	12.58	0.41
India	2,603	9,277	3.56	38.15	11.06	0.37
Taiwan	1,758	6,965	3.96	37.37	11.49	0.42
Germany	9,622	89,137	9.26	22.26	27.36	0.97
USA	20,007	259,131	12.95	20.85	31.16	1.36

Based on the above mentioned measures of quality, it is observed that in both publication counts or citation times, great gaps exist between the Asian countries (region) and the two western countries in semiconductor research. The *CPP* shows that the average citation rate of China was less than a half of the Germany's and about one third of the USA's. It also shows that Japan is the leading power of semiconductor research in either quantity or quality in Asia. Comparing between Japan and China, Japan produces a total of 2.5 times more publications and receives 4.5 times more citations. The indicator of *%Pnc* suggests that more than one third of papers in China have not been cited during the considered time period. The value of *%Phc* shows that China has only 12.6% of highly cited papers on semiconductor research. Both of the above ratios suggest that the scientific influence of semiconductor research in China, as well as the other three Asian countries (region), is still trailing behind Japan and the two Western countries. It is noted although the publication volume grows fast in China, the uncited papers remain high and probability for highly cited articles is still small.

We look into the data of China in more details. Among 4698 papers published in the ISI database by Chinese scientists, 765 were published in the journals within China (Hereafter we call these domestic journals, although they are indexed by SCI) and the other 3933 abroad (Hereafter we call these international journals). 410 out of the 765 papers in the domestic journals were not cited during the time period considered and the uncited ratio comes to 54%. On the other hand, among 593 highly cited papers, only 19 out of them were published in the domestic journals. The percentage of highly cited papers in the domestic journals is only 3.2%. More than 96% (574/593) highly cited papers were published in those international journals. The percentage of highly cited papers in the international journals is 14.6%.

The above analysis indicates that the scientific publications of Chinese scientists in semiconductor are still rather "local" and have a low international visibility. Our findings in this particular area support a more general conclusion of REN & ROUSSEAU'S (2002) and MOED'S (2002) on international visibility of Chinese scientific journals. The papers published in Chinese domestic journals do not have as much impact as those published in international journals in the field of semiconductor. Therefore, publishing papers in international semiconductor journals is one way to increase the international visibility of research results of Chinese scientists in the area of semiconductor. Contributing more papers to international journals covered by SCI by Chinese researchers is perhaps a way to achieve more readership.

The Publication Effective Index indicates that in general the impact of research in the Asian countries (region) is very weak despite their devoted research efforts as compared with USA and Germany, while Japan is an exception. In other words, the Asian publications have not received enough citations in comparison to their large number of published papers. In this regard, the scientists in Asian countries and region, particularly for those in China, South Korea, India and Taiwan, are suggested trying to make themselves more widely informed in the international research community, as to raise the level of impact in the average sense.

The Leimkuhler curve and Gini Index

1) The Leimkuhler Curve. It is argued by BURRELL (2005) that, the absent or concentration of items associated with some sources over a time period is of interest in informetric studies. With respect to the research productivity, the source are authors and the items are papers written by those authors. When concerned with journal productivity, the sources are journals in a specific field and the items are papers on the journals (LOTKA, 1926). In citation analysis, the sources are individual papers and the items are citations of the papers.

It is indicated in the above mentioned studies that the variations or differences in items associated with the sources are of interest. In this regard, our present study was to illustrate the inequality between the publications and citations within our dataset for additional citation analysis.

In informetrics, a simple way of illustrating differences or gaps is via the Leimkuhler curve, as indicated by BURRELL (1991, 1992, 2005). Leimkuhler curve provides a highly intuitive graphical representation for the Gini Index (Coefficient). It can quickly grasp the magnitude of inequality by a glance in the areas below the diagonal. Unlike Lorenz curve, in which one arranges the sources in increasing order of the productivity, the sources are arranged in decreasing order in the Leimkuhler curve. Leimkuhler curve can illustrate the inequality of citation times over the publication counts for the compared countries, and distinguishes the details of maldistribution.

The definitions in the present study follow the ones described in BURRELL (2005) using X to denote the number of items produced by a randomly chosen source. The following definition is given in the discrete case, for X is in this study a non-negative integer-valued variable.

Definition 1

I. Mean of X: $\mu_X = E[X] = \sum_{X=0}^{\infty} x p_X(x)$

II. Tail distribution function of X: $\Phi_X(x) = P(X \geq x) = \sum_{y=x}^{\infty} p_X(y)$

III. Tail-moment distribution function of X: $\Psi_X(x) = \left(\sum_{y=x}^{\infty} y p_X(y) \right) \Big/ \mu_X$

The Leimkuhler curve is then given by $\Psi = L(\Phi)$, which is the plot of Ψ on the vertical axis against Φ on the horizontal axis. Since X is discrete, we will have only a series of discrete points plotted. The discrete points are joined and smoothed to give the Leimkuhler curve. The curve is concave, with starting point at the origin (0, 0) and ending point at (1, 1).

In the present study, we use $f(j)$ for the number of publications receiving j citations, $j = 0, 1, 2, \ldots, n$, where n is the largest observed cited times, N for the total number of publications, and M for the total number of citations. Then, the tail distribution and tail-moment distribution in application form are accordingly given as:

$$\Phi(j) = \left(\sum\nolimits_{k \geq j} f(k) \right) \Big/ N, \quad \Psi(j) = \left(\sum\nolimits_{k \geq j} k f(k) \right) \Big/ M$$

Due to the huge size of the original dataset, we have adopted a method of equidistant sampling to reduce the number of points and illustrate more clearly. The labels for each country were approximately linked by curves rather than connecting them with lines, since they could mix up sometimes. The Leimkuhler curves for different countries are depicted in Figure 3.

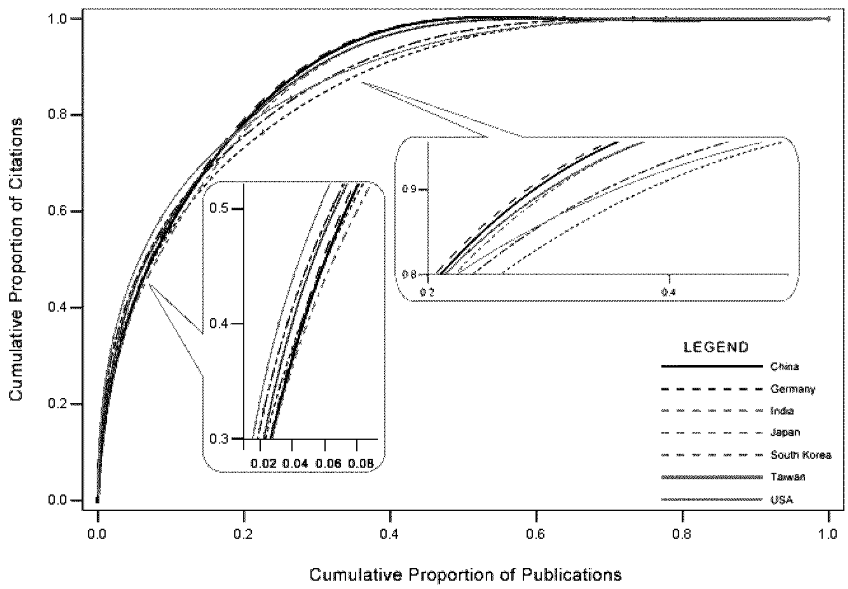

Figure 3. Leimkuhler curves of different countries and region

It can be easily identified from Figure 3 that the distribution of citation times over the number of publications for the Asian countries and region, except for Japan, is slightly skewed compared with Germany and USA. As the publication counts are arranged in the decreasing order of citation times, it could be concluded that the citation distribution of papers receiving considerable number of citations did not depart a lot from each other for the seven selected countries and region.

The main distinction is within papers receiving a few or no citations, in which the four Asian countries and region, except for Japan, have raised up faster and reached the top line earlier than the other three countries. This points to a fact that a large number of papers receiving no citations have contributed a low total number of citations in these 4 Asian countries and region, especially for China and India. On the other hand, in the case of Germany, USA and Japan, a large number of papers receiving modulate number of citations has actually contributed much to the high total number of citations which in turn led to the high level of research quality.

2) The Gini Coefficient/Index. In this sub-section, we continue the investigation in citation inequality. Following BURRELL (2005), the Gini Indexes for both individual nation and pair of nations are given separately as *Definition 2*. The mean and tail distribution are given as before with symbols μ_X and $\Phi_X(j)$, and similarly for the Y population.

Definition 2

$$\text{Gini Coefficient: } \gamma_X = 1 - \frac{\sum_{j\geq 1} \Phi_X(j)^2}{\mu_X}$$

$$\text{Gini Ratio: } G(X,Y) = 1 - \frac{2\sum_{j\geq 1} \Phi_X(j)\Phi_Y(j)}{\mu_X + \mu_Y}$$

In fact, the measurement of informetric productivity by Gini Index is exactly same as the Leimkuhler curve. As it has been already proven that the value of Gini Coefficient of a specific population is the two times of the area beneath its Leimkuhler Curve minus 1 (BURRELL, 1991). That is to say, if the Leimkuhler curve of one productivity distribution is higher than another, then its Gini Coefficient is greater. The Gini Ratio between two populations crystallize the usefulness of the Gini Coefficient. It is used to quantify the difference in productivities between a pair of subjects (DAGUM, 1987). In the following Table 4, we have shown the above mentioned two types of Gini Indexes.

Table 4. The Gini Index for each nation and each pair of nations

Gini Index	Japan	China	South Korea	India	Taiwan	Germany	USA
Japan	*0.7374*	0.7518	0.7554	0.7545	0.7562	0.7304	0.7308
China	–	*0.7409*	0.7438	0.7373	0.7441	0.7575	0.7964
South Korea	–	–	*0.7466*	0.7400	0.7468	0.7614	0.8000
India	–	–	–	*0.7414*	0.7398	0.7634	0.8043
Taiwan	–	–	–	–	*0.7466*	0.7627	0.8012
Germany	–	–	–	–	–	*0.7155*	0.7399
USA	–	–	–	–	–	–	*0.7219*

We can make the following observations based on the Gini Index in Table 4:

1. The Gini Coefficient for each individual population once again suggests that distributions of citation times are slightly skewed in the four Asian countries and region than those in Japan, Germany and USA.

2. The Gini Ratios between pairs of the Asian countries (region) remain below 0.75, except those in Japan. On the other hand, the Gini Ratios between Asian and western countries are relatively higher than those between Asian ones, and especially high in the case of USA. This could once again validate the foregoing result that significant differences in research impact existed between Asian and western countries.

Concluding remarks

In this study we have analyzed data in the semiconductor literatures indexed by the SCI – Expanded database of the five Asian countries and region during the time span 1995–2004. The analysis shows that there have been significant changes in the number of publications and connectivity of these countries during the recent 10 years. We have shown that it is important to examine the characteristics of some surrogate impact measures such as *CPP*, *%Pnc*, *%Phc* and *PEI*. The present study has generated an enormous amount of empirical data related to the publication characteristics and research performance of the five Asian countries and region in the field of semiconductor. Based on the analysis, the following conclusions have been drawn:

1. China has greatly increased it scientific activities in the semiconductor-related field. The influence in the region has increased significantly in the recent 10 years. And it was proven that some fast growing developing countries, like China, can catch up in scientific activities rapidly in a new emerging science discipline.

2. China closely followed the trends in Asia, with a large proportion of papers published in USA, England, Netherlands and Switzerland. Papers published domestically have increased from 1995 to 2004 and the growing number of Chinese domestic papers are included in the ISI databases. The scientists in Japan, China and South Korea preferred to work in large groups with more than 4 fellows.

3. Generally speaking, Asian countries have still a long way to go with respect to research impact compared with western countries, as reflected by some indicators based on "Times Cited". The average citation rate of China was not as high as half of the Germany's and one third of the USA's. Similar findings of contrast in numbers of publications and citations in the Essential Science Indicators developed by ISI also indicated that, China ranked 9th by publications and 19th by citations over the period 1993–2002. It is also concluded from JIN & ROUSSEAU (2001) that low citation counts suggest Chinese science still being at the periphery of world mainstream research.

4. The analysis indicates that Japan is leading in semiconductor research in both publication number and research impact among the Asian countries (region). The percentage of highly cited papers in China was relative low, and the percentage of highly cited papers published in Chinese domestic journals was even lower. Furthermore, over one third of the papers by Chinese scientists received no citations

during the period. It is partly due to low international readership, and partly caused by the fact that as the number of publications increases, the proportion of uncited papers also increases and proportion of highly cited papers decreases. The Publication Effective Index indicated that the research impact of Asian countries were contacted unfavorably with their large research efforts compared with USA and Germany. Hence it is suggested that Asian scientists have a gap to fill in improving their research quality and international visibility.

5. The characteristics of inequality of the citation times over the publication counts measured by Leimkuhler curve were studied for the 5 Asian countries and region plus the two western countries for comparison. Furthermore, the Gini Indexes for each nation and each pair of nations were separately given and validated again the skewed distribution of citation times.

In total, the striking growth rate characterized both emerging feature of Chinese semiconductor research and fast scientific development of the developing country. Anyway, the proportion of Chinese international scientific production devoted to the world semiconductor research was relatively small and even smaller while considering the fact of total population. The research results of Chinese scientists in semiconductor are still rather "local" and suffer from a low international visibility. However, with the extraordinary growth of the national economy, scientific research in China can be expected to have more rapid development because more funding can be made available for R&D in the future.

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