Scientometrics (2013) 96:259–276
DOI 10.1007/s11192-012-0912-5

Comparison of independent research of China's top universities using bibliometric indicators

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Received: 26 August 2012 / Published online: 24 November 2012
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Abstract The institutionally independent publications of Tsinghua University and Peking University were compared by two main indicators namely peak-year citations per publication and *h*-index, based on the data extracted from the Science Citation Index Expanded, Web of Science from 1974 to 2011. Analyzed aspects covered total publication outputs, annual production, impact, authorships, Web of Science categories, journals, and most cited articles. Results shows that the two universities were in the same scale based on the peak-year citations per publication, the *h*-index, and top cited articles with no less than 100 citations. Publication of the top three most productive Web of Science categories differed between these two universities. Tsinghua University published more articles in applied science and engineering fields, while Peking University had more basic science articles. In addition, article life was applied to compare the impact of the most cited articles and single author articles of the two universities.

Keywords Scientometrics · Peak-year citations per publication · *h*-Index · Science indicators · Web of science

Introduction

Without publication, science is dead (Piel 1986). van Raan (1999) noted that "science would not exist, if scientific results are not communicated". Publication performance of institutions has attracted much attention for more than three decades (Anderson et al. 1978; Mokhnacheva and Kharybina 2011) in various countries, such as India (Nagpaul 1995), Brazil (Zorzetto et al. 2006), and UK (Sullivan et al. 2011). China, as the world's most populous country, has moved into the front ranks in science and technology in recent years

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(He 2009; Mervis 2010). The bibliometric analysis of institutions could provide guidance for research management (Leonardelli and Belmin 2008). China's research institutional contributors—universities calls for attention. Many studies were conducted on some particular universities of Harbin Medial University (Zhang 2000), Traditional Chinese medicine colleges and universities (Huang et al. 2006), South China Normal University (Wang 2007), and South China Agriculture University (He 2007) for the quantity, coauthorship, category, academic influence, and management policy. However, the most two famous universities in China: Peking University (PKU) and Tsinghua University (THU) with a long history, more typically, remain systematically underinvestigated for comparison. PKU and THU have been consistently ranked top in China based on the Times Higher Education World University Rankings (http://www.timeshighereducation.co.uk/world-university-rankings), and the Academic Ranking of World Universities by researchers at the Center for World-Class Universities of Shanghai Jiao Tong University (http://www.shanghairanking.cn). Both universities experienced a long development with over 100 years of history. Founded in 1898, PKU was the first national university covering comprehensive disciplines in China, and served as the highest administration for education at the beginning of its founding (http://english.pku.edu.cn/AboutPKU/History/). THU was founded a little more than a decade after PKU in 1911 with the support of American Boxer Indemnity Funds and it functioned at first as a preparatory school for those students who were sent by the government to study in the United States (http://www.tsinghua.edu.cn/publish/then/5779/index.html). These two universities were called together as the phrase "Beida Tsinghua" by Chinese, roughly equivalent to Oxbridge in the British context or Harvard and Yale in the United States (Hayhoe 2005). In two important projects by Chinese Ministry of Education: Project 211 in 1990 and Project 985 in 1998, PKU and THU were injected the highest and the same funding (http://www.moe.edu.cn/). To compare the two universities with an in-depth analysis, their independent publications without any institutional collaboration were abstracted for this study.

Publication performance of institutions can be evaluated by bibliometric indicators (Moed et al. 1985; van Raan 1999). Aiming at assessing the research performance of institutions, some bibliometric indicators, namely, numbers of publications, citations, self-citations, citations per publication, relative citation rates, *h*-index, and journal impact factors have been widely applied. The properly applied indicators would be helpful on the research performance and nature of research carried out in university departments (Zachos 1992). The early 1970 s' study was ranking of entire institutions by the bibliometric ratings including the number of university papers, influence per paper, total influence, the product of number of papers and influence per paper (Anderson et al. 1978). The later studies concentrated on performance differences between departments and individual researchers within disciplines of German university sector (Daniel and Fisch 1990), Indian universities (Nagpaul 1995), and Belgium (Van den Berghe et al. 1998). Simultaneously, comparison of two Greek university departments was based on their similarities with a number of publication and citation indicators, especially self- and in-house citations (Zachos 1992). In the 2000s' studies, not only various data covering budget, teaching (Schloegl et al. 2003), graduate programs, graduates, advisors (Zorzetto et al. 2006), and academic staff (Usang et al. 2007), but also more kinds of research indicators related to number of publications and citations were used, such as number of citations per person, relative citation rate, and relative subfield citedness (Aksnes and Taxt 2004), disciplinary strengths (Pouris 2007), and *h*-index (Annibaldi et al. 2010) were employed. As for the comparison of different institutions, the scholars recently focused on the number of published articles per year, number of citations per year, number of citations, *h*-index, impact factors, top authors, top

journals, and categories (Annibaldi et al. 2010; Fakhree and Jouyban 2011; Wang et al. 2011a). Journal impact factor provides an accessible quality indicator of science journal publishing, and allow people to scale for institutional size in terms of output and research staff (Davis and Royle 1996). The impact factor values and *h*-index should set no more than minimum requirements to be considered and help to limit the possibility of over or underestimating the value (Annibaldi et al. 2010). Bibliometric indicators *h*-index (Hirsch 2005), peak-year citations per publication, and journal impact factors were applied to compare these two university's performances.

The main target of this study was to investigate and compare the THU and PKU publication performances, based on their own independent articles in the Science Citation Index Expanded. The investigation of independent research without any national and international collaboration could be considered more typical in their own research performance.

Methodology

Data collection

Documents reported in this study were derived from the online version of Science Citation Index Expanded (SCI-Expanded) Thomson Reuters Web of Science database. According to Journal Citation Reports (JCR) of 2011, it indexes 8,281 with citation references across 176 Web of Science categories in the science edition. First of all, Peking University (Peking Univ and Beijing Univ) and Tsinghua University (Tsing Hua Univ and Tsinghua Univ) were searched in terms of address within the publication year limitation from 1899 to 2011 based on SCI-Expanded (updated on 03 August 2012). Secondly, only the article of document type was the retrieved for the subsequent analysis. Thirdly, independent publications of the two universities were estimated by the affiliation of all authors to the articles. Except Peking University (PKU) and Tsinghua University (THU), all the articles contributed by the other organizations were excluded. Finally, 14,336 articles for PKU were refined by the affiliation of "Peking Univ" and "Beijing Univ" and excluding "Tsing Hua Univ" and "Tsinghua Univ". The same method was used to obtain the 17,097 articles for Tsinghua University.

Analyzing structure and indicators

The analytic structure of characteristics of independent research of THU and PKU is presented in Fig. 1. First, the analysis of overall scientific performance of THU and PKU were conducted. The second section dealt with annual production, with major focus on its quantity, quality, and co-authorship. THU and PKU favored journals and Web of Science categories were identified in the third section, respectively. Finally, the most cited papers in THU and PKU, as well as most cited single author articles are examined as a statement of discipline emphases and impact.

The indicators displayed in Fig. 1 were explained. Single author article was assigned if the article was published by only one author. SP stands for single author articles, while TP represents the number of total articles. AU which could be employed to characterize co-authorship is authors per article. In terms of citations, TC2011, the total number of citations since publication to 2011 (Chuang et al. 2011; Ho 2012), was employed due to its invariability and repeatability (Fu et al. 2012). The *h*-index related to total citations were

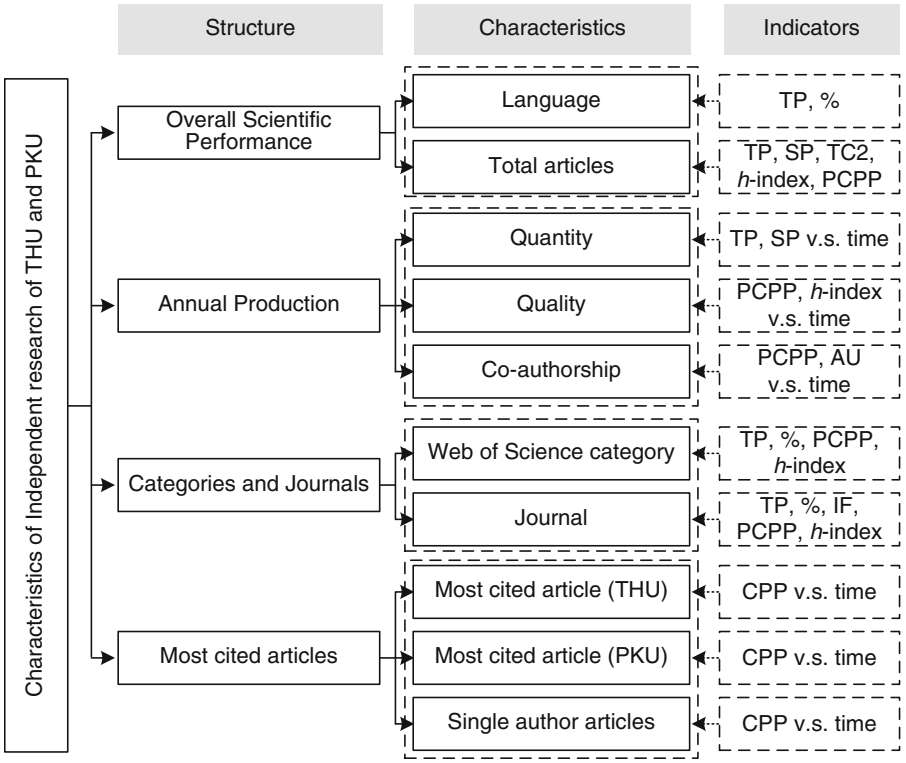

Fig. 1 Analytic structure of Tsinghua University and Peking University's independent research

thus calculated by the newly developed indicator, TC2011. *h*-index is defined by the h of Np papers having at least h citations each and the other (Np-h) papers have h citations each (Hirsch 2005). However, *h*-index was observed to be size dependent, correlated with the total number of citations and publications (van Raan 2006). A single indicator is not enough to assess multi-dimensional research (Martin 1996).

Another indicator, citations per publication (CPP) as the citations divided by publications was therefore provided to supplement the shortcomings of *h*-index. Figure 2 shows the relationship between the CPP and the number of years since its publication for the articles published by PKU and THU, respectively. The frequency of being cited was the highest in the second full year since its publication year for both PKU and THU, and began to decrease thereafter. Similar peak-year phenomena of citation history has also been observed in the typical cited article (Garfield 1972), and some medical topics (Chiu and Ho 2005; Chuang et al. 2007). The peak position depended on the research disciplines and might be shifted to three or more years (King 1988; Hsieh et al. 2004; Li and Ho 2008; Zhang et al. 2009; Wang et al. 2011a; Chuang et al. 2012). Here, the variable TC2, total citations from publication year to second full year, was used to calculate the peak-year citation per publication (PCPP) to assess the impact of articles. For instant, a TC2 for the year 2009 would be the number of times being cited from 2009 to the end of 2011 for all the articles published in 2009. Articles published after 2009 would not have the values of TC2. The PCPP assesses the visibility or impact of publications, much more appropriate

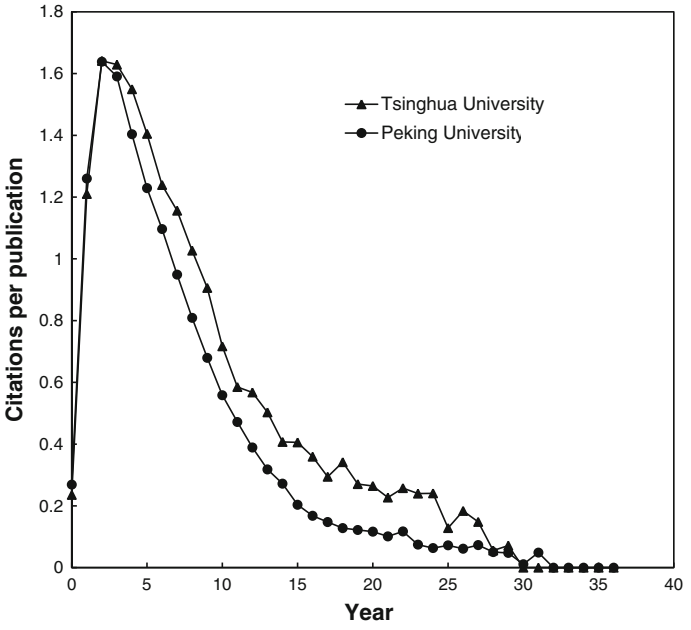

Fig. 2 Citations per publication by article life

than the previous used indicator CPP. The accumulated time for CPPs decreased for the annual articles from 1992 to 2011, and CPPs would experience a decreasing trend in the latest years due to no enough time for citations. As for PCPP, the accumulated time for citations was always the same of 2 years (TC2), which could eliminate the time-changing factors. Thus, *h*-index and PCPP were used to compare research performance for the two universities. The reported impact factor (IF) of each journal was obtained from the 2011 JCR.

Results and discussion

Overall scientific performance

Total number of THU independent articles was 17,097, including 15,415 (90 %) in English, 1,674 (10 %) in Chinese, and Japanese (4), German (3), and Catalan (1). The number of PKU independent articles was 14,336, including 12,607 (88 %) in English, 1,713 (12 %) in Chinese, and Japanese (14), Russian (1), and French (1).

Comparison of THU and PKU research performances were examined by number of articles, single author articles, highest TC2011, *h*-index and PCPP in Table 1. Since PCPPs were calculated based on the articles before 2010, characteristics of the articles during 1974 and 2009 were also displayed. Although THU published more articles than PKU, there were more single author articles from PKU than THU. However, their *h*-index, PCPP, and number of top articles (TC2011 $\geq$100) were very closely. These two renowned universities could be considered pretty even according to these indicators. The difference in the number of publications or the average citation index was also insignificant in a

Table 1 Comparison of Tsinghua University and Peking University Research Performance

Indicators	Tsinghua University	Peking University
Number of total articles (TP)	17,097	14,336
h-Index	97	96
Highest TC2011	1,165	719
Number of top articles (TC2011 ≥100)	91 (0.53 %)	91 (0.63 %)
Number of single author articles (SP)	1,025	1,384
h-Index	31	31
Highest TC2011	118	172
Number of top articles (TC2011 ≥100)	2	3
Number of total articles (1974–2009)	14,085	11,911
TC2	41,504	36,373
PCPP	3.0	3.1
Number of single author articles (1974–2009)	919	1,269
TC2	1,281	1,525
PCPP	1.4	1.2

comparison of two groups with widely differed reputation (Makino 1998). Both *h*-index and PCPP for single author articles were lower than total articles, which indicated that collaboration of co-authors played an important role in enhancing the impact of articles. In addition, the highest TC2011 1,165 of THU was found from the article "synthesis of gallium nitride nanorods through a carbon nanotube-confined reaction" (Han et al. 1997) published by the Department of Physics and Center of Atomic and Molecular Sciences. The corresponding author of this article was Prof. Shoushan Fan who is the academician of Chinese Academy of Sciences. Article with the highest TC2011 (719) in PKU was "ultraviolet-emitting ZnO nanowires synthesized by a physical vapor deposition approach" (Kong et al. 2001) published by the Department of Physics and the Electron Microscopy Laboratory. The most cited THU single author article with TC2011 = 118 was "fuzzy random chance-constrained programming" (Liu 2001) by Prof. Baoding Liu in Department of Mathematical Sciences. "Second-order kinetic model for the sorption of cadmium onto tree fern: a comparison of linear and non-linear methods" (Ho 2006) with TC2011 = 172 was the most cited single author articles published by Prof. Yuh-Shan Ho in Department of Environmental Sciences in Peking University.

Annual production

The characteristics of annual production of THU and PKU including number of total articles and single author articles, PCPP, *h*-index, and co-authorship were identified. Both universities published the first article in SCI-Expanded in 1974. The growth trends of total independent articles and the single author articles of both universities are displayed in Fig. 3. In earlier years (1974–1999), PKU was more active in the publication of independent articles and single author articles. However, THU has increased at a quicker pace than PKU after 2000, and now still produced more articles according to total articles and was about the same with PKU with respect to single author articles. The early restructuring of higher education might be the reason of more articles of PKU in earlier years. The paths of PKU and THU diverged dramatically in 1952 due to China's restructuring of higher

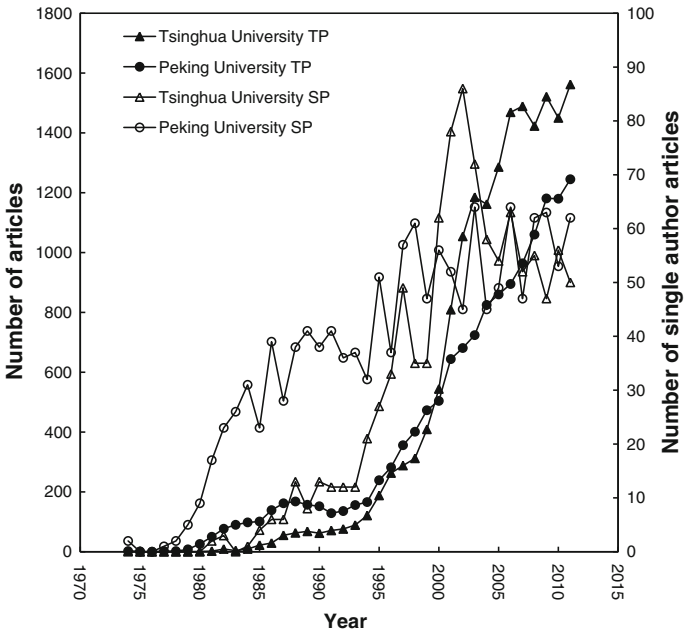

Fig. 3 Publication trends for number of total articles and single author articles

education. THU was stripped of its faculties of arts and sciences and shaped into a polytechnical university, with multiple departments of engineering; it produced graduates who moved into important positions of power within the bureaucracy (Pan 2004). PKU, by contrast, lost its engineering, medical, and agricultural faculties and had departments only in the pure sciences and arts, and its graduates typically became researchers, writers, and university teachers (Hayhoe 2005). Today, while THU's teaching is still focused on engineering, it concurrently offers degrees in other sciences, the liberal arts, management and law (http://www.tsinghua.edu.cn/publish/then/5779/index.html).

The impact of articles in PKU and THU was assessed in terms of PCPP and *h*-index. *h*-index was proposed to characterize the scientific output and impact of a researcher (Hirsch 2005), and has been applied in the comparison of departments (van Raan 2006) and Chinese universities' publications (Luan et al. 2010). Likewise, PCPP with "peak-year citations" (TC2) was also used to evaluate publication performance of universities (Chuang et al. 2007; Wang et al. 2011a). Figure 4 shows that *h*-index and PCPPs were increasing especially in last two decades, which indicated that the articles published in recent years obtained more attention than that in earlier years. This might be attributed to more possibilities of being cited by the rapid increase of journals from 5,686 in 2000 to 8,281 in 2011 journals in SCI-Expanded. The fluctuation in 1970s and 1980s might due to the low productivity. For example, only one top cited articles of 1980 in THU made the PCPP to be a high value of 4. The low level of two universities' scientific production in 1970s and 1980s was possibly influenced by the Cultural Revolution. Cultural Revolution (1966–1976), also known as "10 year catastrophe", had devastating influence on Chinese science and technology. Universities were shut down entirely from 1966 to 1972 (Treiman 2002), and intellectuals (including scientists and engineers) were sent to the countryside or to factories to work. China's scientific work suffered considerably, reflected in its output of

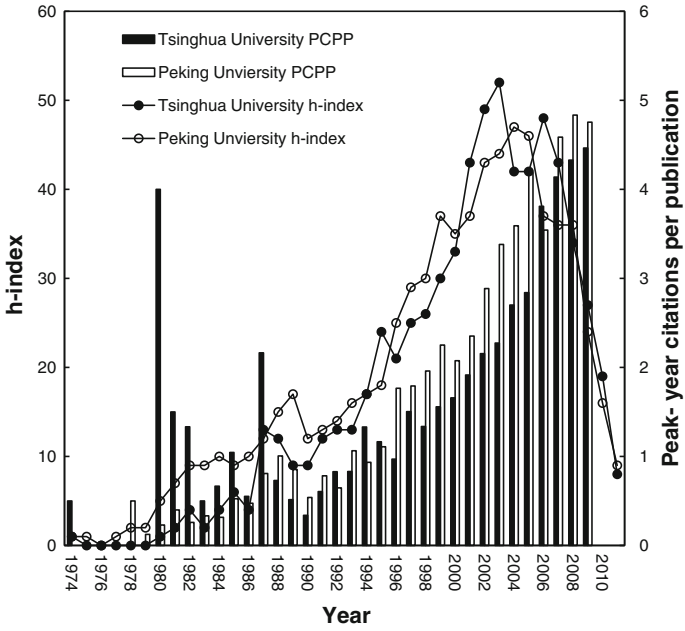

Fig. 4 PCPP and *h*-index trends of Tsinghua University and Peking University

scientific literature. In 1973, only one Chinese paper appeared in the world's 2,300 most central journals in the SCI; however, scientific papers grew exponentially after restrictive policies were loosened (Frame and Narin 1987). As Chinese top universities, PKU and THU also suffered a lot from the Cultural Revolution, and only had their first scientific publications at the end of this activity. Furthermore, the decrease in 2003–2010 of PCPP might be explained in part by the less time for their articles to accumulate citations (Picknett and Davis 1999). H-indices of these two universities were too closely to tell the difference. Although in the earlier period before 1988 the PCPPs of THU were like to be higher than that of PKU, overall the PCPPs of PKU were higher than that of THU in recent two decades. In addition, the greater production of PKU and THU in 2000s could be partly explained by that PKU merged with Beijing Medical University in 2000, (http://english.pku.edu.cn/AboutPKU/History/), while in 1999 THU opened the School of Arts and Design by merging with the Central Academy of Arts and Design (http://www.tsinghua.edu.cn/publish/then/5779/index.html).

Seventy percent of THU articles had two to four authors while three, the most occurring coauthor number, accounted for 27 % of the total. A similar phenomenon was found for PKU. Two to four authorships were 55 % articles. Besides, three of authorship was the most frequent with 22 % articles. Figure 5 shows PCPPs and numbers of authors per article (AU) from 1974 to 2009. Similar growth trends of PCPPs and numbers of authors per article for both universities were found, especially in last two decades. The number of authors per article increased from 2.7 in 1990 to 3.9 in 2009 (THU), with a number of 3.8 authors per article ranging from 1 to 14. A slightly different increase from 2.5 to 4.6 in the same period (PKU) with a number of authors per article was 3.0, ranging from one to 21. Among all the articles of two universities, the article with the most authors of 21 was titled "performances of a beta-delayed neutron detection array at Peking University" of *Nuclear*

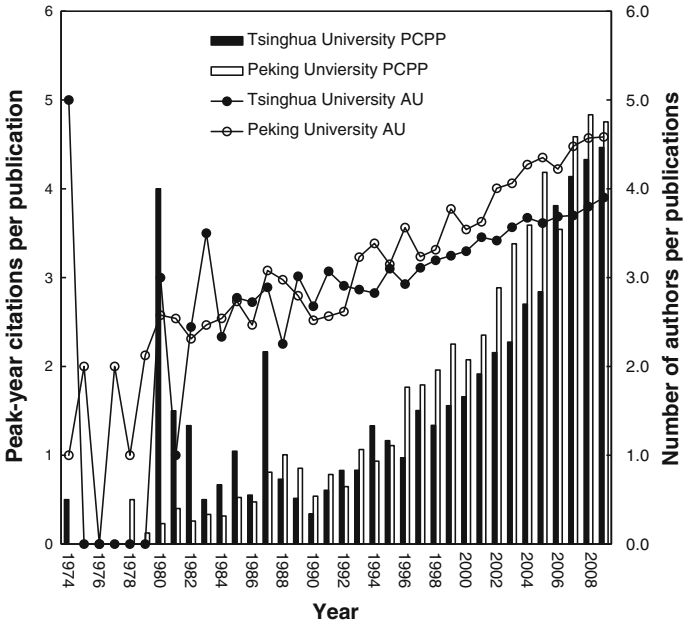

Fig. 5 PCPP and numbers of authors per article for Tsinghua University and Peking University

Instruments & Methods in Physics Research Section A-Accelerators Spectrometers Detectors and Associated Equipment, and published in 2009 by School of Physics (Lou et al. 2009). PKU research usually involved more authors and held higher PCPP than THU.

Web of science categories and journals

Based on the classification of Web of Science categories in 2011, the publication output data of THU was distributed in 148 categories while 168 categories for PKU. The performance of top 20 productive categories obtained from SCI-Expended of THU and PKU were exhibited in Table 2. The three most productive Web of Science categories in THU were multidisciplinary materials science (2,460; 17 %), applied physics (1,556; 11 %), electrical and electronic engineering (1,282; 9.1 %). The three most productive categories in PKU were physical chemistry (1,298; 11 %), multidisciplinary chemistry (1,297; 11 %), and multidisciplinary physics (998; 8.4 %). Accordingly, the research of PKU found that the highest cited papers cover physics and chemistry fields only, followed by materials sciences, electrical engineering and interdisciplinary field, like nanotechnology (Zhu et al. 2004). The results show that THU and PKU had different focus with eight different categories in Table 2. PKU published more articles in basic sciences including 11 chemistry and physics related categories while THU had seven categories. The centennial celebration of chemistry at PKU (Gao et al. 2010), and chemistry and physics in materials science on the occasion of THU's centennial anniversary (Zhang 2011) have also been reported with an overview of their great development. By contrast, five of THU's top 20 categories were related to engineering, while there was only one category of PKU concerning engineering. This is consistent with that the THU focused on engineering, and PKU concentrated more on pure sciences, which was caused by the early restructuring of

Table 2 Top 20 Web of Science categories of Tsinghua University and Peking University

Web of Science category	Tsinghua University			Web of Science category	Peking University		
	TP (%)	PCPP	*h*-Index		TP (%)	PCPP	*h*-Index
Multidisciplinary materials science	2,460 (17)	3.0	61	Physical chemistry	1,298 (11)	4.3	62
Applied physics	1,556 (11)	4.2	53	Multidisciplinary chemistry	1,297 (11)	4.2	63
Electrical and electronic engineering	1,282 (9.1)	2.0	34	Multidisciplinary physics	998 (8.4)	2.1	29
Physical chemistry	1,028 (7.3)	5.9	57	Mathematics	718 (6)	0.72	21
Chemical engineering	949 (6.7)	2.9	36	Multidisciplinary materials science	710 (6)	5.8	56
Optics	901 (6.4)	2.5	27	Biochemistry and molecular biology	671 (5.6)	3.6	38
Metallurgy and metallurgical engineering	899 (6.4)	1.3	24	Applied physics	620 (5.2)	5.1	46
Multidisciplinary chemistry	787 (5.6)	6.1	56	Multidisciplinary sciences	619 (5.2)	0.80	17
Multidisciplinary physics	718 (5.1)	2.3	22	Applied mathematics	553 (4.6)	1.0	20
Condensed matter physics	673 (4.8)	4.7	46	Condensed matter physics	540 (4.5)	3.9	39
Mechanics	641 (4.6)	1.8	32	Analytical chemistry	479 (4)	4.3	40
Mechanical engineering	616 (4.4)	1.7	30	Polymer science	385 (3.2)	3.4	30
Applied mathematics	495 (3.5)	1.0	22	Electrical and electronic engineering	372 (3.1)	2.0	19
Polymer science	450 (3.2)	3.4	29	Organic chemistry	343 (2.9)	4.9	31
Mathematics	406 (2.9)	1.0	19	Pharmacology and pharmacy	306 (2.6)	3.8	25
Biochemistry and molecular biology	397 (2.8)	2.9	31	Optics	305 (2.6)	2.3	18
Nanoscience and nanotechnology	384 (2.7)	6.9	42	Biophysics	279 (2.3)	3.4	28
Thermodynamics	343 (2.4)	2.4	28	Atomic, molecular and chemical physics	265 (2.2)	3.5	26
Ceramics materials science	340 (2.4)	2.3	26	Particles and fields physics	263 (2.2)	2.4	14
Multidisciplinary engineering	339 (2.4)	1.4	18	Environmental sciences	256 (2.1)	4.8	28

higher education (Hayhoe 2005). The highest *h*-index 61 was conducted by multidisciplinary materials science while the highest PCPP 6.9 by nanoscience and nanotechnology in the top 20 Web of Science categories in THU. For PKU, the highest PCPP was in the categories of multidisciplinary materials science (PCPP = 5.8) and the highest *h*-index was multidisciplinary chemistry (*h*-index = 63). These top two universities obtain some achievements, such as radiation/detection technology (Kang 1978), molecular simulation software package (Hou and Xu 2001), compact AMS system (Liu et al. 2007), and X-pinch experiments with pulsed power generator (Liu et al. 2008) in related top categories.

The total numbers of 17,097 THU articles were published in 1,805 journals, while researchers in PKU published 14,336 articles in 2,065 journals. Large percentages of articles of THU (3,423 articles; 20 %) and PKU (3,998 articles; 28 %) were published in China's own journals. As for THU, eight articles of two journals having the IFs more than 30 were *Nature* with five articles and *Science* with three articles. In terms of PKU, there were six articles in four journals with IFs more than 30 including *New England Journal of Medicine*, *Lancet*, *Nature*, and *Cell*. Table 3 presents top ten journals in THU and PKU, including the number of articles with respective percentages, the IFs, PCPP, and *h*-index. PCPPs analyzed in this study employ 2 years for citations, the similar with the calculation for IF. Similar trends appeared according to these three indicators. The coefficients of determination between the *h*-index and the IF of journal outputs were calculated with their coefficient of determinations of 0.81 and 0.63 (Wang et al. 2011b). *Applied Physics Letters* in the top ten journals had the highest IF of 3.844 in both THU and PKU. Eight out of the top ten journals of THU and six of top ten journals of PKU had higher PCPPs than IFs, which indicated that the research usually made positive contribution to their publication journals. The most popular journal in THU *Rare Metal Materials and Engineering* (IF = 0.164) which published 447 articles with PCPP of 4.7 and *h*-index of 5. The following two journals in the leading position were *Chinese Physics Letters* (PCPP = 1.71; *h*-index = 12) and *Applied Physics Letters* (PCPP = 7.67; *h*-index = 35). In the case of PKU, the most active journals were *Acta Physico-Chimica Sinica* with 491 articles (PCPP = 0.644; *h*-index = 11), *Chinese Science Bulletin* with 324 articles (PCPP = 0.637; *h*-index = 11) and *Chinese Physics Letters* with 324 articles (PCPP = 1.39; *h*-index = 12).

Most cited articles

The patterns of citation life cycles of top cited articles could provide the characteristics for the top articles (Aksnes 2003). The life citation curves of six top articles with the highest citations from THU and PKU are displayed in Figs. 6 and 7. Five out of six articles were published in the 2000s, while only one article was in 1997 for THU and 1995 for PKU. Three articles were published by the Department of Chemistry, and three articles by Department of Physics, Department of Mathematical Sciences, and Department of Biological Sciences and Biotechnology at THU, respectively. The Department of Chemistry, founded in 1926, has three academicians of Chinese Academy of Sciences or Chinese Academy of Engineering, and has become a well-recognized center for scientific research in chemistry in China (http://www.chem.tsinghua.edu.cn). For PKU, two articles were contributed by College of Chemistry and Molecular Engineering, two by Department of Chemistry, and two by Department of Physics and Department of Geophysics, respectively. In fact, Department of Chemistry belongs to College of Chemistry and Molecular Engineering including ten members of the Chinese Academy of Sciences. The College of Chemistry and Molecular Engineering from PKU, founded in 1910 in Qing Dynasty, was the oldest institution of modern chemistry in China (Gao et al. 2010). The number of

Table 3 Top ten journals for Tsinghua University and Peking University

Journal	Tsinghua University				Journal	Peking University			
	TP (%)	IF	PCPP	*h*-Index		TP (%)	IF	PCPP	*h*-Index
Rare Metal Materials and Engineering	447 (2.6)	0.164	0.57	5	Acta Physico-Chimica Sinica	491 (3.4)	0.780	0.64	11
Chinese Physics Letters	285 (1.7)	0.731	1.7	12	Chinese Science Bulletin	324 (2.3)	1.321	0.64	11
Applied Physics Letters	283 (1.7)	3.844	7.7	35	Chinese Physics Letters	324 (2.3)	0.731	1.4	12
Chinese Science Bulletin	217 (1.3)	1.321	1.2	11	Chinese Medical Journal	250 (1.7)	0.864	1.6	13
Acta Physica Sinica	192 (1.1)	1.027	2.0	11	Acta Chimica Sinica	238 (1.7)	0.533	0.61	11
Materials Letters	185 (1.1)	2.307	2.2	21	Chemical Journal of Chinese Universities-Chinese	194 (1.4)	0.619	1.2	13
Journal of Applied Physics	166 (1)	2.168	5.0	20	Chinese Chemical Letters	163 (1.1)	0.978	0.54	6
Acta Polymerica Sinica	153 (0.89)	0.769	0.90	7	Communications in Theoretical Physics	162 (1.1)	0.747	1.2	10
Journal of the American Ceramic Society	146 (0.85)	2.272	3.9	19	Chinese Physics	152 (1.1)	N/A	4.1	14
Electronics Letters	144 (0.84)	0.965	1.3	12	Applied Physics Letters	143 (1.0)	3.844	9.6	28

N/A not available

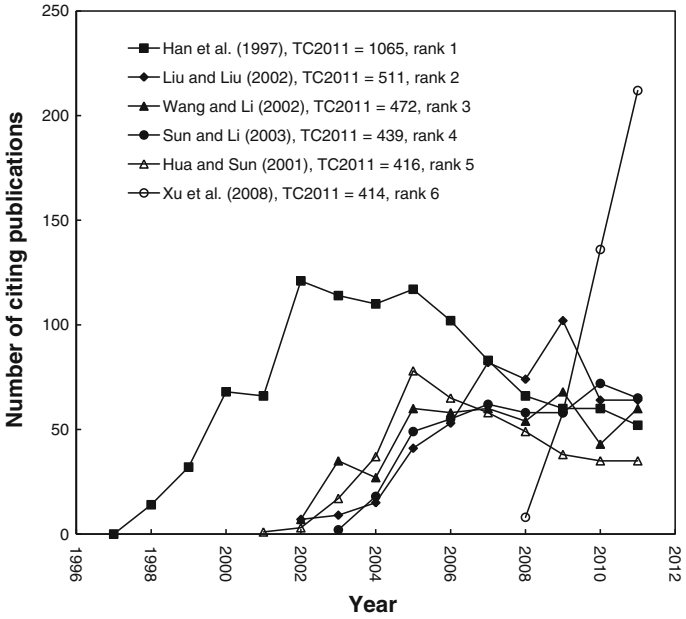

Fig. 6 The most cited articles of Tsinghua University (TC2011 >400)

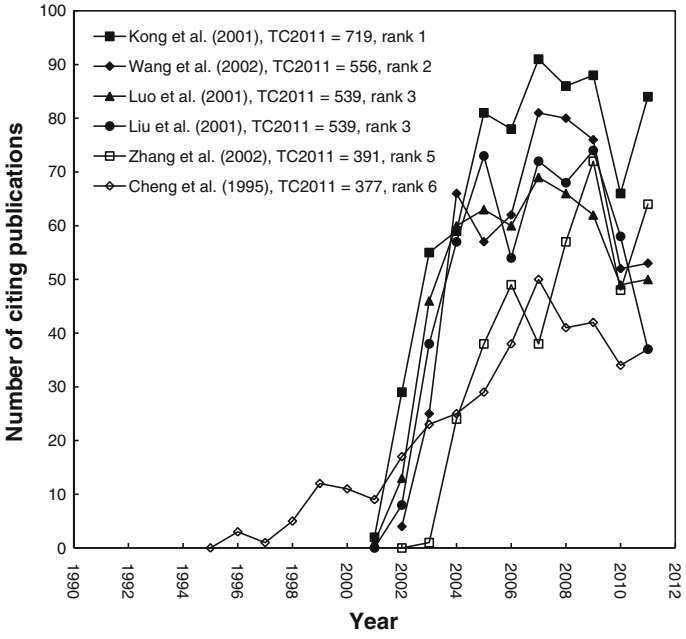

Fig. 7 The most cited articles of Peking University (TC2011 >400)

articles recruited by SCI-Expanded keeps about 400 per year since 2000, and high level articles are still increasing (http://www.chem.pku.edu.cn). In terms of THU, two articles were in *Journal of the American Chemical Society* (IF = 9.907), and one in *Science*

(31.201), *IEEE Transactions on Fuzzy Systems* (4.26), *Chemistry-A European Journal* (5.925) and *Bioinformatics* (5.468) each in multidisciplinary sciences, electronics, and chemistry related categories. With respect to PKU, two articles were published in *Analytical Chemistry* (5.856) and *Chemistry of Materials* (7.286) each, and one article contributed to *Applied Physics Letters* (3.844) and *Physics Letters A* (1.632) each in the chemistry and physics related categories. The categories top articles assigned to were consistent with the results of categories of two universities. Four of six top articles in THU and five of six top articles in PKU were about nanotechnology. China's science has become the second largest nation in citations and quantity (Leydesdorff and Wagner 2009), and its citation counts continues to grow in nanoscience and nanotechnology (Kostoff 2012). Tsinghua University and Peking University belonged to the second tier contributing to the nanotechnology of China (Kostoff et al. 2008).

Only one article "Han et al. (1997)" having more than 1,000 citations was contributed by THU. It was also the eldest top article of THU in 1997, and kept the leading of high annual citations since its publication till 2007. The article focused on synthesis of gallium nitride nanorods through a carbon nanotube-confined reaction (Han et al. 1997). The article's corresponding author Shoushan Fan as an academician of Chinese Academy of Sciences worked in Department of Physics and Center of Atomic and Molecular Sciences at THU. The latest article "Xu et al. (2008)" was published in 2008 also contributed by Department of Chemistry at THU. The annual citations of this article experienced the highest growth of 68 citations per year. The article centered on flexible graphene films via the filtration of water-soluble noncovalent functionalized graphene sheets (Xu et al. 2008). The other four articles in 2001–2003 experienced similar trends of annual citations since publication. The eldest top article of PKU was published in 1995 by Cheng et al. in the Department of Chemistry, and was titled "hydrothermal preparation of uniform nanosize rutile and anatase particles". The other five articles in 2000s increased closely in terms of annual citations. Kong et al. (2001) in Department of Physics of PKU published the top article with the highest TC2011 = 719 and C2011 = 84, which concerned ultraviolet-emitting ZnO nanowires synthesized by a physical vapor deposition approach. According to the types of citation frequency curves (Avramescu 1979), most of articles in THU and PKU were (1) initially much praised articles or (2) basic recognized work.

In addition, single author articles which were likely to be with more theoretical and greater share of initial idea were also identified in terms of most cited articles (Farber 2005). Five single author articles with TC2011 $\geq$100 were illustrated in Fig. 8. These articles were found in the categories of environmental engineering, environmental sciences, water resources, multidisciplinary physics, astronomy and astrophysics, computer science, artificial intelligence, electrical and electronic engineering, and multidisciplinary engineering. Three articles were published in 2000s, and two in 1980s and 1990s respectively. The most attractive single author article examined non-linear method for isotherms for the sorption (Ho 2006). Y.S. Ho was selected as the Chang Jiang Scholar in College of Environmental Sciences and Engineering of PKU by the Ministry of Education in 2006. Another article related to pseudo second order proposed by Ho took the lead in annual citations in 2011 in the category of chemical engineering (Ho 2012). The second position article by S.L. Zhu from Department of Physics in PKU as principal investigator of several grants from National Science Foundation and Ministry of Education was entitled "understanding pentaquark states in QCD" (Zhu 2003). The third position article by C.Y. Tu from Department of Geophysics in PKU as an academician of Chinese Academy of Sciences, concerned the damping of interplanetary alfvénic fluctuations and the heating of the solar-wind (Tu 1988). The fourth position article by B.D. Liu from Department of

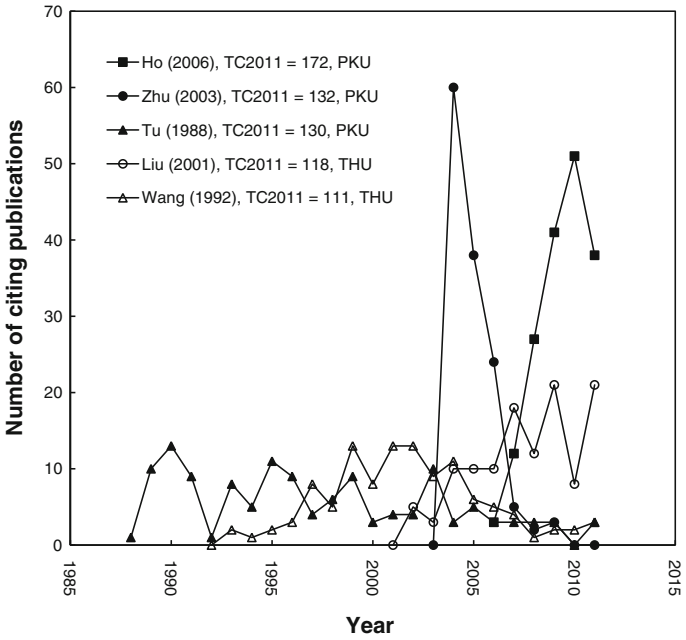

Fig. 8 Comparison of the most cited single author articles (TC2011 >100)

Mathematical Sciences of THU as National Science Fund for Distinguished Young Scholar was titled "fuzzy random chance-constrained programming" (Liu 2001). The fifth position article by B. Wang from Department of Engineering Mechanics of THU focused on three-dimensional analysis of a flat elliptic crack in a piezoelectric material (Wang 1992).

Conclusion

Peking University and Tsinghua University were pretty even with many similarities in the quantity and quality of total publications, the trend of annual production, and common co-authorship. THU published more total articles, while PKU produced more single author articles; and *h*-index and PCPP of both universities were almost the same. Cultural Revolution had devastating influence on Chinese science including two universities. They suffered from Cultural Revolution, and started to publish articles at the end of it. Both universities grew rapidly after 1990, and moved into a higher level of scientific production by merging with another institution around 2000. Two to four authorships were common in both universities. However, THU and PKU had their own predominance with respect to specific aspects in Web of Science category, journals, departments, and most cited articles. They still maintained the features by the early China's restructuring of higher education, though THU and PKU are now aiming at become the world-class comprehensive universities. THU focused on engineering while PKU concentrated on science. The most productive categories of THU were multidisciplinary materials science, applied physics, electrical and electronic engineering, and basic sciences including chemistry and physics led the PKU research. The most favored journal of THU is *Rare Metal Materials and*

Engineering, and PKU is *Acta Physico-Chimica Sinica*. Researchers in these two universities favored more in Chinese journals. Department of Chemistry of THU and College of Chemistry and Molecular Engineering of PKU maintained a high research level with most top articles. Both universities contributed a lot to China's nanoscience and nanotechnology. There is a significant correlation between a country's scientific policy and scientific activities of its institutions. These two top universities were influenced greatly by China's policy and management, and now are playing an important role to bring China's science forward.

Although the widely used indicators, namely, *h*-index and CPP have been employed to characterize the performance of THU and PKU's independent research, some limitation should also be noticed. Highly cited papers are important for the determination of the *h*-index, but once a paper is selected to belong to the top h papers, it is unimportant in the determination of h as a variable over time (Egghe 2006). *h*-index may undervalue the performance of unit with an intermediate productivity level but a high impact and a great international visibility (Costas and Bordons 2007). As for *h*-index, the big of the sample for analysis is important, while for CPP small can also be good (van Raan 2006). It is still true that science is multidimensional and therefore multidimensional methods are suggested to evaluate scientific performance (Martin 1996).

References

Aksnes, D. W. (2003). Characteristics of highly cited papers. *Research Evaluation, 12*(3), 159–170.

Aksnes, D. W., & Taxt, R. E. (2004). Peer reviews and bibliometric indicators: a comparative study at a Norwegian university. *Research Evaluation, 13*(1), 33–41.

Anderson, R. C., Narin, F., & Mcallister, P. (1978). Publication ratings versus peer ratings of universities. *Journal of the American Society for Information Science, 29*(2), 91–103.

Annibaldi, A., Truzzi, C., Illuminati, S., & Scarponi, G. (2010). Scientometric analysis of national university research performance in analytical chemistry on the basis of academic publications: Italy as case study. *Analytical and Bioanalytical Chemistry, 398*(1), 17–26.

Avramescu, A. (1979). Actuality and obsolescence of scientific literature. *Journal of the American Society for Information Science, 30*(5), 296–303.

Chiu, W. T., & Ho, Y. S. (2005). Bibliometric analysis of homeopathy research during the period of 1991 to 2003. *Scientometrics, 63*(1), 3–23.

Chuang, K. Y., Huang, Y. L., & Ho, Y. S. (2007). A bibliometric and citation analysis of stroke-related research in Taiwan. *Scientometrics, 72*(2), 201–212.

Chuang, K. Y., Wang, M. H., & Ho, Y. S. (2011). High-impact papers presented in the subject category of water resources in the Essential Science Indicators database of the institute for scientific information. *Scientometrics, 87*(3), 551–562.

Chuang, K.Y., Tunbosun, O., & Ho, Y.S. (2012). A bibliometric analysis of the Polish Journal of Environmental Studies (2000–2011). *Polish Journal of Environmental Studies*, *21*(5), 1175–1183.

Costas, R., & Bordons, M. (2007). The h-index: advantages, limitations and its relation with other bibliometric indicators at the micro level. *Journal of Informetrics, 1*(3), 193–203.

Daniel, H. D., & Fisch, R. (1990). Research performance evaluation in the German university sector. *Scientometrics, 19*(5–6), 349–361.

Davis, G., & Royle, P. (1996). A comparison of Australian university output using journal impact factors. *Scientometrics, 35*(1), 45–58.

Egghe, L. (2006). Theory and practise of the g-index. *Scientometrics, 69*(1), 131–152.

Fakhree, M. A. A., & Jouyban, A. (2011). Scientometric analysis of the major Iranian medical universities. *Scientometrics, 87*(1), 205–220.

Farber, M. (2005). Single-authored publications in the sciences at Israeli universities. *Journal of Information Science, 31*(1), 62–66.

Frame, J. D., & Narin, F. (1987). The growth of Chinese scientific-research, 1973–84. *Scientometrics, 12*(1–2), 135–144.

Fu, H. Z., Wang, M. H., & Ho, Y. S. (2012). The most frequently cited adsorption research articles in the Science Citation Index (Expanded). *Journal of Colloid and Interface Science, 379*(1), 148–156.

Gao, S., Wu, K., & Liu, Z. F. (2010). Chemistry at play in materials science: the centennial celebration of chemistry at Peking University. *Advanced Materials, 22*(13), 1428–1429.

Garfield, E. (1972). Citation analysis as a tool in journal evaluation: journals can be ranked by frequency and impact of citations for science policy studies. *Science, 178*(4060), 471–479.

Han, W. Q., Fan, S. S., Li, Q. Q., & Hu, Y. D. (1997). Synthesis of gallium nitride nanorods through a carbon nanotube-confined reaction. *Science, 277*(5330), 1287–1289.

Hayhoe, R. (2005). Peking University and the spirit of Chinese scholarship. *Comparative Education Review, 49*(4), 575–583.

He, J. X. (2007). Quantitative and qualitative analysis of academic papers of South China Agriculture University under network environment. *Journal of Library and Information Sciences in Agriculture, 19*(6), 181–184.

He, T. W. (2009). International scientific collaboration of China with the G7 countries. *Scientometrics, 80*(3), 571–582.

Hirsch, J. E. (2005). An index to quantify an individual's scientific research output. *Proceedings of the National Academy of Sciences of the United States of America, 102*(46), 16569–16572.

Ho, Y. S. (2006). Second-order kinetic model for the sorption of cadmium onto tree fern: a comparison of linear and non-linear methods. *Water Research, 40*(1), 119–125.

Ho, Y. S. (2012). Top-cited articles in chemical engineering in Science Citation Index Expanded: a bibliometric analysis. *Chinese Journal of Chemical Engineering, 20*(3), 478–488.

Hou, T. J., & Xu, X. J. (2001). A new molecular simulation software package—Peking University Drug Design System (PKUDDS) for structure-based drug design. *Journal of Molecular Graphics and Modelling, 19*(5), 455–465.

Hsieh, W. H., Chiu, W. T., Lee, Y. S., & Ho, Y. S. (2004). Bibliometric analysis of patent ductus arteriosus treatments. *Scientometrics, 60*(2), 205–215.

Huang, R. M., Zhao, W. Z., & Lin, X. H. (2006). Scientific papers in China's TCM colleges and universities from 1997 to 2005: a bibliometric analysis. *Chinese Journal of Medical Library and Information Science, 15*(6), 74–76.

Kang, K. J. (1978). Recent developments and applications of radiation/detection technology in Tsinghua University. *Nuclear Physics A, 834*(1–4), 736C–742C.

King, J. (1988). The use of bibliometric techniques for institutional research evaluation: a study of avian virology research. *Scientometrics, 14*(3–4), 295–313.

Kong, Y. C., Yu, D. P., Zhang, B., Fang, W., & Feng, S. Q. (2001). Ultraviolet-emitting ZnO nanowires synthesized by a physical vapor deposition approach. *Applied Physics Letters, 78*(4), 407–409.

Kostoff, R. N. (2012). China/USA nanotechnology research output comparison-2011 update. *Technological Forecasting and Social Change, 79*(5), 986–990.

Kostoff, R. N., Barth, R. B., & Lau, C. G. Y. (2008). Quality vs. quantity of publications in nanotechnology field from the People's Republic of China. *Chinese Science Bulletin, 53*(8), 1272–1280.

Leonardelli, S., & Belmin, J. (2008). International publications from the French geriatric teams: evolution in the course of last 22 years. *Journal of Nutrition Health and Aging, 12*(4), 285–288.

Leydesdorff, L., & Wagner, C. (2009). Is the United States losing ground in science? A global perspective on the world science system. *Scientometrics, 78*(1), 23–36.

Li, Z., & Ho, Y. S. (2008). Use of citation per publication as an indicator to evaluate contingent valuation research. *Scientometrics, 75*(1), 97–110.

Liu, B. D. (2001). Fuzzy random chance-constrained programming. *IEEE Transactions on Fuzzy Systems, 9*(5), 713–720.

Liu, K. X., Ding, X. F., Fu, D. P., Pan, Y., Wu, X. H., Guo, Z. Y., et al. (2007). A new compact AMS system at Peking University. *Nuclear Instruments and Methods in Physics Research Section B-Beam Interactions with Materials and Atoms, 259*(1), 23–26.

Liu, R., Zou, X., Wang, X., He, L., & Zeng, N. (2008). X-pinch experiments with pulsed power generator (PPG-1) at Tsinghua University. *Laser and Particle Beams, 26*(1), 33–36.

Lou, J. L., Li, Z. H., Ye, Y. L., Hua, H., Faisal, Q. J., Jiang, D. X., et al. (2009). Performances of a beta-delayed neutron detection array at Peking University. *Nuclear Instruments and Methods in Physics Research Section B-Beam Interactions with Materials and Atoms, 606*(3), 645–650.

Luan, C. J., Zhou, C. Y., & Liu, A. Y. (2010). Patent strategy in Chinese universities: a comparative perspective. *Scientometrics, 84*(1), 53–63.

Makino, J. (1998). Productivity of research groups: relation between citation analysis and reputation within research communities. *Scientometrics, 43*(1), 87–93.

Martin, B. R. (1996). The use of multiple indicators in the assessment of basic research. *Scientometrics, 36*(3), 343–362.

Mervis, J. (2010). Science indicators: trends document China's prowess. *Science, 327*(5964), 407–408.

Moed, H. F., Burger, W. J. M., Frankfort, J. G., & Vanraan, A. F. J. (1985). The use of bibliometric data for the measurement of university research performance. *Research Policy, 14*(3), 131–149.

Mokhnacheva, Y. V., & Kharybina, T. N. (2011). Research performance of RAS institutions and Russian universities: a comparative bibliometric analysis. *Herald of the Russian Academy of Sciences, 81*(6), 569–574.

Nagpaul, P. S. (1995). Contribution of Indian universities to the mainstream scientific literature: a bibliometric assessment. *Scientometrics, 32*(1), 11–36.

Pan, S. Y. (2004). *How higher education institutions cope with social change: the case of Tsinghua University? China.*. Hong Kong: University of Hong Kong.

Picknett, T., & Davis, K. (1999). The 100 most-cited articles from JMB. *Journal of Molecular Biology, 293*(2), 173–176.

Piel, G. (1986). The social process of science. *Science, 231*(4735), 201.

Pouris, A. (2007). The international performance of the South African academic institutions: a citation assessment. *Higher Education, 54*(4), 501–509.

Schloegl, C., Gorraiz, J., Bart, C., & Bargmann, M. (2003). Evaluating two Austrian university departments: lessons learned. *Scientometrics, 56*(3), 287–299.

Sullivan, R., Lewison, G., & Purushotham, A. D. (2011). An analysis of research activity in major UK cancer centres. *European Journal of Cancer, 47*(4), 536–544.

Treiman, D.J. (2002). The growth and determinants of literacy in China. On-Line Working Paper Series, California Center for Population Research, UC Los Angeles.

Tu, C.Y. (1988). The damping of interplanetary alfvénic fluctuations and the heating of the solar-wind. *Journal of Geophysical Research-Space Physics*, *93*(A1), 7–20.

Usang, B., Basil, A., Lucy, U., & Franca, U. (2007). Academic staff research productivity: a study of Universities in South–South Zone of Nigeria. *Educational Research and Review, 2*(5), 103–108.

Van den Berghe, H., Houben, J. A., de Bruin, R. E., Moed, H. F., Kint, A., Luwel, M., et al. (1998). Bibliometric indicators of university research performance in Flanders. *Journal of the American Society for Information Science, 49*(1), 59–67.

van Raan, A. (1999). Advanced bibliometric methods for the evaluation of universities. *Scientometrics, 45*(3), 417–423.

van Raan, A. F. J. (2006). Comparison of the Hirsch-index with standard bibliometric indicators and with peer judgment for 147 chemistry research groups. *Scientometrics, 67*(3), 491–502.

Wang, B. (1992). Three-dimensional analysis of a flat elliptic crack in a piezoelectric material. *International Journal of Engineering Science, 30*(6), 781–791.

Wang, Y. B. (2007). Bibliometric analysis of scientific papers of the South China Normal University. *Journal of Library and Information Sciences in Agriculture, 18*(2), 181–184.

Wang, M. H., Fu, H. Z., & Ho, Y. S. (2011a). Comparison of universities' scientific performance using bibliometric indicators. *Malaysian Journal of Library and Information Science, 16*(2), 1–19.

Wang, M. H., Li, J. F., & Ho, Y. S. (2011b). Research articles published in water resources journals: a bibliometric analysis. *Desalination and Water Treatment, 28*(1–3), 353–365.

Xu, Y. X., Bai, H., Lu, G. W., Li, C., & Shi, G. Q. (2008). Flexible graphene films via the filtration of water-soluble noncovalent functionalized graphene sheets. *Journal of the American Chemical Society, 130*(11), 5856–5857.

Zachos, G. (1992). Research output evaluation of two university departments in Greece with the use of bibliometric indicators. *Scientometrics, 21*(2), 195–221.

Zhang, M. W. (2000). Bibliometric analysis of medical literature in Harbin Medial University. *Information Science, 18*(2), 177–179.

Zhang, X. (2011). Chemistry and physics at play in materials science: the centennial celebration of Tsinghua University. *Advanced Materials, 23*(9), 1042–1043.

Zhang, W. W., Qian, W. H., & Ho, Y. S. (2009). A bibliometric analysis of research related to ocean circulation. *Scientometrics, 80*(2), 305–316.

Zhu, S.L. (2003). Understanding pentaquark states in QCD. *Physical Review Letters*, *91*(23), Article Number: 232002.

Zhu, X., Wu, Q., Zheng, Y. Z., & Ma, X. (2004). Highly cited research papers and the evaluation of a research university: a case study: Peking University 1974–2003. *Scientometrics, 60*(2), 237–247.

Zorzetto, R., Razzouk, D., Dubugras, M. T. B., Gerolin, J., Schor, N., Guimaraes, J. A., et al. (2006). The scientific production in health and biological sciences of the top 20 Brazilian universities. *Brazilian Journal of Medical and Biological Research, 39*(12), 1513–1520.