Comparison of universities' scientific performance using bibliometric indicators

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ABSTRACT
The scientific performance of National Taiwan University (NTU) and Peking University (PKU) were compared by two indicators, namely citations per publication and h-index, based on the data extracted from the Science Citation Index Expanded (SCI-Expanded), Social Science Citation Index (SSCI), and Arts & Humanities Citation Index (A&HCI) Web of Science from 2000 to 2009. Analyzed aspects covered publication outputs, publication patterns, and international and inter-institutional collaborations of the two universities. The two universities were in the same scale based on the number of publications. Articles from electrical and electronic engineering dominated the other articles in NTU while PKU researchers published a great number of articles in the basic science fields. Material science was the new field for these two universities. The USA had the greatest number of collaborated articles accounting for 15% and 12% of total articles with NTU and PKU respectively. Article impact followed a decreasing order of international collaboration, inter-institutional collaboration, and independent articles for both universities. PKU articles had higher visibility. In addition, the Essential Science Indicators were applied to investigate the research activities of NTU and PKU.

Keywords: Scientometrics; Research Performance; Citations per Publication; *h*-index; Science indicators; web of science.

INTRODUCTION

Bibliometric analysis can be used to identify new research areas, to evaluate the research performance of individual scientists (van Raan 2006), research groups (Seglen and Aksnes 2000), and countries (Schubert et al. 1989). It can also be used to examine knowledge within one discipline or across disciplines. The recoveries of bibliometrics which have been used in the library and information sciences are very useful to find out research trends in many research fields. Indicators of publication output and citation impact have been frequently employed to assess research institutions, such as French National Institute (Le Minor and Dostatni 1991), European Universities (Melin and Persson 1998), Flanders University (van den Berghe 1998), and Brazilian Universities (Zorzetto et al. 2006).

Common bibliometric indicators, number of publications (Frohlich and Resler 2001), citations (Borić 2008), and journal impact factors (Lehrl 1999), were used for research

evaluation. The citations per publication as a citation indicator were interpreted as dividing the total citations received by a group during a certain period over their total publications (Moed et al. 1985). Independent and collaborative publications and their citations per publication were reported (Hsieh et al. 2004; Chiu and Ho 2005). The scale of number of publications should be large enough to allow statistically reliable conclusions. Peak-year citations per publication with total, independent, and collaborative publications for evaluation of countries and institutions' performances were applied to evaluate topics of contingent valuation (Li and Ho 2008), ocean circulation (Zhang, Qian and Ho 2009), and volatile organic compounds research (Zhang, Xie and Ho 2010). Latterly, the five indicators including number of total publications, independent, collaborative, first author, and corresponding author articles were extended to compare the countries and institutions' performances in the subject categories of environmental sciences (Hu et al. 2010; Mao, Wang and Ho. 2010), ecology and environmental engineering (Zhang et al. 2010), water resources and chemical engineering (Tanaka and Ho 2010), and general and internal medicine (Ho, Satoh and Lin 2010). The total number of citations and the number of citations per publication would be hard to find but for bibliometric research groups these indicators must be directly available from their data system (Van Raan 2006). Furthermore, *h*-index was reported in 2005 (Hirsch 2005) and has a better predictive power than other measures such as total number of papers published and total number of citations acquired (Hirsch, 2007). The *h*-index has been used for evolution of research groups (Van Raan 2006), institutions (Molinari and Molinari, 2008), individual researchers (Cronin and Meho 2006), and journals (Vanclay 2008). In recent years, the five indicators with *h*-index were also presented for the topic of adsorption technologies for dye containing wastewaters (Malarvizhi, Wang and Ho. 2010).

The main target of this paper was to investigate and compare the two universities' research performance. One was the National Taiwan University (NTU) founded by the Japanese in Taiwan in 1928 and the other one, Peking University (PKU) was originally known as the Imperial University of Peking, founded in 1898. Articles published in the Science Citation Index Expanded (SCI-Expanded), Social Science Citation Index (SSCI), and Arts & Humanities Citation Index (A&HCI) by PKU and NTU from 2000 to 2009 were analyzed by five indicators including total, university independent, inter-institutionally collaborative, first author, and corresponding author articles. In addition, two indicators *h*-index (Hirsch 2005) and year citations per publication (Li and Ho 2008; Zhang et al. 2009) were employed to compare university's performance of first and corresponding author articles as well as internationally and inter-institutionally collaborative articles. Furthermore, papers listed in the Essential Science Indicators (ESI) were also collected and analyzed for comparison of the universities' research impact.

DATA SOURCES AND METHODOLOGY

The data presented were based on the Institute for Scientific Information (ISI, Philadelphia, USA) citation indexes under the Web of Science (WoS) including SCI-Expanded, SSCI, and A&HCI. According to 2009 edition of the Journal Citation Reports (JCR) database, it indexed 7,387 SCI major journals with citation references across 174 scientific disciplines and 2,557 SSCI journals in 56 subject categories. The terms of (Peking Univ and Beijing Univ) and (Natl Taiwan Univ) were used as keywords to search the address field. The schematic diagram for searching PKU and NTU articles is shown in Figure 1. Articles originating from England, Scotland, Northern Ireland, and Wales were reclassified as from the United Kingdom (UK). Articles addressed in Hong Kong were not included under the heading of China. The

reported impact factor (IF) of each journal was obtained from the 2009 JCR. Contributions of different institutes and countries/territories were estimated by affiliating at least one author to the article. Collaboration type was determined by the addressof the authors. The term "internationally collaborative article" was associated to those articles that were collaborative with authors from overseas' institutes. The term "inter-institutionally collaborative article" was assigned if authors were not from PKU or NTU only. Only articles published from 2000-2009 were selected.

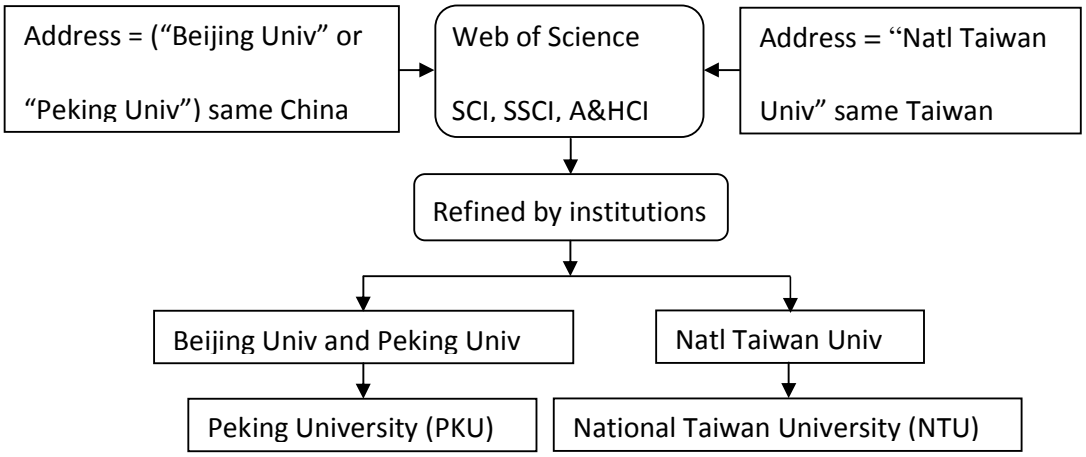

Figure 1: Schematic for Searching Articles from National Taiwan University and Peking University

Characteristics of article outputs, distribution of output in subject categories and journals, collaborative countries/territories and institutes were discussed. The impact of articles was assessed in terms of year citations per publication and *h*-index. The TC2009 for an article was identified by the number of times being cited from its year of publication to the end of 2009. The *h*-index was calculated by this value. Figure 2 shows the relationship between the average number of times cited per article and the number of years since its year of publication for the articles published by PKU and NTU respectively. It shows that the frequency of being cited was the highest in the 2nd full year since its publication year for PKU and 3rd full year for NTU, and began to decrease thereafter. Similar to the journal IF, the variable TC2, total citations from publication year to 3rd full year, was used to calculate peak year citations per publication (PCPP) to assess the impact of articles. For example TC2 for all the articles published in 2000 would be the number of times being cited from its publication time of 2000 to the end of 2002. In addition, the typical cited article is the most cited during the late 2 years after its publication year (Garfield 1972). The same results were also presented in medical topics (Chuang, Huang and Ho 2007) and condensed matter physics (Marx and Cardona 2003), though the peak position depended on the research discipline and might be shifted to 3 or more years (Hansen and Henriksen 1997; Li and Ho 2008). Publication and citation counts of papers listed in the Essential Science Indicators (ESI) were also collected by the university names and analyzed to compare the universities' research impact. The time period of ESI data has been updated as of July 1, 2010, covering a 10-year plus 4-month period (January 1, 2000 to April 30, 2010).

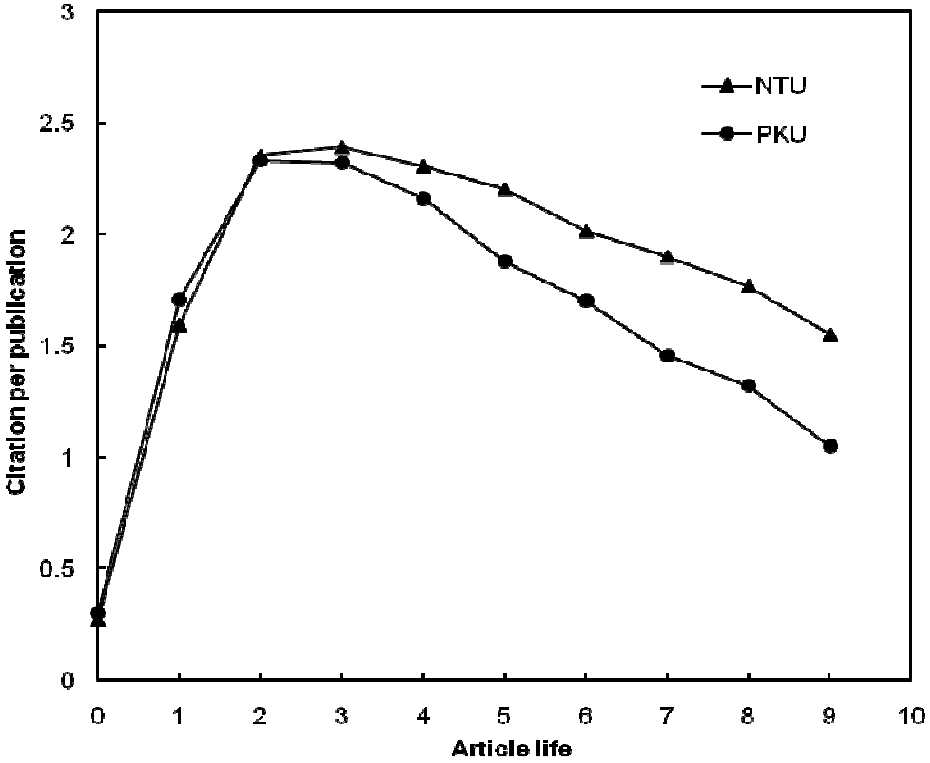

Figure 2: Citation per Publication by Article Life

RESULTS AND DISCUSSION

The *h*-index is the most popular indicator in recent years. However, it has been noticed that *h*-index is not obviously superior to other indices that rely on citations and publication counts to assess research performance (Kelly and Jennions 2006). Thus, not only *h*-index but also PCPP were used to compare research performance for the two universities.

Characteristics of Publication Outputs

Characteristics of the annual production were investigated. Total number of NTU articles was 24,597, while for PKU it was 24,030 during the 2000-2009 period. NTU had 98 *h*-index and 3.30 PCPP while PKU had a higher *h*-index and PCPP with values of 106 and 3.36 respectively. The growth trends of publications by NTU researchers related to PKU publications are displayed in Figure 3. NTU publishes at a quicker pace compared to PKU. However, the annual number of PKU's publications increased by 228% (from 1,189 to 3,905 articles), while NTU increased its publication output by 136% (from 1,538 to 3,629 articles) during the same period. The PCPPs of NTU were higher than that of PKU in the earlier period from 2000 to 2002, while in the recent period from 2003 to 2008, the PCPPs of PKU were higher than that of NTU. Furthermore, 5.6% of all articles published by NTU during the time span of 2000 to 2002 had TC2009 higher than 100 times and 1.1% articles had high TC2009 (> 100) in later years. For PKU, 2.6% articles from 2003 to 2009 and 1.1% articles in earlier year (2000-2002) had higher TC2009 (> 100). In 2000, Peking University and Beijing Medical University were merged to be Peking University. It could be one of the reasons that the number of articles in PKU caught up with that of NTU in 2002 (Figure 3).

The number of authors per article increased from 3.7 in 2000 to 6.1 in 2009 for NTU, and

from 5.4 in 2000 to 7.0 in 2009 for PKU. The average article's length fluctuated and slightly increased, with an overall average length of 9.0 (NTU) and 8.0 pages (PKU). The comparison of publication trends of NTU and PKU is displayed in Figure 3. From 2000 to 2002, NTU was in prepotency position, but in 2009, PKU stood in the flagship.

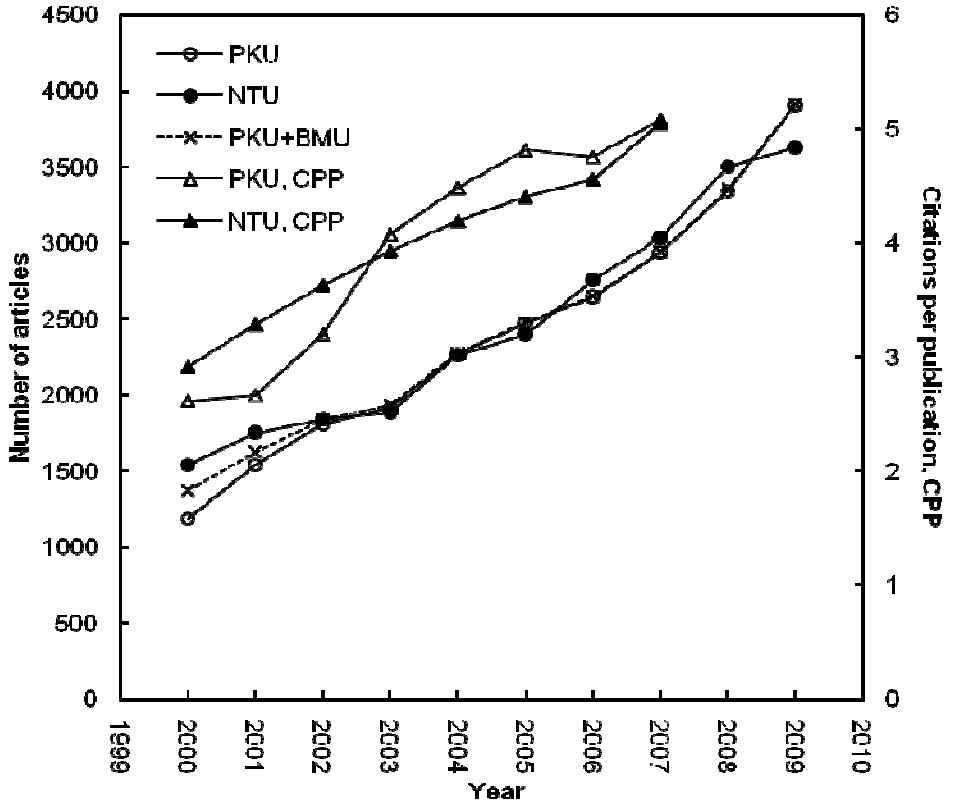

Figure 3: Comparison of Publication Trends between National Taiwan University and Peking University

Publication Patterns: Subject Categories and Journals

The use of statistics in any scientific discipline could be considered as a key element in evaluating its degree of maturity (Palmer, Sesé and Montaño 2005). Based on the classification of subject categories of JCR in 2009, the publication output data of NTU was distributed in 173 SCI and 46 SSCI subject categories while 167 SCI and 45 SSCI categories for PKU. The performance of top 20 productive categories obtained from SCI-Expanded of NTU and PKU are exhibited to describe performances of NTU and PKU with PCPP and *h*-index in Table 1. The most two productive subject categories in SSCI were economics and management, with 229 and 98 articles in NTU, and 207 and 65 articles in PKU respectively.

Table 1: Top 20 Subject Categories from National Taiwan University and Peking University

National Taiwan University	TP (%)	TC2	PCPP	*h*-index	Peking University	TP (%)	TC2	PCPP	*h*-index
electrical & electronic engineering	2,045 (8.3)	4,559	2.2	39	multidisciplinary chemistry	1,931 (8.0)	9,117	4.7	68
applied physics	1,571 (6.4)	5,695	3.6	43	multidisciplinary physics	1,792 (7.5)	8,363	4.7	52
multidisciplinary materials science	1,382 (5.6)	4,681	3.4	41	physical chemistry	1,659 (6.9)	6,865	4.1	53
physical chemistry	1,095 (4.5)	4,768	4.4	44	biochemistry & molecular biology	1,532 (6.4)	6,628	4.3	46
biochemistry & molecular biology	1,029 (4.2)	4,886	4.7	41	multidisciplinary materials science	1,325 (5.5)	5,898	4.5	49
environmental sciences	936 (3.8)	2,325	2.5	32	applied physics	1,105 (4.6)	4,335	3.9	46
multidisciplinary chemistry	866 (3.5)	4,487	5.2	43	mathematics	900 (3.7)	711	0.8	19
pharmacology & pharmacy	785 (3.2)	2,780	3.5	35	pharmacology & pharmacy	886 (3.7)	2,523	2.8	26
optics	665 (2.7)	1,753	2.6	25	applied mathematics	877 (3.6)	926	1.1	19
chemical engineering	655 (2.7)	1,318	2.0	23	particles & fields physics	852 (3.5)	3,476	4.1	33
oncology	639 (2.6)	3,625	5.7	42	condensed matter physics	815 (3.4)	2,929	3.6	38
condensed matter physics	605 (2.5)	2,596	4.3	36	environmental sciences	742 (3.1)	2,375	3.2	30
general & internal medicine	573 (2.3)	2,314	4.0	25	astronomy & astrophysics	735 (3.1)	4,198	5.7	37
mechanics	542 (2.2)	710	1.3	19	organic chemistry	708 (2.9)	2,942	4.2	32
food science & technology	530 (2.2)	1,231	2.3	27	electrical & electronic engineering	649 (2.7)	1,217	1.9	23
multidisciplinary geosciences	502 (2.0)	1,194	2.4	23	nuclear physics	644 (2.7)	1,594	2.5	26
nanoscience & nanotechnology	499 (2.0)	2,301	4.6	32	analytical chemistry	637 (2.7)	2,349	3.7	32
biotechnology & applied microbiology	475 (1.9)	1,595	3.4	27	inorganic & nuclear chemistry	623 (2.6)	2,898	4.7	44
plant sciences	464 (1.9)	1,000	2.2	24	multidisciplinary sciences	593 (2.5)	2,634	4.4	39
multidisciplinary physics	463 (1.9)	4,764	10	49	polymer science	582 (2.4)	1,742	3.0	28

TP (%): Total number of articles (percentage of all articles published in the field)

The most active SCI category in NTU was electrical & electronic engineering with 2,045 articles, PCPP 2.2, and *h*-index 39, followed by applied physics with 1,571 articles (PCPP = 3.6, *h*-index = 43) and multidisciplinary materials science with 1,382 articles (PCPP = 3.6, *h*-index = 41). The highest PCPP 10 was conducted by multidisciplinary physics also with the highest *h*-index, 49 in the top 20 subject categories. The smallest value of PCPP and *h*-index were noticed by the category of mechanics. The most productive subject category in PKU was multidisciplinary chemistry with 1,931 articles, 4.7 of PCPP, and 68 of *h*-index, followed by multidisciplinary physics with 1,792 articles (PCPP = 4.7, *h*-index = 52) and physical chemistry with 1,659 articles (PCPP = 4.1, *h*-index = 53). The highest PCPP was in the categories of astronomy & astrophysics (PCPP = 5.7) and the highest *h*-index was multidisciplinary chemistry (*h*-index = 68) respectively. NTU had greater number articles in medical related fields, while PKU had more articles in basic science related fields, such as mathematic, chemistry and physics.

In Web of Science databases, the total numbers of 24,597 NTU articles were published in 3,535 journals including 69 journals issued by Taiwan, Hong Kong, and China. Researchers in PKU published a total number of 24,030 articles in 3,142 journals, 112 journals of which publishing 5,109 (21%) articles were issued by Taiwan, Hong Kong, and China. The five most productive subject categories published at least 1,000 articles over these ten years for NTU are shown in Figure 4. The articles quantity in electrical & electronic engineering was in the top every year among these categories and the yearly number of articles obviously increased after 2002. The number of articles in the subject of multidisciplinary materials science increased sharply after 2005 and ranked 2nd in 2009. PKU was active in the fields of chemistry, physics and materials science. The development trends of number of articles in subjects of multidisciplinary materials science and applied physics also increased rapidly from 2004 to 2009 for PKU (Figure 5).

The most popular journal in NTU was *Applied Physics Letters* which published 525 articles with PCPP of 4.7 and *h*-index of 32. The following six journals which published at least 200 articles in the leading position were *Journal of the Formosan Medical Association* with 432 articles (PCPP = 0.92; *h*-index = 12), *Physical Review D* with 245 articles (PCPP = 8.5; *h*-index = 30), *Journal of Applied Physics* with 232 articles (PCPP = 2.7; *h*-index = 17), *Physical Review Letters* with 217 articles (PCPP = 17; *h*-index = 46), and *Physical Review B* with 201 articles (PCPP = 4.8; *h*-index = 25). In addition, 217 articles in *Physical Review Letters* which had the highest IF (7.328), PCPP (17), and *h*-index (46) among the top 20 journals. In the case of PKU, the most active journals were *Chinese Physics Letters* with 471 articles (PCPP = 1.5; *h*-index = 13) followed by *Chinese Science Bulletin* with 325 articles (PCPP = 0.94; *h*-index = 12), *Chinese Medical Journal* with 322 articles (PCPP = 1.0; *h*-index = 10), *Physical Review D* with 318 articles (PCPP = 7.4; *h*-index = 30), and *Acta Petrologica Sinica* with 377 articles (PCPP = 2.2; *h*-index = 16).

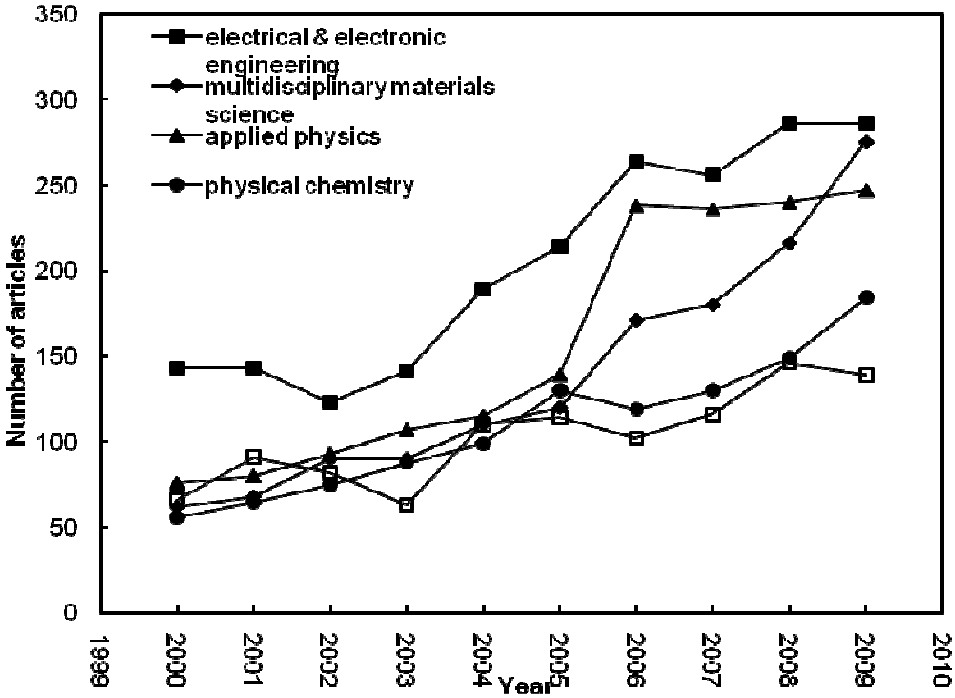

Figure 4: Comparison the Growth Trends of the Top 6 Productive Subject Categories (National Taiwan University)

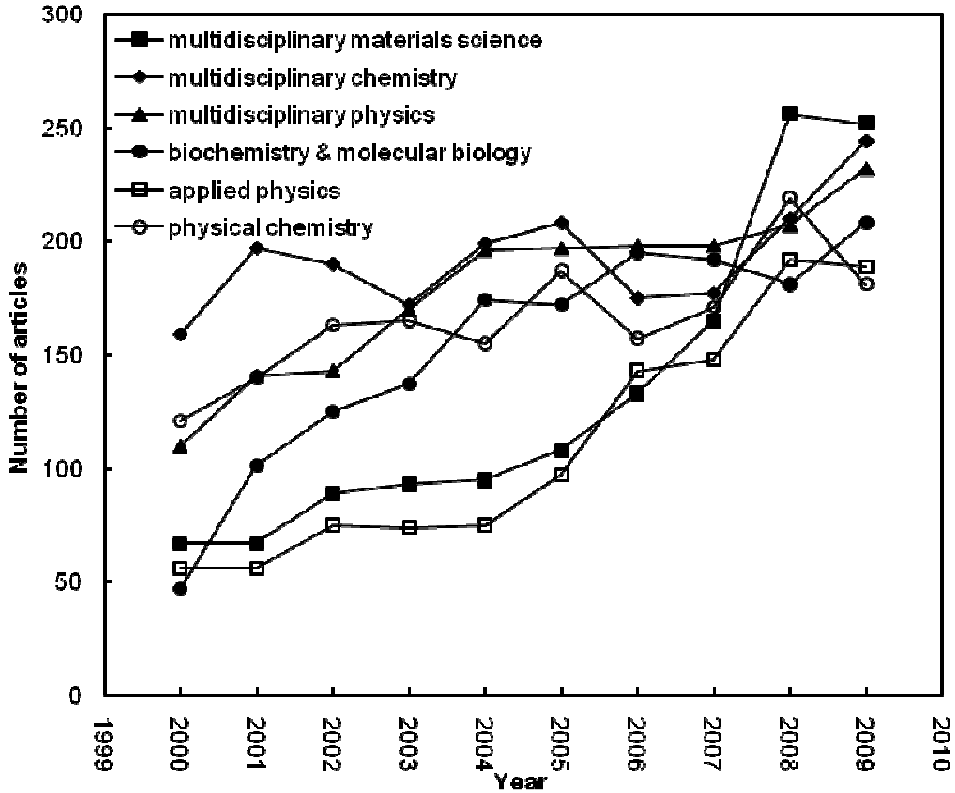

Figure 5: Comparison the Growth Trends of the Top 6 Productive Subject Categories (Peking University)

International and Inter-institutional Collaborations

Collaboration, playing a growing role in scientific research, usually manifests itself in internationally co-authored papers tracked by bibliometric tools (Schubert and Braun, 1990). The 20 most collaborative countries/territories with NTU are shown in Table 2. USA was the most popular collaborative country followed by China, Japan, India, Australia, and South Korea. The USA had the highest *h*-index (74) but the PCPP was 6.3 and ranked 17th in Table 2. It has been noticed that the *h*-index took into account both the quantity and the quality of the scientific production, but is size dependent (i.e. for a same quality of research, a large university will have a larger h-index than a small university) (Molinari and Molinari 2008). The PCPPs were compared even though the PCPPs were hard to be calculated. The India, Australia, South Korea, Russia, Germany, and Switzerland had the similar level in terms of PCPP and *h*-index values. Articles with first authors from Japan had the highest value of PCPP (10). The value of *h*-index with first author from USA was found to be the highest (51) but its PCPP was 5.9 and just ranked 9th. However, Sweden had excellent PCPP values of 17 and 18 of first and corresponding author articles, respectively. A region bias was found in the 20 collaborative countries with NTU, most of which such as China, Japan, South Korea, Hong Kong, and Singapore were all in Asia region. The top three ranking countries of PCPP were Spain (21), Austria (15), and Poland (15). The 20 most productive countries/territories collaborative with PKU are listed in Table 3. The leading country of collaborative articles with PKU was USA with 3,707 articles (PCPP = 6.3; *h*-index = 77), followed by Japan (1,073), Hong Kong (924), and Germany (832). The USA also had the highest *h*-index of first (61) and corresponding author (62) articles. The highest PCPP for total collaborative articles with PKU was found to be 16 (Russia). The first and corresponding authors from Slovenia had the highest PCPP (23) and low *h*-index of 3.

Twenty-one percent of all NTU articles were internationally collaborative articles with 94 countries while PKU had 31% articles with 86 countries. The most productive internationally collaborative articles country was the USA with 12% and 15% for NTU and PKU respectively. Seven developed countries/territories including USA, Japan, Hong Kong, Germany, Australia, UK, and Canada published about one third PKU international collaborated articles. More countries/territories (95) had international collaborated articles with NTU. However one third NTU international collaborated articles were published with more countries including USA, China, Japan, India, Australia, South Korea, Russia, Germany, Switzerland, UK, Poland, and Austria. Table 4 shows a comparison of collaboration for NTU and PKU. The descending order of the values of PCPP by article categories was internationally collaborative articles, inter-institutionally collaborative articles, and independent articles for both universities. PKU had higher independent PCPP than that of NTU. All *h*-index of collaborative, independent, and all articles for PKU were higher than that of NTU. As a rule, more international collaboration led to more sharing of ideas and workloads, and would cause more concerns than the national papers (Glänzel et al. 1999).

Table 5 exhibits the top 15 NTU collaborative institutes by publication output from 2000 to 2009, including the number of total collaborative, first author, and corresponding author articles with two indicators PCPP and *h*-index. The most productive collaborative institute was National Taiwan University Hospital (NTUH) with 3,334 articles. Among these 15 institutes, only the Chinese Academy of Sciences (China) ranked 10th and University of Tokyo (Japan) ranked 15th, were not from Taiwan. However, articles collaborative with these two institutes had much higher PCPP in total NTU institute collaborative articles (Table 5). The collaborative institute NTUH was affiliated to NTU and the Academia Sinica is a government research institute in Taiwan. Table 6 displays the PKU top 15 most

collaborative institutes. Leading was the Chinese Academy of Sciences which has many branches in different cities throughout China. Articles collaborated with Japanese institutions had the highest PCPP and *h*-index. Articles collaborated with USA and South Korea also had higher PCPP. Among the institution listed in Table 6, national collaboration with PKU had lower PCPP values. Figure 6 demonstrates an interesting phenomenon that Tsing Hua University had a peak number of collaborative publications with PKU in 2005 but decreased to zero in 2009. Furthermore, the Nankai University also had a decreasing trend during 2004-2009. On the other hand, the Beijing Normal University collaborative publications increased by year.

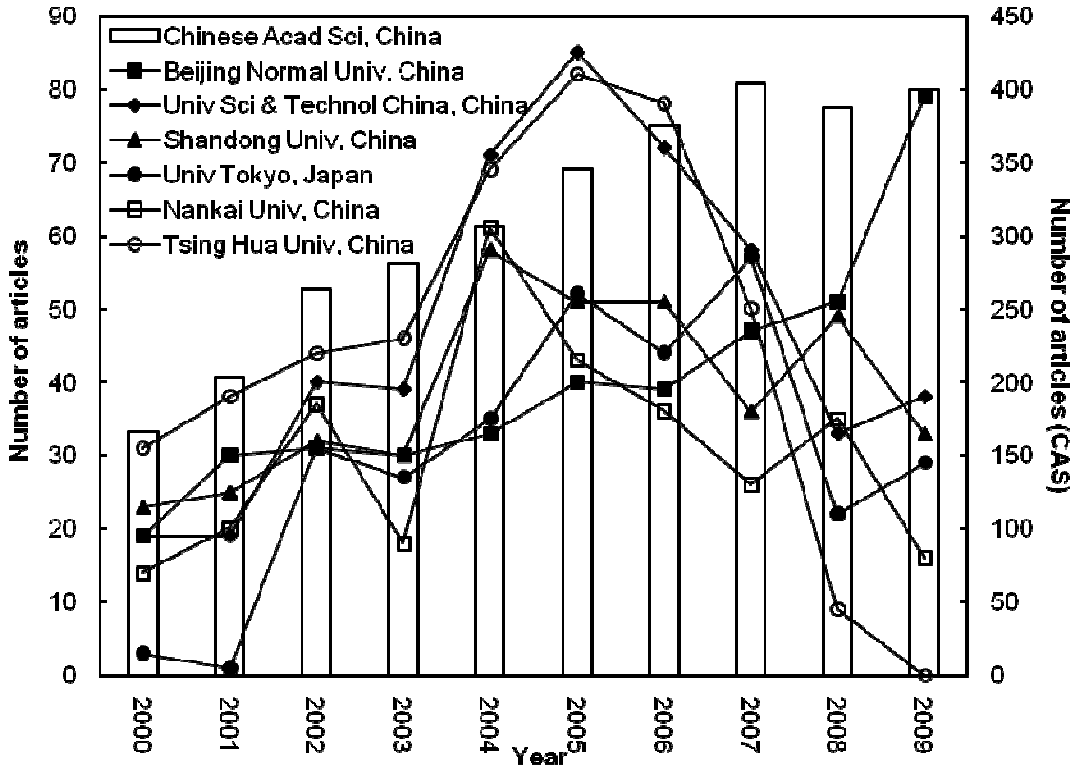

Figure 6: Comparison the Growth Trends of the Top Seven Most Productive Collaborative Institutes with Peking University

Table 2: National Taiwan University's Top 20 Most Collaborative Countries from 2000 to 2009

Country	TP	CPR (%)	PCPP	*h*-index	FAR (%)	PCPP	*h*-index	RPR (%)	PCPP	*h*-index
USA	2,911	1 (55)	6.3	74	1 (3.9)	5.9	51	1 (3.9)	5.8	50
China	966	2 (18)	7.4	53	2 (1.4)	3.7	25	2 (1.4)	3.7	24
Japan	853	3 (16)	9.0	52	3 (1.3)	10	36	3 (1.3)	10	35
India	508	4 (9.6)	10	49	4 (0.50)	3.6	22	4 (0.47)	3.7	20
Australia	482	5 (9.1)	13	50	11 (0.16)	4.4	11	11 (0.18)	4.3	12
South Korea	425	6 (8.1)	12	49	13 (0.15)	9.1	12	13 (0.16)	9.9	13
Russia	390	7 (7.4)	14	49	6 (0.43)	9.6	20	6 (0.42)	8.7	20
Germany	353	8 (6.7)	13	47	9 (0.20)	5.8	13	9 (0.20)	5.9	14
Switzerland	330	9 (6.3)	14	44	16 (0.045)	12	4.0	19 (0.037)	14	4
UK	326	10 (6.2)	9.2	34	5 (0.43)	8.3	21	5 (0.42)	9.0	22
Poland	323	11 (6.1)	15	49	16 (0.045)	3.8	4.0	16 (0.045)	3.8	4
Austria	292	12 (5.5)	15	44	20 (0.033)	4.3	5.0	21 (0.033)	4.3	5
Slovenia	287	13 (5.4)	13	41	24 (0.024)	16	4.0	23 (0.029)	13	4
Canada	230	14 (4.4)	8.2	26	7 (0.25)	2.6	12	7 (0.25)	2.7	12
France	161	15 (3.1)	5.4	23	8 (0.22)	4.7	14	8 (0.20)	4.7	13
Hong Kong	135	16 (2.6)	3.6	20	9 (0.20)	2.7	11	10 (0.19)	2.6	10
Singapore	109	17 (2.1)	5.6	16	11 (0.16)	5.1	10	12 (0.16)	4.8	9
Italy	78	18 (1.5)	12	19	14 (0.081)	6.5	7.0	14 (0.086)	6.2	7
Sweden	49	19 (0.93)	10	19	16 (0.045)	17	8.0	17 (0.041)	18	7
Spain	46	20 (0.87)	21	13	22 (0.028)	5.7	3.0	21 (0.033)	6.0	4

TP: the number of total articles; % TP: the share in total articles; CPR (%), FAR (%), RPR (%): internationally collaborated articles, first author articles, corresponding author publications in total articles

Table 3: Peking University's Top 20 Most Collaborative Countries/Territories from 2000 to 2009

Country	TP	CPR (%)	PCPP	*h*-index	FAR (%)	PCPP	*h*-index	RPR (%)	PCPP	*h*-index
USA	3,707	1 (50)	6.3	77	1 (5.9)	7.3	61	1 (6.2)	7.2	62
Japan	1,073	2 (15)	7.9	53	3 (1.6)	7.6	40	3 (1.6)	7.5	39
Hong Kong	924	3 (13)	3.9	40	2 (1.6)	4.1	30	2 (1.6)	4.2	30
Germany	832	4 (11)	8.5	50	4 (0.91)	5.5	23	4 (1.0)	5.4	23
Australia	537	5 (7.3)	8.8	49	7 (0.44)	4.4	16	7 (0.46)	4.2	16
UK	521	6 (7.1)	6.7	40	5 (0.72)	5.9	23	5 (0.73)	5.4	23
Canada	428	7 (5.8)	4.5	28	6 (0.50)	4.4	15	6 (0.55)	4.3	16
South Korea	416	8 (5.7)	12	47	12 (0.20)	6.2	11	12 (0.21)	7.0	11
Taiwan	387	9 (5.3)	11	43	8 (0.34)	7.5	18	8 (0.34)	7.6	18
France	327	10 (4.5)	8.1	34	10 (0.25)	3.6	10	10 (0.25)	3.6	10
Russia	322	11 (4.4)	16	48	9 (0.27)	10	19	9 (0.26)	10.2	19
India	290	12 (3.9)	15	45	18 (0.058)	7.2	8	18 (0.063)	6.7	8
Switzerland	267	13 (3.6)	14	43	17 (0.071)	12	4	16 (0.076)	11.1	4
Poland	266	14 (3.6)	15	42	28 (0.017)	1.3	2	28 (0.017)	1.3	2
Austria	235	15 (3.2)	14	40	23 (0.042)	3.9	5	22 (0.042)	3.9	5
Slovenia	210	16 (2.9)	15	39	28 (0.017)	23	3	28 (0.017)	22.5	3
Sweden	208	17 (2.8)	9.9	31	13 (0.15)	4.4	12	13 (0.16)	4.2	12
Singapore	176	18 (2.4)	4	22	10 (0.25)	4.6	13	10 (0.25)	4.2	13
Italy	158	19 (2.2)	9.6	24	14 (0.087)	4.3	7	14 (0.10)	3.8	7
Netherlands	135	20 (1.8)	8.3	19	14 (0.087)	6	6	15 (0.080)	6.2	6

TP: the number of total articles; % TP: the share in total articles; CPR (%), FAR (%), RPR (%): internationally collaborated articles, first author articles, corresponding author articles in total articles

Table 4: A Comparison of National Taiwan University and Peking University Research Performances with Two Indicators and Citations

Indicator	International collaboration		Inter-institutional collaboration	
	NTU	PKU	NTU	PKU
CP-PCPP	6.65	6.49	4.63	4.76
IP-PCPP	3.48	3.26	2.96	3.71
All-PCPP	4.13	4.19	4.13	4.19
CP *h*-index	81	88	94	98
IP *h*-index	81	81	59	68
All *h*-index	98	106	98	106
Top cited in CP	933	654	933	654
Top cited in IP	912	555	912	555
Top cited in all	933	654	933	654
Total citations in CP	13,263	14,448	16,792	17,034
Total citations in IP	10,851	11,970	5,872	8,720
Total citations in All	18,400	20,501	18,400	20,501

CP: collaborative articles; IP: Independent articles; PCPP: peak year citations per publication

Table 5: National Taiwan University's Top 15 Most Collaborative Institutes from 2000 to 2009

Institute	TP	CPR (%)	PCPP	*h*-Index	FAR (%)	PCPP	*h*-Index	RPR (%)	PCPP	*h*-Index
National Taiwan University Hospital, Taiwan	3,334	1 (19)	4.0	61	1 (6.8)	3.5	47	1 (7.6)	3.5	50
Academia Sinica, Taiwan	2,932	2 (16)	4.4	59	2 (5.2)	4.6	44	2 (5.2)	4.6	44
National Central University, Taiwan	688	3 (3.9)	5.4	35	8 (0.68)	2.8	15	6 (0.69)	2.8	15
National Yang Ming University, Taiwan	661	4 (3.7)	3.9	34	10 (0.60)	3.1	18	10 (0.57)	3.0	18
National Cheng Kung University, Taiwan	589	5 (3.3)	3.4	30	3 (0.87)	3.3	21	3 (0.86)	3.3	20
National Tsing Hua University, Taiwan	574	6 (3.2)	4.7	35	4 (0.79)	6.3	26	4 (0.80)	6.3	26
Taipei Medical University, Taiwan	512	7 (2.9)	3.0	27	5 (0.70)	2.9	19	8 (0.67)	3.0	19
National Chiao Tung University, Taiwan	494	8 (2.8)	3.4	29	6 (0.70)	2.7	20	5 (0.70)	2.5	20
National Chung Hsing University, Taiwan	428	9 (2.4)	3.7	22	9 (0.61)	2.8	13	9 (0.61)	2.8	13
Chinese Academy of Sciences, China	419	10 (2.4)	12	50	16 (0.29)	5.3	17	17 (0.29)	5.5	17
Chang Gung University, Taiwan	415	11 (2.3)	3.3	27	12 (0.53)	2.8	13	13 (0.51)	2.7	13
National Taiwan Normal University, Taiwan	395	12 (2.2)	3.8	26	11 (0.54)	3.9	19	11 (0.54)	3.8	18
National Health Research Institutes, Taiwan	391	13 (2.2)	5.9	36	18 (0.29)	6.9	18	17 (0.29)	6.7	17
National Sun Yat Sen University, Taiwan	367	14 (2.1)	2.7	21	7 (0.69)	2.7	17	6 (0.69)	2.6	16
University of Tokyo, Japan	367	14 (2.1)	14	49	68 (0.077)	5.1	5	64 (0.078)	5.1	5

TP: the number of total articles; % TP: the share in total articles; CPR (%), FAR (%), RPR (%): internationally collaborated articles, first author articles, corresponding author articles in total articles

Table 6: Peking University's Top 15 Most Collaborative Institutes from 2000 to 2009

Institute	TP	CPR (%)	PCPP	*h*-Index	FAR (%)	PCPP	*h*-Index	RPR (%)	PCPP	*h*-Index
Chinese Academy of Sciences, China	3135	1 (20)	4.2	63	1 (4.6)	3.9	39	1 (4.6)	3.9	39
University of Science and Technology of China, China	474	2 (3.0)	7	49	14 (0.26)	2.8	11	14 (0.26)	2.8	11
Tsing Hua University, China	447	3 (2.9)	4.2	30	2 (0.69)	4	21	2 (0.67)	4.1	20
Beijing Normal University, China	399	4 (2.6)	3.4	25	3 (0.65)	3.2	19	4 (0.64)	3.3	19
Shandong University, China	388	5 (2.5)	2.9	31	4 (0.64)	2.5	14	3 (0.64)	2.4	14
Nankai University, China	306	6 (2.0)	3.3	32	9 (0.38)	3.3	15	9 (0.37)	3.3	15
University of Tokyo, Japan	301	7 (1.9)	8.9	44	59 (0.092)	4.9	8	67 (0.080)	5.5	7
University of Hawaii, USA	294	8 (1.9)	11	44	196 (0.029)	8.1	5	199 (0.029)	8.1	5
Hong Kong University of Science & Technology, Hong Kong	270	9 (1.7)	4	27	7 (0.42)	3.8	17	7 (0.41)	3.8	17
Seoul National University, South Korea	264	10 (1.7)	8.7	45	108 (0.054)	5.5	5	109 (0.055)	5.5	5
Zhejiang University, China	263	11 (1.7)	5.1	28	29 (0.16)	4	11	32 (0.15)	4.1	10
Tokyo Institute of Technology, Japan	261	12 (1.7)	11	46	258 (0.021)	28	5	265 (0.021)	28	5
Tohoku University, Japan	257	13 (1.6)	7.4	40	97 (0.058)	7.1	5	88 (0.063)	6.7	6
Wuhan University, China	256	14 (1.6)	4.2	27	15 (0.26)	3.8	12	16 (0.25)	3.9	11
Korea University, South Korea	250	15 (1.6)	8.4	45	475 (0.0083)	0	0	495 (0.0084)	0	0

TP: the number of total articles; % TP: the share in total articles; CPR (%), FAR (%), RPR (%): internationally collaborated articles, first author articles, corresponding author articles in total articles

Comparison of Research Outputs of Two Institutes in ESI

The Essential Science Indicators (ESI) of the Institute of Scientific Information is a resource that enables researchers to conduct ongoing, quantitative analyses of research performance and track the trends in science (Small 2004). The citation thresholds were set to select roughly the same proportion of entities from each field. For institutes the top 1% of names was selected for each of the fields. Table 7 compares the number of papers in each field listed in ESI ranking within the universities. We compared the difference in performance between most citied paper (MC = most cited times) and publications (TP = number of papers in each field). The NTU contented 16 fields of ESI papers, the most productive field was clinical medicine (43 papers). The fields of chemistry (MC = 254), engineering (MC = 517), biology & biochemistry (MC = 261), and computer science (MC = 94) in NTU were the most highly cited papers listed in Taiwan ESI. The higher percentage in NTU of Taiwan ESI papers was shown in geosciences (55%), chemistry (42%), and materials science (31%). The PKU papers in the fields of plant & animal science, biology & biochemistry, and chemistry provided the outstanding performance. On the contrary, the less focus field in China publication was engineering (1.9%).

CONCLUSION

A bibliometrics method of evaluating universities' scientific research by PCPP and *h*-index was applied to explore the comparison of NTU and PKU scientific performance throughout the period from 2000 to 2009. Although NTU had been taken the lead of PKU in publication outputs and PCPP values at the beginning of 21st century, PKU was active in recent years and ahead of NTU both in publication outputs and PCPP values in 2009. Electrical & electronic engineering was the main research field for NTU while PKU published more articles in the fields of chemistry and physics. Materials science was the new research field for both universities. The collaboration, especially international collaboration, can enhance the PCPP and *h*-index values and USA was the most collaborated country with both universities. The collaborated countries with NTU focused in Asia, and collaborated countries with PKU distributed widely. More countries collaborated with NTU but PKU centered on specific countries. The *h*-index values indicated that PKU was superior to NTU. The NTU had a close inter-institutional relationship with Taiwan institutes, while PKU cooperated more extensively. The inter-institutional collaboration for PKU changed obviously, especially with Tsing Hua University. The *h*-index is size dependent and the PCPP may be an indicator for evaluation of research performance. The 16 and 15 fields were provided in ESI by NTU and PKU respectively.

Table 7: The ESI Performances of National Taiwan University and Peking University

NTU Field	MC	TP	TW (MC)	TW (TP)	% TW	PKU Field	MC	TP	CN (MC)	CN (TP)	% CN
clinical medicine	986	43	133	1,255	3.4	chemistry	612	70	612	828	8.5
chemistry	254	27	254	65	42	physics	630	53	2,891	633	8.4
physics	270	30	896	107	28	clinical medicine	548	15	1,809	346	4.3
engineering	517	35	517	225	16	biology & biochemistry	665	6	665	89	6.7
biology & biochemistry	261	2	261	11	18	geosciences	124	28	1,122	217	13
materials science	157	27	530	87	31	materials science	326	26	864	504	5.2
geosciences	302	11	453	20	55	molecular biology & genetics	383	3	5,745	45	6.7
molecular biology & genetics	145	1	1,535	5	20	engineering	199	17	583	906	1.9
plant & animal science	35	2	734	24	8.3	neuroscience & behavior	65	1	282	16	6.3
environment/ecology	160	3	215	18	17	plant & animal science	1171	13	1,171	165	7.9
pharmacology & toxicology	71	1	130	5	20	environment/ecology	250	6	256	77	7.8
microbiology	37	1	946	7	14	pharmacology & toxicology	87	3	250	34	8.8
agricultural sciences	42	2	157	17	12	mathematics	72	9	302	299	3.0
neuroscience & behavior	104	1	233	4	25	computer science	125	8	304	156	5.1
computer science	94	11	94	50	22	general social sciences	2	1	137	29	3.4
general social sciences	54	1	190	17	5.9						

MC: Most citation; TP: Total publications; TW: Taiwan; CN: China; %; percentage of total publication

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