



Independent research of China in Science Citation Index Expanded during 1980–2011

Hui-Zhen Fu^{a,b}, Yuh-Shan Ho^{a,b,*}

^a Department of Environmental Sciences, Peking University, Beijing 100871, People's Republic of China

^b Trend Research Centre, Asia University, No. 500, Lioufeng Road, Wufeng, Taichung County 41354, Taiwan

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ABSTRACT

The study explores the characteristics of China's independent research articles published from 1980 to 2011, based on the database of Science Citation Index Expanded. The publication outputs of seven major industrialized countries including Canada, France, Japan, Germany, Italy, the UK, and the USA were compared with China. Annual production, field performance, research emphases and trends, top articles, as well as main institutional and individual contributors by its top cited articles were analyzed. Some newly developed indicators related to words in title, author keywords, KeyWords Plus, first author, corresponding author, and Y-index were employed to provide in-depth information on topic and author contributions. Results showed that China has been closing the gap with the USA with the greatest growth, and has stood the second since 2006. Most top cited articles were published in 2000s, made up approximately seven tenths of total articles. Pronounced activities were found in chemistry and physics related categories. The core categories included multidisciplinary chemistry, physical chemistry, multidisciplinary materials science, and applied physics. Moreover, China's performance of nanotechnology and science, especially carbon nanotubes, nanoparticles, nanowires, and nanostructures showed dramatic growth. Six top articles with at least 1000 citations were examined, and were observed to concern medicine, nanotube, and adsorption. In addition, main contributing institutions and authors were also revealed and evaluated. Chinese Academy of Sciences played a dominant role, and Tsinghua University, Peking University and five universities in Hong Kong showed good scientific performance.

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1. Introduction

China has adopted the reform and opening-up policy for global competition and collaboration for more than 30 years, and it has moved into the front ranks in science and technology (Mervis, 2010). Especially during nearly two decades, China's international collaboration measured by scientific publications has been increased significantly, not only in Chinese Science and Technology Papers and Citations Database (Wang, Zhuang, Peng, & Li, 2005; Wang, Wu, Pan, Ma, & Rousseau, 2005), but also in the Science Citation Index Expanded (Zhou & Glänzel, 2010). Collaboration of publication between China and the seven major industrialized countries (G7) (Canada, France, Japan, Germany, Italy, the UK, and the USA) has also shown exponential growth (He, 2009). Such collaboration had positive effects on increasing the quantity of publication in China (Cho, Hu, &

* Corresponding author at: Trend Research Centre, Asia University, No. 500, Lioufeng Road, Wufeng, Taichung County 41354, Taiwan. Tel.: +886 4 2332 3456x1797; fax: +886 4 2330 5834.

E-mail address: ysho@asia.edu.tw (Y.-S. Ho).

Liu, 2010). While collaboration, in the form of technology acquisition could enhance the low-and-medium technology (Du & Tan, 2010), there is a question concerning China's ability to conduct independent and high quality scientific research.

Recently, top cited articles have been employed to reveal the recognition of scientific advancement and to give a historic perspective on the scientific progress (Baltussen & Kindler, 2004; Ohba, Nakao, Isashiki, & Ohba, 2007). Top cited articles were also considered as “classic citations” (Garfield, 1987). Various studies have attempted to identify and analyze the “citation classics”, especially in medical fields, such as leading dermatologic journals (Dubin, Hafner, & Arndt, 1993), and ophthalmology journals (Ohba et al., 2007). Bibliometric method as a common research tool has been widely used to measure the scientific performance of countries, such as China (Zhang & Zhang, 1997), Croatia (Klaić & Klaić, 1997), EU countries (Marshakova-Shaivevich, 2006), Japan (Fukui & Rahman, 2002), and New Zealand (Pon, Carroll, & Mcghee, 2004). Analyses usually covered the distribution of publication output, science disciplines, contributing institutions, collaboration (Jeenah & Pouris, 2008; Marshakova-Shaivevich, 2006), as well as policy implication (Uthman & Uthman, 2007). Furthermore, the citation life cycles of most cited papers with significant influence were revealed to provide more detail citation information (Fu, Wang, & Ho, 2012). In recent years, the frequency of words in title, author keywords, and KeyWords Plus in successive sub-periods have been quantitatively analyzed to figure out the research emphases and trends (Ho, Satoh, & Lin, 2010; Li, Zhang, Wang, & Ho, 2009).

The purpose of this paper is to identify and analyze top cited papers contributed independently by China in the Science Citation Index Expanded (SCI-Expanded) database from 1980 to 2011. The analysis covers annual production, field performance, research emphases, top articles, contributing institutions and authors. Some newly developed indicators related to title words, author keywords, KeyWords Plus, first author, and corresponding author were employed to provide additional insights.

2. Methodology

2.1. Data collection

China's overall publication performance was revealed from 1980 to 2011, since the beginning for its rapid development according to its policy of reform and opening to the outside world. Previous research showed that G7 countries dominated in some topics in recent decades, such as meteorology, atmospheric science, and water research (Li et al., 2009; Wang, Yu, & Ho, 2010). In this study, China's publication output was examined in comparison with G7 countries. The annual number of articles by China and G7 countries was obtained from SCI-Expanded database of the Thomson Reuters Web of Science during 1980–2011. China, the United Kingdom (UK), and Germany were searched by more than one item. China, Hong Kong, and Macao were searched in terms of address for China; articles originating from England, Scotland, Northern Ireland, and Wales were reclassified as being from the United Kingdom (UK); and German Democratic Republic (Ger Dem Rep), Federal Republic of Germany (Fed Rep Ger), and Germany were reclassified as being from Germany.

To analyze China's independent publication performances, the independent top cited publications of China without any international collaboration were abstracted. The data collection process of China's independent publications is illustrated in Fig. 1. First, China, Hong Kong, and Macao were searched in terms of address within the publication year limitation from 1980 to 2011 based on SCI-Expanded (updated on 11 July 2012). A total of 1,343,756 documents in 21 document types were therefore found. Second, only the document type of “article” (1,170,899), excluding “proceedings paper”, “book chapter”, and “book”, was considered, since they represented the majority of document types that also included whole research ideas and results (Ho et al., 2010). Third, articles that have an author address from another country, other than China, were all excluded. The number of independent articles was 907,259. The total number of times an article was cited from its publication to 2011 was recorded as TC_{2011} (Chuang, Wang, & Ho, 2011; Wang, Li, & Ho, 2011). The advantage of TC_{2011} is that it is an invariant parameter, thus ensuring repeatability, while the index of citation would have been updated from time to time (Fu et al., 2012). Since Garfield (1987) introduced the top cited articles as citation classics in 1987, articles that were cited at least 100 times were previously discussed as citation classics (Dubin et al., 1993; Gehanno, Takahashi, Darmoni, & Weber, 2007; Heldwein, Rhoden, & Morgentaler, 2010; Nieri et al., 2007). As the result, 2,701 articles (3.0% of 907,259 articles) qualify as top cited articles with $TC_{2011} \geq 100$.

Since not all articles had information of both first author and corresponding author, only articles with both first author and corresponding author information were used to evaluate the performance of authors and institutions. In instances of single-author articles, the author was considered as the first author, as well as the corresponding author. The records of author

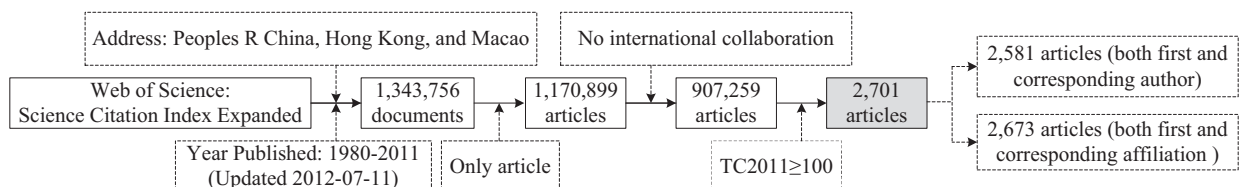


Fig. 1. Schematic for searching China's independent articles in Science Citation Index Expanded.

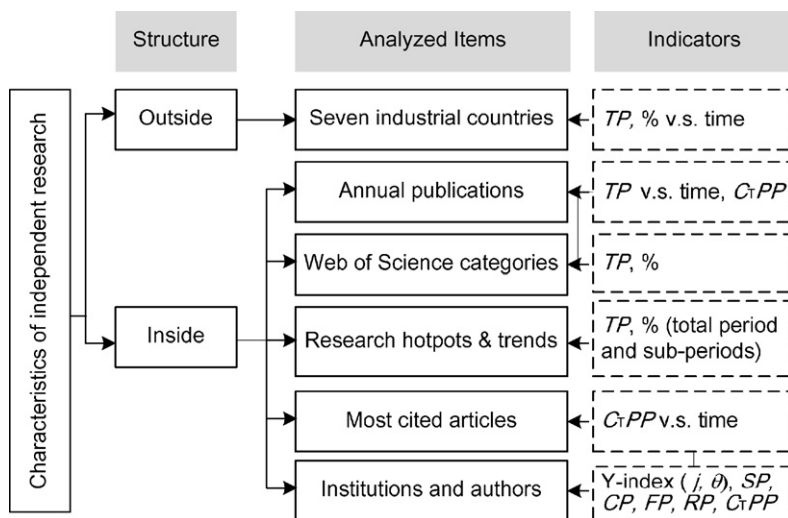


Fig. 2. Analytic structure of characteristics of China's independent research.

and institution were independently generated, and therefore the quantity with information of author and institution was not equal. After these pretreatments, there were 2581 articles with both first author and corresponding author information among 2701 top cited articles. Altogether 2673 articles had the affiliation information of both first author and corresponding author for institution analysis.

2.2. Structure and indicators

This study, not only compared China with G7 countries, but also looked at independent research of China by itself (Fig. 2). The annual production, favored categories, research emphases and trends by the frequency of keywords, the typical top articles, major individual and institutional contributors of China were presented subsequently. Publication outputs indicators, number of articles (TP) and publication share (%) as well as citation indicators, TC_{2011} and total TC_{2011} per article (C_{TPP}) were used. Impact factor of journal, ranking, and frequency of keywords were also employed. The word share of each country was obtained by dividing number of one country's articles by the total number of articles in the world for the comparison with G7. As for the analysis of authors and institutions, more indicators were used to obtain more characteristics. Collaboration type was determined by the affiliations of the authors. (1) The term "single institution article" was assigned if the researchers' affiliation were from the same institution. (2) The term "inter-institutionally collaborative article" was assigned if authors were from different institutions in China. (3) The term "first author article" was assigned if the first author was from the institution for analysis. (4) The term "corresponding author article" was assigned if the corresponding author was from the institution for analysis. An article could either be a single institution article or inter-institutionally collaborative article. However, with respect to a given institution or author, the first author and the corresponding author of one article might be the same person, and the first author and corresponding author might be affiliated to the same institution. An article might be both first author article and corresponding author article of the given institution or author, and thereby belonging to two sets of target articles. Total number of publications (TP), single institution articles (SP), inter-institutionally collaborative articles (CP), first author's articles (FP), and corresponding author's articles (RP) were examined to assess Chinese institutions and authors.

Another newly developed indicator Y-index (j, θ), first proposed in 2012 (Ho, 2012a), was utilized to evaluate Chinese institutions and authors. Y-index provides a single index to identify important characteristics related to first author and corresponding author which could not be obtained by other traditional indicators (Ho, 2012b). This index is related to numbers of first author publications (FP) and corresponding author publications (RP), as defined:

$$j = \sqrt{FP^2 + RP^2} \quad (1)$$

$$\theta = \tan^{-1} \left(\frac{RP}{FP} \right) \quad (2)$$

where, j is the publication performance constant related to publication quantity, and θ is the publication character which can describe the proportion of FP to RP . The greater j is, the more contribution the analyzed unit makes. Different values of θ stand for different proportions of corresponding author publications to first author publications. $\theta > 0.7854$ means more corresponding author publications; $\theta = 0.7854$ means the same quantity of first author publications and corresponding author publications; $0 < \theta < 0.7854$ means more first author publications. When $\theta = 0$, $j =$ number of first author publications and $\theta = \infty$, $j =$ number of corresponding author publications.

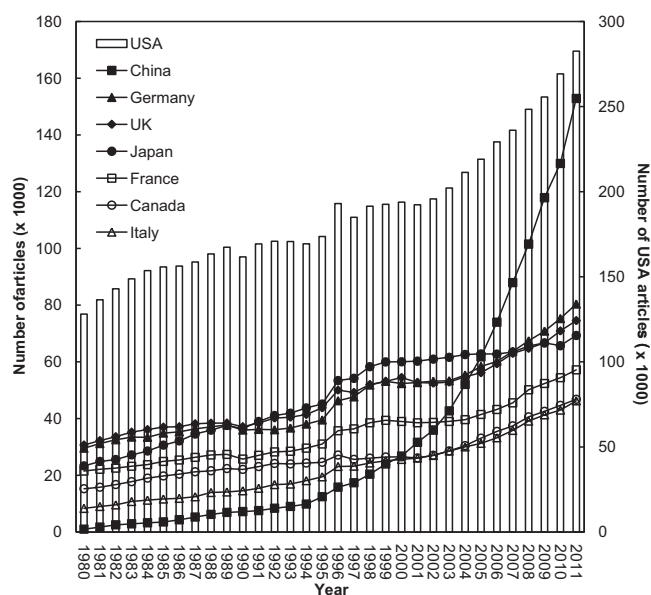


Fig. 3. Comparison of China and seven industrial countries from 1980 to 2011.

3. Results and discussion

3.1. Comparison of China and G7

Fig. 3 shows that G7 countries published the majority of articles from 1980 to 2011, but their world share of articles showed a decreasing trend from 67% in 1980 to 53% in 2011. USA was the overwhelming leader in terms of total scientific outputs. The number of articles by the USA increased from 128,059 in 1980 to 282,579 in 2011, although its world share fell from 34% in 1980 to 26% in 2011. The other six countries, UK, Japan, Germany, France, Canada, and Italy all showed increasing trends, with the world share of 8.1%, 8.0%, 7.9%, 5.8%, 4.5%, and 3.6% in 2011, respectively. Among them, Italy had the greatest growth rate among these seven countries. Its world share climbed from the lowest world share 2.2% to 4.3%. Comparatively, China soared from 1029 in 1980 to 152,856 articles in 2011, increased by 148 times and made up about 14% of world share of articles in 2011. The great growth rate of China might be one of the reasons for the six countries of G7 decreases of world share. After Cultural Revolution (1966–1976), scientific research papers of China grew exponentially (Frame & Narin, 1987). China's science was in a quantitative expansion phase with exponential growth (Jin & Rousseau, 2005). China's become the second since 2006 in scientific production, only behind the USA, leaving other G7 countries behind (ISTIC, 2007, 2011; Leydesdorff & Wagner, 2009). It is no coincidence that large funding has fueled research performance in China (Zhou & Leydesdorff, 2006). The Chinese government focused on science and technology by substantially increasing the expenditure on research and development as a percentage of GDP, from 0.8% in 1999 to 1.7% by 2008, according to the 2012 edition of Science and Engineering Indicators (www.nsf.gov/nsb/sei). The increase in scientific work force has also contributed a lot to this growth of science production (Mervis, 2010).

3.2. Characteristics of annual publications

The annual top cited articles with $TC_{2011} \geq 100$ contributed independently by China are displayed in Fig. 4. The top cited articles has been rising steadily since 1991, reaching a peak of 318 articles in 2003, and then declined. The low level of China's output of scientific literature in 1980s was possible reflected by the Cultural Revolution (Frame & Narin, 1987). The increase of articles from 1991 to 2003 suggested that not only did China's total outputs increase, but also its production level of top cited classics has been advanced. Nearly 74% top cited articles were published in 2000s, similar to the trend of all articles, which enforces the view that China's scientific activities have been strengthened in recent years. The decline of 2003–2010 might be explained in part by the less time for their articles to accumulate citations (Picknett & Davis, 1999). The decline of output of top cited articles in recent years has been observed in previous studies (Fu, Chuang, Wang, & Ho, 2011; Ho, 2012a) due to time needed for citations.

The 2701 articles received a total of 443,296 citations, with an average of 164 citations per article. In terms of TC_{2011} , 2230 articles (83%) received 100–200 citations each; 425 articles (16%) received 201–500 citations each; 40 articles (1.5%) received 501–1000 citations each; and only six articles received at least 1000 citations each. The part of 100–200 citations took a large proportion of more than four fifths. As for annual publications, 30 of these 32 years' had 100–200 C_7PPs , while

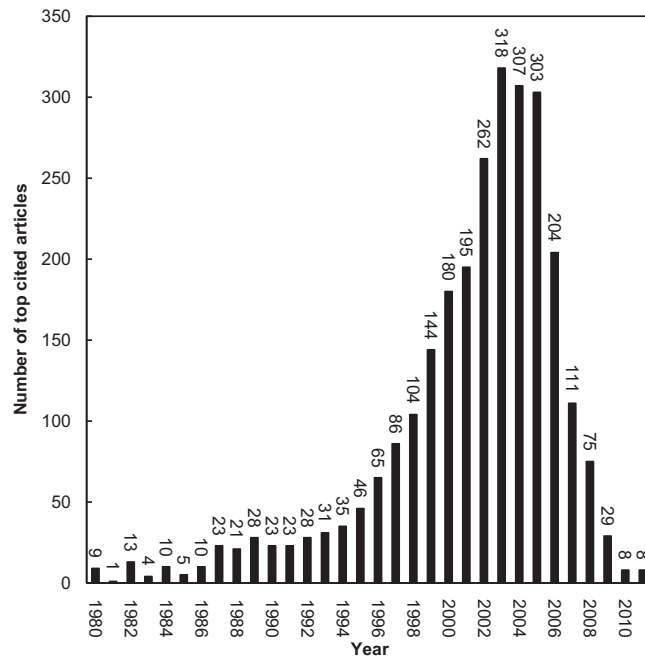


Fig. 4. Top cited articles ($TC_{2011} \geq 100$) from 1980 to 2011.

only 2 year: 1988 and 1983 had C_TPP s more than 200. This phenomenon might be attributed to the low production in 1980s. Another reason for 1988 with the highest C_TPP of 271 may be two heavily cited articles titled “use of all-trans retinoic acid in the treatment of acute promyelocytic leukemia” (Huang et al., 1988) with $TC_{2011} = 1594$, and “the glucose-oxidase dab nickel method in peroxidase histochemistry of the nervous-system” (Shu, Ju, & Fan, 1988) with $TC_{2011} = 1030$. After removing these two articles, the new 1988 C_TPP value was 161, much less than the original 1988 C_TPP value of 271. One previous study stated the impact of China’s science was low, and needs to enhance its quality (Jin & Rousseau, 2005).

3.3. Web of Science categories

According to Journal Citation Reports (JCR) science edition, there were 176 Web of Science categories in 2011. The top cited articles were published across 140 Web of Science categories. Basic sciences, such as physics and chemistry, covered 23 categories with 1737 articles, occupying 64% of total top cited articles. In particular, 13 chemistry related categories with 1269 articles took nearly a half of the total articles. Another 13 categories in physics had 973 articles, made up about 36%, fewer than those in chemistry. The excellent performance of chemistry was also not surprising since China has taken a leading position in publishing journal papers in chemistry during 1998–2007 (Zhou & Leydesdorff, 2009). Among these categories, 14 categories were assigned to engineering with 304 articles, comprising 11% of total articles. Similarly, natural science has been investigated to take approximately three fifths, and field of engineering comprised approximately 15% in China’s publications (Mervis, 2010). Physics, chemistry, and engineering in China had developed well in the last 30 years.

In general, the categories can be classified into three groups, each producing about one-third of all articles. The categories of zone 1 could obviously be recognized as the core categories. Zone 1, representing the most productive third of the total articles, contained four categories (2.9%). Zone 2, representing the next most productive third of total articles, contained 16 categories (11%). Zone 3, representing the least productive third of total articles, contained 120 categories (89%). The number of categories in each zone were found to be proportional to $1:n:n^{2.5}$. The overall top 20 categories were listed in Table 1. The four core categories took no less than 10% of total articles each, and comprised 37% altogether. The core categories were multidisciplinary chemistry, physical chemistry, multidisciplinary materials science, and applied physics, which was consistent with China’s traditional research focus.

3.4. Research emphases and trends

The title and the author keywords, provides a reasonably detailed picture of the article’s theme. KeyWords Plus, generated independently of the title or author keywords go into far more detail, describing the article’s contents with greater depth and variety than only title and author keywords (Garfield, 1990). Statistical analysis of words in title, author keywords, and KeyWords Plus has been developed only in recent years, and has proved to be significant in monitoring the development of science and programs (Ho et al., 2010; Li et al., 2009). Including words in title, author keywords, and KeyWords Plus together

Table 1
Top 20 Web of Science categories in zone 1 and zone 2.

Web of Science category	TP	%	Web of Science category	TP	%
Multidisciplinary chemistry	546	20	Chemistry organic	95	3.5
Physical chemistry	429	16	Biochemistry and molecular biology	93	3.4
Multidisciplinary materials science	359	13	Polymer science	91	3.4
Applied physics	279	10	Atomic molecular and chemical physics	69	2.6
Condensed matter physics	226	8.4	Electrochemistry	62	2.3
Nanoscience and nanotechnology	178	6.6	Optics	61	2.3
Multidisciplinary physics	158	5.8	Physics mathematical	61	2.3
Analytical chemistry	110	4.1	Environmental sciences	58	2.1
Electrical and electronic engineering	107	4.0	Medicine general and internal	57	2.1
Inorganic and nuclear chemistry	101	3.7	Computer science artificial intelligence	53	2.0

%, the percentage of the number of publications in a given category to the total number of articles.

could minimize limitations, such as the uncompleted meaning of single words in title, the small sample size for author keywords, and the indirectly relationship between KeyWords Plus and the research emphases. These kinds of words were examined by time periods to show the trends, as well as to minimize the year-to-year fluctuations. The 20 most frequently used words in title of four sub-periods (1980–1987, 1988–1995, 1996–2003, and 2004–2011) are listed in Table 2. In the title analysis, prepositions, such as “of” and other meaningless words were excluded. Among 2701 articles, only 950 articles (35%) had records information of author keywords, and 3111 author keywords were found. Altogether 2411 articles (89%) had records information of KeyWords Plus, and 7287 KeyWords Plus were then be analyzed from SCI-Expanded (Table 3).

Interestingly, eleven words did not appear in the earliest period of 1980–1987 in Table 2, and seven of these eleven words including “nanotubes”, “nanoparticles”, “nanowires”, “networks”, “ZnO”, “photocatalytic”, and “oxide” emerged after 1995. Most frequently used words in title emerged in the latest 16 years (1996–2003 and 2004–2011) provided the evidence that the China’s research has been more prosperous in recent years. “Synthesis” (244; 9.0%), “carbon” (140; 5.2%), and “nanotubes” (113; 4.2%) were the three most frequently used words in title. According to the results of author keywords, the 3rd position “carbon nanotubes”, the “carbon” and “nanotubes” came together as “carbon nanotubes” in 78 articles’ titles. Three words: “nanotubes”, “nanoparticles”, and “nanowires” in the top six of the words in title, two words: “nanostructures” and “carbon nanotubes” in the top three author keywords, and the 1st place “nanoparticles” in the KeyWords Plus list were related to the field of nanoscience and nanotechnology, which suggested that China played better in this field than China’s other fields, based on the active performance of its basic science. There were 262 articles with nanotubes, nanoparticles or nanowires in their titles, having 101 articles in the category of physical chemistry, 78 in multidisciplinary chemistry, and 74 in multidisciplinary materials science. The ascent of nanoscience in China has early been noticed in 2005 in *Science* (Bai, 2005). China’s emerging presence in nanoscience was compared with France, Germany, Japan, and the USA from 1985 to 2004 (Guan & Ma, 2007), and was closing the gap with the USA during 1991–2005 (Kostoff, Koytcheff, & Lau, 2007). Its nanotechnology publication activity has grown exponentially at an annual rate of about 20% from 2000 to 2009 (Ye, Liu, & Porter, 2012), and has already surpassed the USA since 2009 in terms of publications outputs (Kostoff, 2012). The growth

Table 2
The 20 most frequently used title words in the whole period and different sub-periods.

Words in title	TP	1980–2011	1980–1987	1988–1995	1996–2003	2004–2011
		Rank (%)	Rank (%)	Rank (%)	Rank (%)	Rank (%)
Synthesis	244	1 (9.0)	12 (2.7)	8 (3.0)	1 (10)	1 (9.0)
Carbon	140	2 (5.2)	N/A	85 (0.85)	2 (5.7)	2 (5.9)
Nanotubes	113	3 (4.2)	N/A	N/A	3 (5.3)	4 (4.0)
Nanoparticles	88	4 (3.3)	N/A	N/A	6 (3.0)	3 (4.6)
Characterization	76	5 (2.8)	52 (1.3)	39 (1.3)	5 (3.3)	13 (2.6)
Nanowires	71	6 (2.6)	N/A	N/A	4 (4.3)	88 (1.3)
Structure	65	7 (2.4)	N/A	39 (1.3)	7 (2.9)	21 (2.2)
Patients	64	8 (2.4)	5 (4.0)	1 (8.1)	14 (2.3)	109 (1.1)
Networks	63	9 (2.3)	N/A	N/A	19 (2.0)	5 (3.5)
Reaction	62	10 (2.3)	5 (4.0)	18 (1.7)	10 (2.5)	26 (2.0)
Films	61	11 (2.3)	52 (1.3)	18 (1.7)	12 (2.4)	18 (2.3)
Stability	60	12 (2.2)	N/A	236 (0.43)	12 (2.4)	13 (2.6)
Complexes	58	13 (2.1)	52 (1.3)	18 (1.7)	8 (2.7)	52 (1.5)
ZnO	58	13 (2.1)	N/A	N/A	30 (1.7)	6 (3.4)
Activity	57	15 (2.1)	52 (1.3)	85 (0.85)	26 (1.8)	10 (2.9)
Photocatalytic	57	15 (2.1)	N/A	N/A	30 (1.7)	8 (3.3)
China	56	17 (2.1)	5 (4.0)	12 (2.1)	9 (2.6)	88 (1.3)
Coordination	54	18 (2.0)	52 (1.3)	N/A	33 (1.6)	9 (3.0)
Oxide	54	18 (2.0)	N/A	N/A	15 (2.2)	18 (2.3)
Surface	54	18 (2.0)	N/A	85 (0.85)	19 (2.0)	17 (2.4)

N/A, not available; %, the percentage of the frequency of a given word in title to the total number of articles.

Table 3

The 15 most frequently used author keywords and KeyWords Plus.

Author keywords	TP	%	KeyWords Plus	TP	%
Nanostructures	32	3.4	Nanoparticles	114	4.7
Chitosan	25	2.6	Growth	109	4.5
Carbon nanotubes	22	2.3	Films	100	4.1
Copper	21	2.2	Complexes	86	3.6
Electrocatalysis	15	1.6	Water	77	3.2
Biosensor	13	1.4	Particles	72	3.0
Luminescence	13	1.4	Nanowires	69	2.9
Magnetic properties	13	1.4	Design	64	2.7
Stability	13	1.4	Chemistry	64	2.7
Photocatalytic activity	13	1.4	Systems	58	2.4
Lyapunov functional	13	1.4	Crystal-structure	55	2.3
Linear matrix inequality (LMI)	12	1.3	Optical-properties	54	2.2
Titanium dioxide	12	1.3	Nanotubes	53	2.2
Hydrothermal synthesis	12	1.3	Polymers	51	2.1
N ligands	12	1.3	Oxidation	49	2.0

N/A, not available; %, the percentage of frequency of a given keyword to the number of articles with keywords information.

patterns of China's nanotechnology patent publications also experienced a high rate, followed far by Russia and India (Liu et al., 2009).

The extraordinary pace of nanotechnology development achieved has been promoted primarily by the public sector rather than being driven by industry and market forces (Huang & Wu, 2012), and the authors who were holding patent inventors (Guan & Wang, 2010). As a academician of Chinese Academy of science Bai (2005) observed, when the concept of nanoscience and nanotechnology was first introduced in the 1980s, it was received favorably in China. In the 1990s, support for the development of nanoscience and nanotechnology increased substantially. It has also been reported that State Science and Technology Commission launched the nearly decade-long "Climbing Up" project on nanomaterial science in 1990 (Bai, 2005). From 1990 to 2002, nearly 1000 related projects (with a total funding of about \$27 million) were implemented. Tens of nation-wide conferences have been held in China since 1990 covering a wide range of topics in the related fields (Bai, 2001). During this period, National Natural Science Foundation of China approved nearly 1000 grants for small-scale projects (Bai, 2005). Some achievements were obtained according to these substantial supports. Four top cited article with $TC_{2011} > 1000$ were published in 1990s. Two independent articles without any international collaboration: "large-scale synthesis of aligned carbon nanotubes" (Li et al., 1996), and "synthesis of gallium nitride nanorods through a carbon nanotube-confined reaction" (Han, Fan, Li, & Hu, 1997) were contributed by Chinese Academy Science and Tsinghua University, respectively. Another two international collaborative articles with $TC_{2011} > 1000$, "a chemically functionalizable nanoporous material $[Cu_3(TMA)_2(H_2O)_3]_n$ " (Chui, Lo, Charmant, Orpen, & Williams, 1999), and "hydrogen storage in single-walled carbon nanotubes at room temperature" (Liu et al., 1999) was published by the collaboration with the UK and USA, respectively. Furthermore, in 2000, National Steering Committee for Nanoscience and Nanotechnology was created to oversee national policy and coordinate action (Bai, 2005). This committee drafted the first Chinese national policy document intended to promote nanotechnology development, which was announced as the National Nanotechnology Development Strategy (2001–2010) (Huang & Wu, 2012). Again, the article titled "piezoelectric nanogenerators based on zinc oxide nanowire arrays" (Wang & Song, 2006) with $TC_{2011} > 1000$ was published in 2006 by Georgia Institute of Technology in USA, Peking University and National Center for Nanoscience and Technology in China.

In addition, "networks" (63; 2.3%), "stability" (60; 2.2%), "ZnO" (58; 2.1%), and "photocatalytic" (57; 2.1%) received increasing attention from no articles in 1980–1987 to no less than 2.6% articles in 2004–2011. Particularly, there were 58 articles with "ZnO" which appeared in the titles together with the composite words related to nanometers including "nanostructures", "nanowire(s)", "nanotubes", and "nanorods" in more than a half articles, having 33 articles in the Web of Science category of applied physics. This provides another evidence for China's good performance in the category of applied physics and the research hotspot of nanotechnology. There were 63 articles with "networks" in their titles, having 19 articles in multidisciplinary physics, 17 articles in electrical and electronic engineering, and 14 articles in mathematical physics. The words "networks" in 38 articles appeared as "neural networks". Neural networks, based on the study of the human brain which would have a prominent role in decision support (Cross, Harrison, & Kennedy, 1995) have a large appeal to Chinese researchers. Moreover, for KeyWords Plus, the 3rd place "films" also got a high ranking of 8th in the analysis of title, and was also mainly studied in the categories related to physics and chemistry.

3.5. Characteristics of top articles

The articles with the highest TC_{2011} can be considered the most popular articles in China's independent research. The patterns of citation life cycles of top cited articles could provide the characteristics for the top articles (Aksnes, 2003). The citation life cycles of these articles of six top articles with $TC_{2011} \geq 1000$ are illustrated in Fig. 5. Two articles were published in 1980s, three in 1990s, and one in 2000s. These six articles were "Ho and McKay (1999)" in biochemistry and molecular

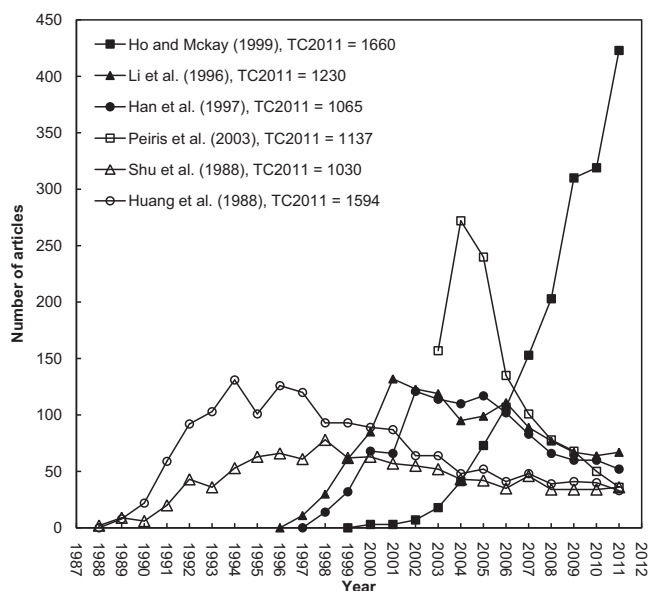


Fig. 5. Citation life cycles of seven top articles with $TC_{2011} \geq 1000$.

biology, biotechnology and applied microbiology, and chemical engineering, “Li et al. (1996)” and “Han et al. (1997)” in multidisciplinary sciences, “Huang et al. (1988)” in hematology, “Peiris et al. (2003)” in general and internal medicine, and “Shu et al. (1988)” in neurosciences. Except the most attractive article “Ho and McKay (1999)” on adsorption in *Process Biochemistry* with impact factor (IF) = 2.627, three out of six articles “Huang et al. (1988)”, “Peiris et al. (2003)”, and “Shu et al. (1988)” related to medicine were published in *Blood* (IF = 9.898), *Lancet* (IF = 38.278), and *Neuroscience Letters* (IF = 2.105); and two articles “Li et al. (1996)” and “Han et al. (1997)” about nanotubes were published in *Science* (IF = 31.201). Moreover, three articles were contributed independently by one institution. They were “Ho and McKay (1999)” in Hong Kong University Science and Technology, “Han et al. (1997)” in Tsinghua University, and “Shu et al. (1988)” in Fourth Military Medical University, respectively.

The article “Ho and McKay (1999)” had the highest number of citations in 2011, as well as the steepest growth rate in recent years. This article was cited 423 times in 2011, much more than other articles. The article was also the leader in terms of annual citations in 2011 in the category of chemical engineering (Ho, 2012a). Ho and McKay (1999) reviewed the use of sorbents and biosorbents to treat polluted aqueous effluents containing dyes: organics or metal, and proposed the pseudo-second order kinetic model. Since the introduction of pseudo-second-order model for the description of adsorption kinetics in 1999, it has been widely applied to the adsorption of pollutants from aqueous solutions (Ho, 2006; Wu, Tseng, Huang, & Juang, 2009). Although the other five top articles got increasing attention after publication, the citations all had declines afterwards. Huang et al. (1988) reported that all-trans retinoic acid was an effective inducer for attaining complete remission in acute promyelocytic leukemia. Shu et al. (1988) stated that a combination of the glucose oxidase diaminobenzidine (DAB) method and the DAB nickel method could successfully bring out details of immunoreactive structures in immunostained preparations. The latest article in 2003 from Peiris provided an evidence that a virus in the coronavirus family is the causal agent of Severe Acute Respiratory Syndrome (SARS) (Peiris et al., 2003). It is also the highest cited article in the publication year of 2003 among these six top articles. SARS has become the major of health issues since its outbreak early 2003 in China. Li et al. (1996) discussed the large-scale synthesis of aligned carbon nanotubes in *Science*. Another article in *Science*, Han et al. (1997) suggested that it might be possible to synthesize other nitride nanorods through similar carbon nanotube-confined reactions. It is noticeable that four authors Zhen-yi Wang, Sishen Xie, Shoushan Fan, and Gong Ju in these four articles were academicians of Chinese Academy of Engineering or Chinese Academy of Sciences. Wang in “Huang et al. (1988)” has become academician of Chinese Academy of Engineering in 1994; Sishen Xie in “Li et al. (1996)” and Shoushan Fan in “Han et al. (1997)” has become academician of Chinese Academy of Sciences in 2003, and Gong Ju in “Shu et al. (1988)” has become academician of Chinese Academy of Sciences in 1991. These four authors all became academicians after several years since the publication of the top articles, which indicated that the heavily cited articles could be considered important symbols for the evaluation of research management.

3.6. Institutional and individual contributors

The author, as well as the affiliation of the author, listed in one publication could be considered as the evidence of contribution (Coats, 2009). Both the number of authors on a paper and their positions in the byline need to be taken into account accurately when measuring author contribution (Mattsson, Sundberg, & Laget, 2011). It has been accepted conventionally

Table 4
 Characteristics of top 20 institutions ($j \geq 30$) using Y-index, SP, CP, FP, RP, C_T PP.

Institution	Rank (j)	SP rank (%)	CP rank (%)	FP rank (%)	RP rank (%)	θ	C_T PP
Chinese Academy of Sciences	1(841.5)	1(24)	1(38)	1(22)	1(22)	0.7837	161
University of Hong Kong	2(301.2)	2(8.6)	2(12)	2(8.0)	2(7.9)	0.7807	175
Chinese University of Hong Kong	3(239.7)	3(6.4)	3(11)	3(6.4)	3(6.3)	0.7765	156
Tsinghua University	4(207.2)	5(5.0)	4(10)	4(5.5)	4(5.5)	0.7820	182
Peking University	5(184.6)	5(5.0)	5(8.3)	5(4.9)	5(4.9)	0.7892	174
Hong Kong University Science & Technology	6(179.6)	4(5.8)	7(5.0)	6(4.8)	6(4.8)	0.7854	186
University of Science & Technology China	7(117.4)	7(3.8)	9(4.5)	7(3.1)	7(3.1)	0.7854	166
Nanjing University	8(113.1)	8(3.0)	8(4.8)	8(3.0)	8(3.0)	0.7854	145
Fudan University	9(96.17)	9(2.9)	9(4.5)	9(2.5)	9(2.5)	0.7854	150
City University of Hong Kong	10(74.95)	10(2.1)	6(5.5)	10(2.0)	10(2.0)	0.7854	170
Zhongshan University	11(74.95)	12(1.6)	13(3.4)	10(2.0)	10(2.0)	0.7854	165
Zhejiang University	12(59.4)	11(2.0)	18(2.1)	12(1.6)	12(1.6)	0.7854	140
Hong Kong Polytechnic University	13(57.28)	15(1.2)	11(3.9)	13(1.5)	13(1.5)	0.7977	140
Shanghai Jiao Tong University	14(56.57)	13(1.5)	11(3.9)	13(1.5)	14(1.5)	0.7854	167
Jilin University	15(50.91)	14(1.3)	13(3.4)	15(1.3)	15(1.3)	0.7854	148
Southeast University	16(46.67)	18(0.88)	19(2.0)	16(1.2)	16(1.2)	0.7854	145
Nankai University	17(42.43)	15(1.2)	19(2.0)	17(1.1)	17(1.1)	0.7854	160
Lanzhou University	18(38.18)	17(1.1)	35(1.2)	18(1.0)	18(1.0)	0.7854	164
Xiamen University	19(32.53)	18(0.88)	35(1.2)	19(0.86)	19(0.86)	0.7854	139
Wuhan University	20(31.11)	20(0.82)	19(2.0)	20(0.82)	20(0.82)	0.7854	137

%, the percentage of the number of a given institution to the number of articles with institution information.

that the most important positions are the first and the last, whom very often is the corresponding author (Costas & Bordons, 2011; Zuckerman, 1968). The first author has actually made the most contribution, and should receive a greater proportion of the credit (Marušić et al., 2004; Reisenberg & Lundberg, 1990). Accordingly, the non-first authors made less contribution (Shapiro, Wenger, & Shapiro, 1994). As important as the first author, another prominent authorship position is the corresponding author. The honorary authors including Nobel laureates were more likely to be listed last authors on scientific papers, rather than the first author (Bates, Anić, Marušić, & Marušić, 2004; Zuckerman, 1968). The first author is commonly contributed the most, but the corresponding author obviously increases the author's credit for contributions to the study (Bhandari et al., 2004). Corresponding author was the one who contributed the most to the initial conception and supervision (Wren et al., 2007). Straight counting that accredits only the first or the corresponding author fractional counting that accredits each collaborator with partial and weighted credit might be the better choices (Huang, Lin, & Chen, 2011). Y-index (j, θ) (Ho, 2012a) which takes the first author articles and corresponding author articles into consideration could provide more fair information for evaluation of Chinese institutions and authors.

There were 474 institutions contributing to 2673 articles. Of these articles, 1821 articles (68%) came from independent institution, 852 articles (32%) from inter-institutional collaboration. In terms of Y-index (j, θ), nearly a half of institutions (231) had no first author articles and corresponding articles. Among the remaining 243 institutions, a high percentage of institutions (235; 97%) had $\theta = 0.7854$ with the same number of first author articles and corresponding author articles. Within respect to j , 198 institutions (82%) had $1 \leq j < 10$; 25 institutions $10 \leq j < 30$; and 20 institutions had $j \geq 30$, published 75% top cited articles. The top 20 institutions are listed in Table 4. The leading institution was the Chinese Academy of Sciences with $j = 841.5$ (28% of total articles). Chinese Academy of Sciences (CAS) is the China's highest academic institution in natural sciences, with the affiliated University of Science and Technology of China and University of Chinese Academy of Sciences. CAS has dominated publications with a contribution around one fourth in other studies, such as total publications in 1981–1985 (Arunachalam, Singh, & Sinha, 1993), and highly cited articles in 1999–2009 using Essential Science Indicators (Fu et al., 2011). However, a bias appeared because the Chinese Academy of Sciences has over 100 branches in different cities (Li et al., 2009). There are 113 institutions directly under CAS, including 92 research institutes (including three botanical gardens), six universities and supporting organizations (including two universities, one supporting organization, one documentation and information unit, two news and publication units), 12 management organizations that consist of the headquarters and branches, and three other units (www.cas.cn). The publications of different institutions were pooled as one heading now, and publications divided into branches would result in different rankings. Other than the Chinese Academy of Sciences, the other leading institutions were University of Hong Kong ($j = 301.2$), Chinese University of Hong Kong ($j = 239.7$), and Tsinghua University ($j = 207.2$). In addition, the 2nd position University of Hong Kong ranked 2nd in inter-institutionally collaborative articles, as well as the 2nd in the first author articles and corresponding author articles. Of the top 20 institutions, except for five universities located in Hong Kong and the Chinese Academy of Sciences, the other 14 productive universities were all included in the "985 Project" of China. Project 985, a constructive project for founding world-class universities in the 21st century conducted by the government of China with a huge funding injection, might be a boost for the well scientific performance of these universities (Fu et al., 2011). China's research and development funding was mainly conducted in its universities (Zhou & Leydesdorff, 2006).

As for author analysis, 2581 articles with the information of both first author and corresponding author were evaluated by Y-index (Ho, 2012a). Fig. 6 displays the distribution of the top 27 authors with $j > 11$, where the FP and RP are chosen

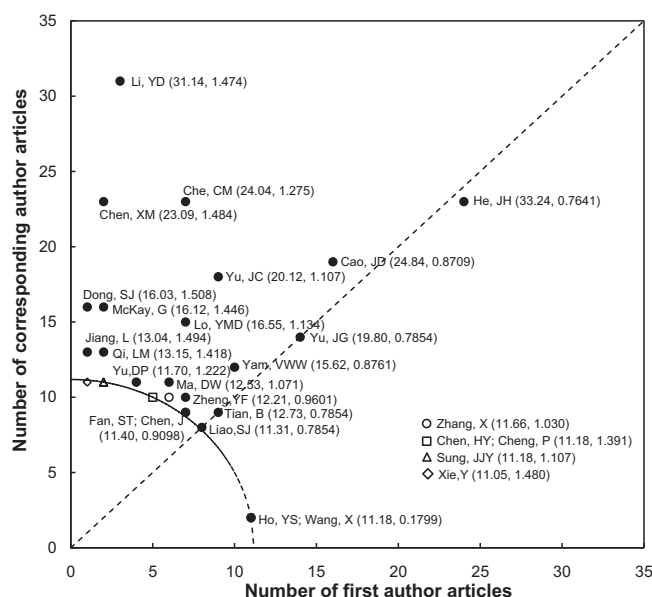


Fig. 6. Y-index of the top 27 authors with the greatest j ($j > 11$).

as the x and y coordinate axes. Publication character θ could help obtain the different proportion of first author articles to corresponding author articles. Each dot was displayed with its Y-index (j, θ). The authors who contributed the most were He ($j = 33.24$), followed by Li ($j = 31.14$), and Cao ($j = 24.84$). The 1st place He from Donghua University published 24 first author articles and 23 corresponding author articles, twenty of which were conducted with single author. The most cited article of He with $TC2011 = 681$ was related to variational iteration method – a kind of non-linear analytical technique (He, 1999). He is the only top author who had more first author articles than corresponding author articles ($\theta = 0.764$). The 2nd position Li from Tsinghua University published three first author articles and 31 corresponding author articles. Li's most popular article was entitled "a general strategy for nanocrystal synthesis" ($TC2011 = 826$) in *Nature* (Wang, Zhuang, et al., 2005; Wang, Wu, et al., 2005). The 3rd ranking Cao from Southeast University published 16 first author articles and 19 corresponding author articles. The most heavily cited article of Cao concerned about global stability conditions for delayed CNNs with $TC2011 = 251$ (Cao, 2001). As constant θ is publication character, only three authors He, Ho, and Wang who had $\theta < 0.7854$, showing great contribution to their publications, such as conducting research and writing of the manuscript to research work (Herbertz & Müller-Hill, 1995; Reisenberg & Lundberg, 1990). Three authors Yu ($j = 19.80$), Tian ($j = 12.73$), and Liao ($j = 11.31$) had the same values of θ , just on the boundary of 0.7854 line owning the same quantity first authors articles and corresponding author articles. Yu with a greater value of j published much more first and corresponding author articles than that of Tian and Liao, since j is a constant related to publication quantity. Except these six authors, 21 authors had more corresponding author articles than first author articles ($\theta > 0.7854$). Most top authors had more corresponding author articles than first author articles, an indication that the leading authors were more likely to be the corresponding authors than the first author. Moreover, publication character θ is an important parameter of Y-index for publication character, which is very helpful especially when j of authors is too close to distinguish the performance of authors. One group of authors with the same j was exhibited in a dash line of an arc in Fig. 6, where each dot of the line had the same distance to the original point. Five authors Wang (11.18, 0.1799), Ho (11.18, 0.1799), Sung (11.18, 1.107), Chen (11.18, 1.391), and Cheng (11.18, 1.391), had the same value of $j = 11.18$, but θ are 0.1799, 1.107, and 1.391, respectively. An investigation presented that the corresponding author usually contributed more to the initial conception and supervision, while the first author contributed more to the work performed (Wren et al., 2007). It meant that Chen and Cheng were more likely to be credited for initial conception and supervision, while Wang and Ho probably deserved more credits for the work performed. A potential bias would appear in the analysis of authorship of authors who use the same name and those who use different names in their publications. Another potential confounder arises when an author moves from one affiliation to another. It is strongly recommended that an "international identity number" for all authors when they published their first paper in a Web of Science-listed journal (Chiu & Ho, 2007).

4. Discussion and conclusions

By focusing on China's independent top cited articles, this research has identified the discipline strength, research hotspots, and key contributors of China without considering external roles of international collaboration. The dramatic increase of China's scientific outputs was observed, and China was ranked second, consistent with findings in previous

studies (Leydesdorff & Wagner, 2009; Mervis, 2010). China's ability of publishing top cited articles has also been improving from 1991 to 2003. Furthermore, pronounced activities in chemistry and physics were observed, which is also in line with China's overall research results, such as China's all publications from 1997 to 2007 (Zhou & Glänzel, 2010) and China's highly cited articles from 1999 to 2009 (Fu et al., 2011). China has made dramatic strides to overtake the USA in most of the technical areas, especially in physical and engineering sciences (Kostoff, 2008). China's independent research was active in four core categories including multidisciplinary chemistry, physical chemistry, multidisciplinary materials science, and applied physics. China's research hotspots were observed to be nanotubes, nanoparticles, nanowires and nanostructures of nanoscience and nanotechnology, neural networks, ZnO, and films. Six classic articles included three in medicine, two in nanotube, and one in adsorption. Not only was China's emerging presence in nanoscience found in its independent research, but also it was in the global research (Guan & Ma, 2007; Kostoff, 2012; Kostoff et al., 2007). China has become the second largest nation in citations behind the USA during 1995–2006 (Leydesdorff & Wagner, 2009), and its citation counts continue to grow (Kostoff, 2012). The international scientific collaboration played a major role in this Chinese research advance (Ye et al., 2012). This study provided an evidence that in despite of the international collaboration, China's independent research in nanoscience and nanotechnology contributed a lot to its scientific performance.

Chinese Academy of Sciences dominated the production of top cited articles. The other most productive universities were located in Hong Kong and involved in the 985 Project with a large funding injection. The domination of Chinese Academy of Sciences, and the good performance of China's universities with a large funding have also been found in other studies (Fu et al., 2011; Zhou & Leydesdorff, 2006). Most top authors were likely to be corresponding authors than first authors. This independent research for China was partly consistent with previous related studies, and provides more information of top cited articles, research emphases, classic articles, and Y-index. Y-index (j, θ) as a newly developed indicator which was recently proposed by Ho (2012a,b), has successfully attempted to evaluate both the publication quantity and character of contributing authors and institutions of China's independent research. j indicates publication quantity, identifying "important authors", while θ publication character differentiates its nature of leadership role (Ho, 2012b). Y-index providing another choice could be adapted in other studies for the evaluation of authors, institutions and countries from a different angle of authorship.

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