An evaluation based on highly cited publications in Taiwan

Kun-Yang Chuang[1] and Yuh-Shan Ho[2,*]

[1]School of Public Health, Taipei Medical University, 250 Wu-Hsing Street, Taipei 11014, Taiwan
[2]Trend Research Centre, Asia University, 500 Lioufeng Road, Wufeng, Taichung 41354, Taiwan

Bibliometric analysis of highly cited papers of a country can provide interesting insights concerning authors, institutions, collaboration patterns and even useful recommendations for future research policy. The purpose of this study is to conduct bibliometric analysis of highly cited papers from Taiwan. Data used in the study were extracted from the SCI-Expanded database of the Web of Science Core Collection of Thomson Reuters. Authorship, collaboration pattern and Y-index were reported. Results showed that highly cited papers might not have high citations in early years and may be published in journals with low impact factors. International collaboration was responsible for the increasing number of highly cited papers over the years. Institutions can be categorized into three phenotypes and majority of the institutions were characterized with high dependency and low leadership in the collaboration. The United States was the leading choice for international collaboration, while National Taiwan University was the leading choice of institutions for domestic collaboration. With a few exceptions, leading authors tended to be the corresponding author, rather than the first author as in previous studies. It is speculated that this phenomenon may be due to a pecking order among institutions, traditional Confucius values of seniority, and inequality in resource allocation by funding agencies. Providing more balanced research funding, increasing the number of Ph D students studying abroad, eliminating gift authorships, especially partners in a project but not in papers and increasing the emphasis on independent research may be needed to amend the observed patterns.

Keywords: Bibliometric analysis, highly cited papers, impact factor, scientometrics, Y-index.

HIGHLY cited papers have been presented in journal citation studies[1] and in clinical research[2]. They have provided interesting and useful insights into which authors, papers, and topics influence the research profession over time[3]. Garfield[4] was one of the first to systematically use citation analyses to identify potential Nobel Prize winners based on their publication citation rankings. Highly cited papers were considered as 'classic citations'[5]. Moreover, highly cited papers can reveal the profile of scientific advancement and give a historic perspective on scientific progress[6,7]. Various studies have attempted to identify and analyse highly cited papers in the *Web of Science* (*WoS*) categories, for example, in dermatology[8], environmental and occupational health[9], obstetrics and gynecology[10], water resources[11], chemical engineering[12], and environmental sciences[13]. Bibliometric studies of highly cited articles[14] and reviews[15] in the Science Citation Index Expanded (SCI-Expanded) were recently conducted to reveal interesting patterns of citation life. Citation life cycles of most cited papers were revealed to provide more detailed citation information and its impact[16]. In some instances, researchers focused on highly cited papers of certain countries, such as India and China, and it was concluded that the next step is for researchers in these two countries to write papers that will be cited far more often than now[17].

For the last decade, the h-index has been the most widely applied index to evaluate papers since it was presented in 2005 (ref. 18). Similarly, the g-index[19], A-index[20], R-index[21] and AR-index[21] were also reported. The Y-index (j, h), with two constants, has been used in recent studies to evaluate especially highly cited papers in, for example, chemical engineering[12], independent research of China[22], SCI-Expanded[14], social work research[23] and adsorption research[24]. The Y-index is useful, especially in an era with an increasing number of authors, when unethical authorship practices are more likely[25,26], and when contributions of authors are diluted. The Y-index considers two prominent authorships: the first and corresponding authors. It reveals major contributors, ignoring unethical authors, such as gift authors, but also provides deep insights into the features of contributions[24].

The purpose of this article was to identify and analyse highly cited papers from Taiwan in the SCI-Expanded database from 1900 to 2012. Taiwan, with its close-knit institutional network and high dependence on international collaboration, provides an excellent case study on the influence of authorship and collaboration on highly cited papers. The document type, authorship, annual production, field performance, contributing institutions, Y-index, and other indicators were used in this bibliometric research.

*For correspondence. (e-mail: ysho@asia.edu.tw)

Methodology

Data used in this study were extracted from the SCI-Expanded database of the Web of Science Core Collection of Thomson Reuters. A search was conducted for papers with the phrase 'Taiwan' in the address field. An initial search of papers from 1900 to 2012 yielded a total of 333,676 documents, distributed in 21 document types. Further examination revealed that 104 documents were not by researchers in Taiwan despite having a phrase 'Taiwan' in the author field. For instance, papers with Pig Res Inst Taiwan, South Korea; Anim Technol Inst Taiwan, South Korea; NXP Semicond Taiwan Semicond Mfg Co, The Netherlands, and Taiwan Hosp, U Arab Emirates were excluded. Thus 333,595 papers were published by at least one author with an affiliation to Taiwan from 1900 to 2012 based on the SCI-Expanded (updated on 10 January 2014). The total number of times article cited from the Web of Science Core Collection since its publication to the end of 2012 was recorded as TC_{2012} (refs 27, 28), and was used as a filter to retrieve papers. Papers with a TC_{2012} of ≥ 100 were selected for analysis as highly cited Taiwanese papers. Likewise, C_{2012}, the total number of citations of a paper in 2012 (ref. 12), and C_0, the total number of citations of a paper in its publication year[15] were employed to characterize highly cited Taiwanese papers. The ratio TCPY, the average citation per year since publication, was also used to compare highly cited papers.

Several indicators were used to present the profile of highly cited papers in Taiwan: (i) Taiwan independent (TI) papers, if the researchers' affiliations were all from Taiwan; (ii) internationally collaborative (IC) papers, if the papers were co-authored by researchers from other countries; (iii) institutionally independent (INI) papers, if the researchers' affiliations were from the same institute in Taiwan; (iv) inter-institutionally collaborative (INC) papers, if authors were from different institutions; (v) nationally collaborative (NC) papers, if all of the authors were from different institutions in Taiwan; (vi) first author (FP) papers, if the first author was from a institution in Taiwan, and (vii) corresponding author (RP) papers, if the corresponding author was from a institution in Taiwan.

Y-index

The Y-index (j, h) includes two constants[12,14], j related to the publication intensity and h related to publication characteristics, which can be described by the number of first-author paper (FP) and the number of corresponding author papers (RP) as

$$j = FP + RP, \qquad (1)$$

$$h = \tan^{-1}\left(\frac{RP}{FP}\right), \qquad (2)$$

where j is the total number of times an author has published as a first or corresponding author. It is easy to compare the publication intensity and publication characteristics from the distribution of authors in a Y-index figure.

Results and discussion

General profile

A total of 2456 highly cited papers from Taiwan were identified in the SCI-EXPANDED database from 1973 to 2012. All were published in English, in seven document types: 2270 (92%) articles, 139 (5.7%) reviews, 80 (3.3%) proceedings papers, 24 (1.0%) notes, 14 (057%) letters, seven (0.29%) editorial materials, and two (0.081%) meeting abstracts. Among these, the percentage of TI, IC, INI, INC, NC, FP and RP papers was 52, 48, 27, 73, 25, 65 and 66% respectively.

Figure 1 shows the distribution of these papers over the years and their citations per publication (CPP = TC_{2012}/TP). The year with the most papers was 2002 with 205 papers (8.3%), followed by 2004 with 196 papers (8.0%) and 2001 with 191 papers (7.8%). Before 1973, no highly cited Taiwanese papers were found. From 1991 to 2002, it increased at a much quicker pace, and then showed a rapidly decreasing trend after 2002. Independent Taiwanese papers showed a similar trend. However, from 1992 to 2002, independent papers showed a much smaller increasing rate relative to the overall trend, an indication that international collaborations, rather than independent Taiwanese papers, contributed more to the overall increasing trend. As for CPP, it remained steady from 1973 to 2011 with the exception of 1981, in which there
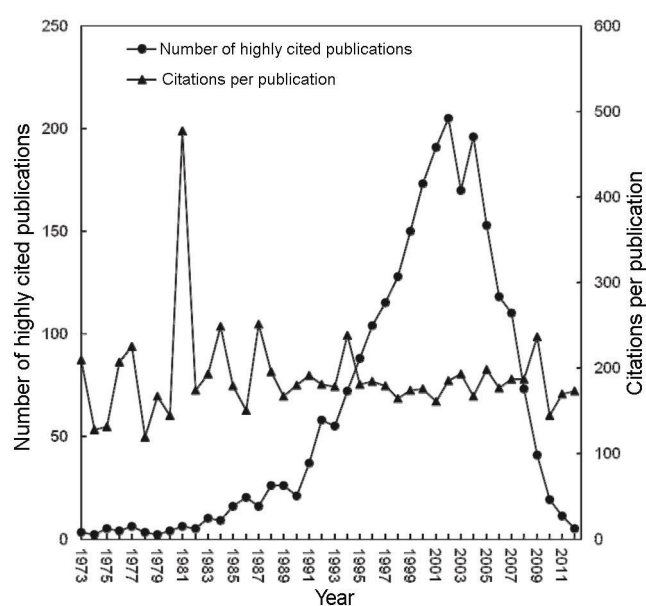
Figure 1. Number of papers and citations per publication by year.

were six papers and a much higher CPP of 477. This can be attributed to a publication in *Lancet*[29] with TC_{2012} of 1854.

Citation frequency is highly correlated with the length of time since publication, and recent papers need time to accumulate citations[30]. Based on Figure 1, it takes highly cited papers about 10 years to reach a peak. Similar phenomenon could also be found in the top-cited research works in the SCI-Expanded[14] and independent research from China in the SCI-Expanded[22]. To verify this 10-year lag, Figure 2 was constructed using TC_{2012}, TC_{2011}, TC_{2010}, TC_{2009} and TC_{2008} to show the number of highly cited papers by year. Regardless of the year of data, they all showed approximately a 10-year period between the time of data collection and the peak output of highly cited papers. Thus, it might be necessary to reconsider the practice of focusing on a 5-year time-span that has traditionally been adopted by many institutions when evaluating the impact of a researcher or a paper. To emphasize this point, a total of 1216 highly cited Taiwan papers (50% of 2456 highly cited Taiwan papers) had no citations in the publication year ($C_0 = 0$). Although with an increasing number of journals, papers have had higher citations in the publication year (C_0) in recent years[15]. Furthermore, among the top 100 C_0 papers, only 30 were among the top 100 TC_{2012} papers. In other words, using a 5-year time-span as the assessment period might not reflect the true impact of a paper.

International collaborations

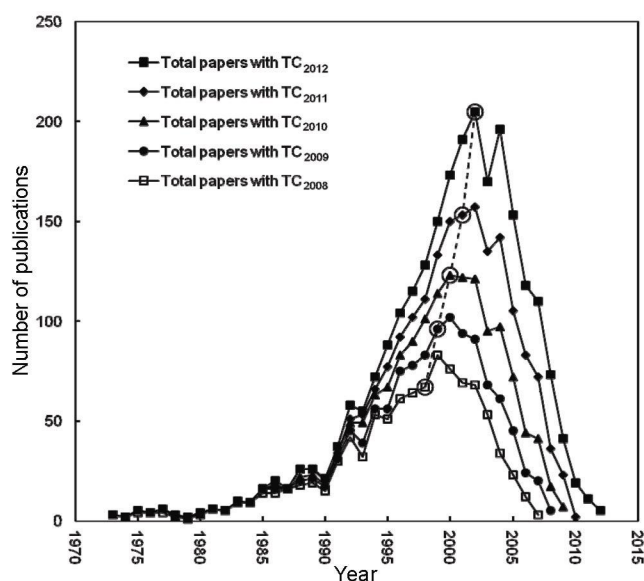Internationally collaborative papers made up a large proportion of highly cited papers from Taiwan. Among highly cited papers, only 52% were independent Taiwanese papers. A closer look at the collaborative partners of highly cited papers revealed that as many as 38% of highly cited papers were based on collaborative efforts with institutions in the US, followed by Germany (8.3%), China (8.2%), Japan (7.9%) and UK (7.6%), as indicated in Table 1. Moreover, among all highly cited papers, as many as 22% had a first author and 21% had a corresponding author affiliated with an US institution, an indication that the US has had more of a leadership role in collaborative relationships with Taiwan, and Taiwan is heavily dependent upon the US to publish highly cited papers. On the contrary, Taiwanese researchers and institutions had a leadership role in collaborative relationships with Germany, China, Japan and UK. Previous research indicated that international collaborative efforts tended to produce a higher number of authors and frequently wider exposure, and thus, was more likely to have higher citations[31]. Figure 3 shows that internationally collaborative papers have higher citations than independent Taiwanese papers. Interestingly, those with a first author and/or corresponding author from a foreign institution tended to have higher citations than those with a first author and/or corresponding author from a Taiwanese institution.

Leading papers

The earliest highly cited Taiwan paper was by Kauffman *et al.*[32] with a TC_{2012} of 324. The paper with the highest citations ($TC_{2012} = 3531$) was by Jin *et al.*[33] in 1994. For papers with TC_{2012} of >2000, no first or corresponding authors were Taiwan. The top institutionally independent papers in each document type are listed below: an article by Hsu and Lin[34] from National Taiwan University with a TC_{2012} of 1559; a review paper by Cheng *et al.*[35] from National Chiao Tung University with a TC_{2012} of 743; a proceedings paper by Chang *et al.*[36] from National Chung Cheng University with a TC_{2012} of 403; a note by Tsai[37] from National Chiao Tung University with a TC_{2012} of 280, and a letter by Yu *et al.*[38] from National Chung Cheng University with a TC_{2012} of 894. The only institutionally independent editorial material by Wei *et al.*[39] from Academia Sinica had TC_{2012} of 134.

Table 2 shows TC_{2012} values for the 14 papers that have been cited more than 1000 times. Among them, nine were published in the 2000s, three in the 1990s, and two in the 1980s. The first paper to be cited more than 1000 times was published in 1981 and the most recent one was published in 2009. The 14 papers showed wide variations in TC_{2012}, C_{2012}, C_0 and TCPY values, with no particular pattern. Some of them had a low ranking in C_{2012}, while some had a low ranking in C_0. Among the 14 papers, four were published in the *New England Journal of Medicine* (impact factor $IF_{2012} = 51.658$), three in *Nature* ($IF_{2012} = 38.597$), and one each in the *Lancet* ($IF_{2012} = 39.060$),

Figure 2. Number of highly cited papers by year at different data collection points.

Table 1. Collaboration characteristics by countries

Country	TP	TP rank (%)	FP rank (%)	RP rank (%)
USA	925	1 (38)	1 (22)	1 (21)
Germany	205	2 (8.3)	5 (1.2)	5 (1.3)
China	202	3 (8.2)	4 (1.8)	4 (1.7)
Japan	193	4 (7.9)	2 (2.0)	2 (2.1)
UK	186	5 (7.6)	2 (2.0)	3 (1.9)
France	152	6 (6.2)	6 (0.73)	6 (0.71)
Canada	138	7 (5.6)	7 (0.61)	8 (0.58)
South Korea	133	8 (5.4)	11 (0.45)	10 (0.49)
Italy	117	9 (4.8)	8 (0.57)	7 (0.63)
Australia	113	10 (4.6)	8 (0.57)	9 (0.54)
Russia	107	11 (4.4)	17 (0.16)	19 (0.13)
Switzerland	104	12 (4.2)	12 (0.41)	12 (0.4)

TP, Total number of papers in collaboration with Taiwan; FP, Number of first-author papers; RP, Number of corresponding author papers.
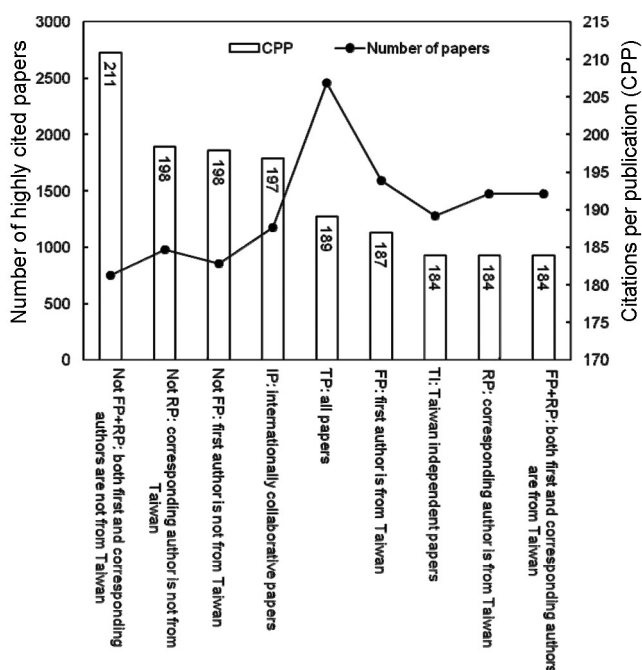

Figure 3. Citations and papers by type of collaboration and authorship.

Science (IF$_{2012}$ = 31.027). *Journal of the American Chemical Society* (IF$_{2012}$ = 10.677), *Proceedings of the National Academy of Sciences of the United States of America* (IF$_{2012}$ = 9.737), *European Physical Journal C* (IF$_{2012}$ = 5.247), *Nuclear Physics A* (IF$_{2012}$ = 1.525) and *IEEE Transactions on Neural Networks* (there is no IF after 2011 for the journal). It was expected that papers published in journals with a high IF would probably have high citations. However, in this instance, some papers with more than 1000 citations could be also found in journals with a low IF. In evaluating the research impact of a researcher, it might not be sufficient to assess the extent of influence based solely on the IF of journals in which the papers are published.

Journals and Web of Science categories

According to the *Journal Citation Reports* (*JCR*) Science Edition, there were 8471 journals, distributed across 176 *WoS* categories in 2012. Highly cited Taiwanese papers were published by 746 journals across 150 *WoS* categories. The leading journal, *Physical Review Letters* (IF$_{2012}$ = 7.943) published 89 papers (3.6% of 3456) followed by *Applied Physics Letters* (IF$_{2012}$ = 3.794) with 53 papers (2.2%), *New England Journal of Medicine* (IF$_{2012}$ = 51.658) with 40 papers (1.6%), *Proceedings of the National Academy of Sciences of the United States of America* (IF$_{2012}$ = 9.737) with 40 papers (1.6%), *Hepatology* (IF$_{2012}$ = 12.003) with 39 papers (1.6%), *Journal of the American Chemical Society* (IF$_{2012}$ = 10.677) with 37 papers (1.5%) and *Science* (IF$_{2012}$ = 31.027) with 36 papers (1.5%). While leading journals are likely to attract the most cited papers, which in turn helps maintain their high IF[40], highly cited papers still could be found in journals with lower IFs[14,16]. In this study, we found that some highly cited Taiwanese papers were also found in journals with lower IF, such as *Journal of Information Science and Engineering* (IF$_{2012}$ of 0.299), *Journal of Food and Drug Analysis* (IF$_{2012}$ of 0.333), and *Journal of Food Processing and Preservation* (IF$_{2012}$ of 0.450). It may be inappropriate to use only one indicator, for example, the IF of a journal to evaluate research and publication performances.

Of the 150 *WoS* categories that published highly cited Taiwanese papers, the top six top categories were electrical and electronic engineering with 191 (7.8%) papers, biochemistry and molecular biology with 164 (6.7%) papers, oncology with 148 (6.0%) papers, multidisciplinary materials science with 141 (5.8%) papers, physical chemistry with 138 (5.6%) papers, and multidisciplinary

Table 2. Fourteen most frequently cited papers ($TC_{2012} > 1000$)

Rank (TC_{2012})	Rank (C_{2012})	Rank (C_0)	Rank (TCPY)	Title	Reference
1 (3531)	26 (132)	253 (6)	8 (186)	Thousandfold change in resistivity in magnetoresistive La–Ca–Mn–O films	33
2 (2401)	5 (264)	620 (2)	2 (240)	The international HapMap project	48
3 (1854)	236 (42)	827 (1)	75 (58)	Hepatocellular carcinoma and hepatitis B virus: a prospective study of 22,707 men in Taiwan	29
4 (1732)	11 (212)	188 (8)	6 (217)	Trastuzumab after adjuvant chemotherapy in HER2-positive breast cancer	49
5 (1559)	9 (215)	223 (7)	18 (142)	A comparison of methods for multiclass support vector machines	34
6 (1475)	205 (46)	4 (138)	16 (148)	A novel coronavirus associated with severe acute respiratory syndrome	50
7 (1403)	124 (59)	620 (2)	63 (64)	Comparison of the structures and wetting properties of self-assembled monolayers of normal-alkanethiols on the coinage metal-surfaces, Cu, Ag, Au	51
8 (1341)	19 (149)	30 (33)	22 (122)	Complete genome sequence of the model actinomycete *Streptomyces coelicolor* A3(2)	52
9 (1294)	252 (40)	99 (13)	36 (86)	A one-year trial of lamivudine for chronic hepatitis B	53
10 (1279)	18 (158)	87 (15)	14 (160)	The map-based sequence of the rice genome	54
11 (1212)	1 (476)	34 (32)	1 (303)	Gefitinib or carboplatin–paclitaxel in pulmonary adenocarcinoma	55
12 (1160)	85 (72)	18 (47)	34 (89)	Global QCD analysis of parton structure of the nucleon: CTEQ5 parton distributions	56
13 (1157)	16 (166)	173 (9)	17 (145)	Formation of dense partonic matter in relativistic nucleus–nucleus collisions at RHIC: experimental evaluation by the PHENIX Collaboration	57
14 (1091)	301 (36)	827 (1)	153 (42)	Supercoiling of the DNA template during transcription	58

TC_{2012}, Number of citations since its publication to the end of 2012; C_{2012}, Number of citations in 2012; C_0, Number of citations in the publication year; TCPY, TC_{2012} per year.

Table 3. Characteristics of the top 15 institutions

Institution	TP	TPR (%[a])	%[b] (TI)	%[b] (IC)	%[b] (NC)	%[b] (INI)	%[b] (INC)	%[b] (FP)	%[b] (RP)	AU (MA)
National Taiwan University	624	1 (25)	60 (373)	40 (251)	37 (233)	22 (135)	78 (489)	50 (312)	43 (270)	40 (3100)
Academia Sinica	437	2 (18)	42 (182)	58 (255)	32 (142)	8.5 (37)	92 (400)	39 (172)	35 (154)	93 (3051)
National Tsing Hua University	202	3 (8.2)	71 (143)	29 (59)	35 (70)	36 (72)	64 (130)	68 (137)	64 (129)	18 (2512)
National Yang Ming University	192	4 (7.8)	62 (119)	38 (73)	53 (102)	8.3 (16)	92 (176)	27 (52)	21 (41)	9.4 (262)
National Taiwan University Hospital	177	5 (7.2)	58 (103)	42 (74)	47 (83)	11 (19)	89 (158)	42 (75)	37 (66)	10 (66)
National Cheng Kung University	173	6 (7.0)	68 (117)	32 (56)	24 (42)	43 (74)	57 (99)	66 (115)	62 (107)	8.6 (262)
National Chiao Tung University	142	7 (5.8)	67 (95)	33 (47)	25 (35)	41 (58)	59 (84)	67 (95)	65 (92)	6 (271)
Taipei Veterans General Hospital	134	8 (5.5)	56 (75)	44 (59)	51 (69)	1.5 (2)	99 (132)	38 (51)	34 (45)	8.9 (45)
Chang Gung Memorial Hospital	124	9 (5.0)	44 (54)	56 (70)	27 (34)	15 (18)	85 (106)	35 (44)	30 (37)	10 (65)
National Central University	118	10 (4.8)	39 (46)	61 (72)	28 (33)	11 (13)	89 (105)	31 (37)	31 (36)	218 (3100)
Chang Gung University	102	11 (4.2)	47 (48)	53 (54)	37 (38)	10 (10)	90 (92)	30 (31)	25 (26)	10 (71)
National Chung Hsing University	68	12 (2.8)	75 (51)	25 (17)	44 (30)	28 (19)	72 (49)	54 (37)	54 (37)	5 (23)
National Defense Medical Center	56	13 (2.3)	50 (28)	50 (28)	45 (25)	3.6 (2)	96 (54)	20 (11)	14 (8)	6.8 (14)
Kaohsiung Medical University	54	14 (2.2)	61 (33)	39 (21)	37 (20)	22 (12)	78 (42)	39 (21)	39 (21)	7.1 (21)
Taipei Medical University	53	15 (2.2)	68 (36)	32 (17)	49 (26)	19 (10)	81 (43)	36 (19)	36 (19)	7.5 (58)

TP, Total number of highly cited papers in Taiwan; TPR, Rank in Taiwan; %, Percentage of papers in an institution; TI, Number of independent Taiwanese papers; IC, Number of internationally collaborative papers; NC, Number of nationally collaborative papers; INI, Number of institutionally independent papers; INC, Number of institutionally collaborative papers; FP, Number of first-author papers; RP, Number of corresponding author papers; AU, Average numbers of authors; MA, Maximum number of authors in a paper. [a]Percentage of highly cited papers among total Taiwanese highly cited papers; [b]Percentage of highly cited papers among an institution's total highly cited papers.

chemistry with 137 (5.6%) papers. The six categories combined accounted for 31% of highly cited papers.

Institutions

Table 3 shows the characteristics of highly cited papers of the top 15 Taiwan institutions. The leaders were National Taiwan University, ranked first with 624 (25% of 2456 highly cited Taiwanese papers) highly cited papers, followed by Academia Sinica (437 papers, 18%), and National Tsing Hua University (202 papers, 8.2%), all of which are public institutions. From Table 3, three phenotypes of institutions can be observed: type I institution, characterized by high collaboration with a low leadership

Table 4. Percentage of inter-institutional collaborations among the top 15 Taiwanese institutions

	NTU	AS	NTHU	NYMU	NTUH	NCKU	NCTU	TVGH	CGMH	NCU	CGU	NCHU	NDMC	KMU	TMU
NTU	100	24	11	8.3	49	4.6	4.9	7.5	11	19	11	8.8	16	15	28
AS	17*	100	12	14	14	6.9	4.2	6.7	8.1	16	2.9	12	29	15	9.4
NTHU	3.7	5.7	100	1.0	0.56	1.2	4.2	1.5	2.4	4.2	2.9	7.4	0	3.7	3.8
NYMU	2.6	5.9	1.0	100	4.5	2.3	0.70	66	5.6	0	7.8	2.9	11	5.6	7.5
NTUH	14	5.5	0.50	4.2	100	1.7	0	5.2	12	0.85	4.9	5.9	3.6	9.3	13
NCKU	1.3	2.7	1.0	2.1	1.7	100	0	1.5	0.81	5.1	0	1.5	1.8	1.9	3.8
NCTU	1.1	1.4	3.0	0.52	0	0	100	0.75	0	4.2	1.0	5.9	0	0	0
TVGH	1.6	2.1	1.0	46	4.0	1.2	0.70	100	5.6	0	5.9	0	13	7.4	5.7
CGMH	1.9	2.1	1.5	3.6	7.9	0.58	0	5.2	100	0	41	2.9	5.4	9.3	5.7
NCU	3.7	4.3	2.5	0	0.56	3.5	3.5	0	0	100	1.0	0	0	0	0
CGU	1.8	0.69	1.5	4.2	2.8	0	0.70	4.5	34	0.85	100	1.5	3.6	1.9	3.8
NCHU	1.0	1.8	2.5	1.0	2.3	0.58	2.8	0	1.6	0	1.0	100	1.8	1.9	0
NDMC	1.4	3.7	0	3.1	1.1	0.58	0	5.2	3.2	0	2.0	1.5	100	0	5.7
KMU	1.3	1.8	1.0	1.6	2.8	0.58	0	3.0	4.0	0	1.0	1.5	0	100	5.7
TMU	2.4	1.1	1.0	2.1	4.0	1.2	0	2.2	2.4	0	2.0	0	5.4	5.6	100

*Indicates that 17% of all NTU highly cited papers were published in collaboration with AS.
NTU, National Taiwan University; AS, Academia Sinica; NTHU, National Tsing Hua University; NYMU, National Yang Ming University; NTUH, National Taiwan University Hospital; NCKU, National Cheng Kung University; NCTU, National Chiao Tung University; TVGH, Taipei Veterans General Hospital; CGMH, Chang Gung Memorial Hospital; NCU, National Central University; CGU, Chang Gung University; NCHU, National Chung Hsing University; NDMC, National Defense Medical Center; KMU, Kaohsiung Medical University; TMU, Taipei Medical University.

contribution; type II institution, characterized by low collaboration with a high leadership contribution, and type III institutions, characterized by high collaboration with a high leadership contribution. Majority of the institutions were of the type I phenotype with a high reliance on international collaboration and institutional collaboration, but low leadership involvement. For instance, Academia Sinica, ranked second in total number of papers, revealed an interesting case of high dependence on collaboration with 58% being internationally collaborative papers, 92% were institutionally collaborative papers, and only 8.5% independent papers. Also, it had a leadership role in <50% of papers, with 39% first-author papers and 35% corresponding authored papers. Another example was National Yang Ming University, with 92% collaboration papers, and even lower percentage of first-author and corresponding author papers. The type II phenotype included National Cheng Kung University, National Chiao Tung University and National Tsing Hua University with the percentage of independent papers at about 40, showing a much higher level of self-reliance. They all had first-author or corresponding authored papers at above 60%. Type III phenotype institutions included National Taiwan University and National Chung Hsing University. Both had a high percentage of collaborative papers, 78 and 72 respectively, and yet were able to maintain a leadership role in about 50% of the papers.

Table 4 shows collaboration patterns among the top institutions with at least 50 papers. National Taiwan University was the largest domestic collaborating partner for many institutes, particularly National Taiwan University Hospital, which collaborated on 49% of its papers with National Taiwan University, followed by Taipei Medical University (28%), and Academia Sinica (24%). Academia Sinica was the largest domestic collaborating partner with National Taiwan University (17%), National Tsing Hua University (12%), National Cheng Kung University (6.9%), National Chung Hsing University (12%), National Defense Medical Center (29%), and Kaohsiung Medical University (15%). Furthermore, National Yang Ming University and Taipei Veterans General Hospital also extensively collaborated, while Chang Gung University and Chuang Gung Memorial Hospital were also close partners. Inter-institutional collaborations were found between universities and their affiliated hospitals. To sum up, there appeared to be a major cluster of collaboration networks headed by National Taiwan University, a type III institution phenotype, which many type I institutions depended upon to publish highly cited papers. This phenomenon could partly be explained by the fact that many faculty members of other institutions may have received their Ph D training at National Taiwan University, and thus inadvertently created a 'pecking order' of institutions, and hence the imbalance in the collaboration relationship. A high proportion of type I institutions contributed little to overall research performance. Government agencies in charge of research and development should assess the reasons leading to such a high proportion of type I institutions. One possible reason could be due to inequality in research resources due to unequal allocation of research funding for certain institutions.

Authors

Results of the author analysis identified those researchers who have made significant contributions. A total of 23,652 authors in 2456 highly cited Taiwan papers

contributed to top-cited papers, among whom 11,842 authors (50%) contributed only one paper, 3340 (14%) contributed two papers, 1505 (6.4%) contributed three papers, 1425 (6.0%) contributed four papers, 1754 (7.4%) contributed five papers, and 3786 authors (16%) contributed more than five papers. The average number of authors per paper was 18, with 3100 as the largest number of authors. Of the 2456 papers, 101 (4.1%) were single-author papers, 407 (17%) had two authors, 393 (16%) had three authors, 282 (11%) had four authors, and 239 (10%) had five authors. Moreover, 290 (12%) papers had about 11–100 authors, 91 (3.7%) papers had about 101–1000 authors, and 14 (5.7%) papers had about 1001–3100 authors. The average number of authors per paper was 18, which was skewed by about 9% of papers with more than 100 authors per paper. The medium number of authors was five. It was reported that papers with a high number of authors are more likely to have unethical authorship practices, such as gift authorship[25,26]. Gift or honorary authorship is defined as the inclusion of an individual as author who did not significantly contribute to the project[41,42]. It is not clear if these highly cited Taiwanese papers had on average more authors per paper than those from other countries. However, earlier studies have shown that the respective averages were 3.5 and 3.6 authors for papers presented in the field of water resources[28] and chemical engineering[43] in the Essential Science Indicators database, and 4.8 authors for highly cited reviews in the SCI-EXPANDED[15], all of which were lower than the average number of 18 authors for highly cited Taiwanese papers.

It is generally accepted that the first author contributed most to the work, including conducting research and writing the manuscript[44,45], while the corresponding author supervised the planning and execution of the study and the writing of the paper[46]. In total, 2190 papers (89% of 2456 highly cited Taiwanese papers) had information on both the first and corresponding authors in the SCI-EXPANDED. There were 22,984 authors who contributed to 2190 papers. Among these authors, 21,012 (91%) had no first- or corresponding author papers. Three hundred and ninety-six authors (1.7%) had only corresponding-author papers, but no first-author papers, while 552 authors (2.4%) had only first-author papers, but no corresponding author papers. Only 991 (4.3%) authors published both first- and corresponding author papers, including 602 authors from Taiwan (61% of 991 authors).

Figure 4 displays the distribution of the Y-index for the top 31 authors ($j \geq 9$) who were the main contributors to highly cited Taiwanese papers. Each dot represents a Y-index (j, h). The publication intensity, j, can help obtain the total number of first and corresponding authors. Figure 4 is helpful as a tool especially in differentiating quantity and quality. For example, h of Y. F. Liaw, D. S. Chen, and S. A. Chen were all 0.9601, but their j values differed at 34, 17 and 17 respectively. Among these three

authors, Liaw had the highest number of first- and corresponding author papers. In another example, j values of J. K. Lin, Y. H. Wei, D. H. Chen and R. P. Beasley were all 14, but their h values differed at 1.406, 1.190, 1.190 and 0.7854 respectively. Also, Lin had the greatest proportion of corresponding to first-author papers. In Figure 4, 24 authors were affiliated with Taiwanese institutions. The leaders were Yun-Fan Liaw ($j = 34$, FP = 14, RP = 20), Chien-Jen Chen ($j = 29$, FP = 11, RP = 18), Yuh-Shan Ho ($j = 19$, FP = 10, RP = 9), Ding-Shinn Chen ($j = 17$, FP = 7, RP = 10), Show-An Chen ($j = 17$, FP = 7, RP = 10), Su-Hsia Lin ($j = 17$, FP = 9, RP = 8), and Shih-Ann Chen ($j = 13$, FP = 3, RP = 10). Leading international authors were F. Abe ($j = 28$, FP = 14, RP = 14), S.S. Adler ($j = 22$, FP = 11, RP = 11), K. Adcox ($j = 18$, FP = 10, RP = 8), and B. B. Back ($j = 17$, FP = 9, RP = 8).

Previous studies have shown that authors with more top articles are more likely to be listed as the first author[6,47]. While this statement is consistent with the small sample of international authors listed in Figure 4, it does not fit the profile of Taiwanese authors. Contrary to previous findings, leading researchers in Taiwan were more likely to be corresponding authors. One may speculate that cultural differences in publishing may have led to such a contrasting phenomenon from the previous findings. Perhaps the traditional Confucius culture, with its emphasis on seniority, has fostered an unwritten practice that the project leader, or the person responsible for obtaining the funding, should be placed as the corresponding author. Such a practice may result in some researchers with a high number of papers within a relatively short period, since they have been credited as the corresponding author. In the long term, research funding and
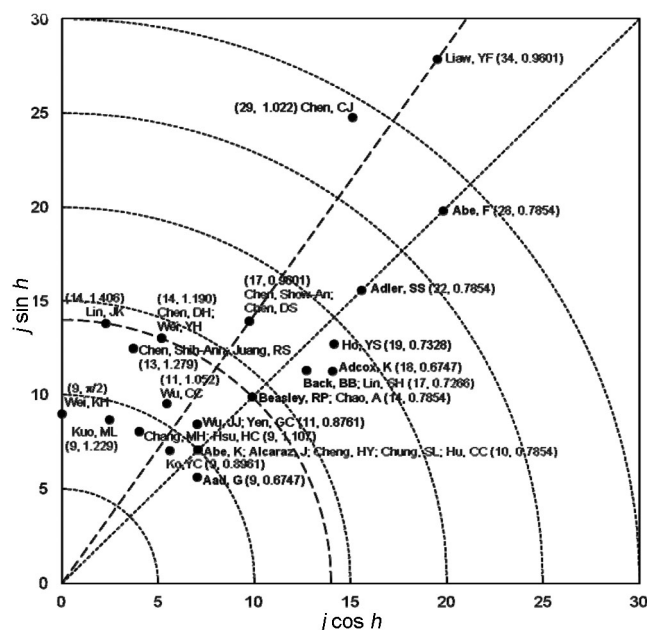

Figure 4. Y-index of the top 31 authors with the greatest j values ($j \geq 9$).

resources may become overly concentrated on a few researchers, since more published papers are likely to attract more funding. The effects of such a practice on a research potential, output, and quality of a country should be carefully studied.

Conclusions

This bibliometric analysis of highly cited paper from Taiwan has yielded some interesting findings. Highly cited papers might not have high citations in early years, and may be published in journals with low IF. A 10-year period may be a more appropriate time-frame for assessing the performance of a researcher and the use of IF as the basis for evaluation might be misleading. The escalating number of highly cited Taiwanese papers has mainly being accomplished through international collaboration. USA is the leading partner for international collaboration. The reliance on collaboration and the lack of leadership in publication fit the profile of the majority of institutions in Taiwan. Research networks headed by National Taiwan University dominated the domestic collaboration patterns. With a few exceptions, leading authors tended to be the corresponding author, rather than the first author as in previous studies. It is speculated that this phenomenon may be due to a pecking order among institutions, traditional Confucius values of seniority, and inequality in resource allocation by funding agencies. To break such patterns, artificial and deliberate interventions, such as providing more balanced research funding, increasing the number of Ph D students studying abroad, eliminating gift authorships especially partners in a project but not in papers, and increasing emphasis on independent research may be needed.

1. Garfield, E., Journal citation studies. VIII. Some highly cited papers from highly cited general medical and clinical journals. *Curr. Contents*, 1974, **27**, 5–12.
2. Ioannidis, J. P. A., Contradicted and initially stronger effects in highly cited clinical research. *JAMA*, 2005, **294**, 218–228.
3. Smith, D. R., Citation indexing and highly cited papers in the *Australian Veterinary Journal. Aust. Vet. J.*, 2008, **86**, 337–339.
4. Garfield, E., Citation indexing for studying science. *Nature*, 1970, **227**, 669–671.
5. Garfield, E., 100 citation classics from the *Journal of the American Medical Association. JAMA*, 1987, **257**, 52–59.
6. Baltussen, A. and Kindler, C. H., Citation classics in anesthetic journals. *Anesth. Analg.*, 2004, **98**, 443–451.
7. Ohba, N., Nakao, K., Isashiki, Y. and Ohba, A., The 100 most frequently cited papers in ophthalmology journals. *Arch. Ophthalmol.*, 2007, **125**, 952–960.
8. Stern, R. S. and Arndt, K. A., Top cited authors in dermatology: a citation study from 24 journals: 1982–1996. *Arch. Dermatol.*, 1999, **135**, 299–302.
9. Smith, D. R., Highly cited papers in environmental and occupational health, 1919–1960. *Arch. Environ. Occup. Health*, 2009, **64**, 32–42.
10. Brandt, J. S., Downing, A. C., Howard, D. L., Kofinas, J. D. and Chasen, S. T., Citation classics in obstetrics and gynecology: the 100 most frequently cited journal articles in the last 50 years. *Am. J. Obstet. Gynecol.*, 2010, **203**, article no.: 355.e1-355.e7.
11. Wang, M. H., Li, J. F. and Ho, Y. S., Research articles published in water resources journals: a bibliometric analysis. *Desalin. Water Treat.*, 2011, **28**, 353–365.
12. Ho, Y. S., Top-cited articles in chemical engineering in Science Citation Index Expanded: a bibliometric analysis. *Chin. J. Chem. Eng.*, 2012, **20**, 478–488.
13. Khan, M. A. and Ho, Y. S., Top-cited articles in environmental sciences: merits and demerits of citation analysis. *Sci. Total Environ.*, 2012, **431**, 122–127.
14. Ho, Y. S., The top-cited research works in the Science Citation Index Expanded. *Scientometrics*, 2013, **94**, 1297–1312.
15. Ho, Y. S. and Kahn, M., A bibliometric study of highly cited reviews in the Science Citation Index Expanded™. *J. Am. Soc. Inf. Sci.*, 2014, **65**, 372–385.
16. Fu, H. Z., Wang, M. H. and Ho, Y. S., The most frequently cited adsorption research articles in the Science Citation Index (Expanded). *J. Colloid Interface Sci.*, 2012, **379**, 148–156.
17. Madhan, M., Chandrasekar, G. and Arunachalam, S., Highly cited papers from India and China. *Curr. Sci.*, 2010, **99**, 738–749.
18. Hirsch, J. E., An index to quantify an individual's scientific research output. *Proc. Natl. Acad. Sci. USA*, 2005, **102**, 16569–16572.
19. Egghe, L., Theory and practise of the *g*-index. *Scientometrics*, 2006, **69**, 131–152.
20. Jin, B. H., *h*-index: an evaluation indicator proposed by scientist. *Sci. Focus*, 2006, **1**, 8–9.
21. Jin, B. H., Liang, L. M., Rousseau, R. and Egghe, L., The R- and AR-indices: complementing the *h*-index. *Chin. Sci. Bull.*, 2007, **52**, 855–863.
22. Fu, H. Z. and Ho, Y. S., Independent research of China in Science Citation Index Expanded during 1980–2011. *J. Informetr.*, 2013, **7**, 210–222.
23. Ho, Y. S., Classic articles on social work field in Social Science Citation Index: a bibliometric analysis. *Scientometrics*, 2014, **98**, 137–155.
24. Fu, H. Z. and Ho, Y. S., Top cited articles in adsorption research using *Y*-index. *Res. Evaluat.*, 2014, **23**, 12–20.
25. Slone, R. M., Coauthors' contributions to major papers published in the *AJR*: frequency of undeserved coauthorship. *Am. J. Roentgenol.*, 1996, **167**, 571–579.
26. Dotson, B. and Slaughter, R. L., Prevalence of articles with honorary and ghost authors in three pharmacy journals. *Am. J. Health-Syst. Pharm.*, 2011, **68**, 1730–1734.
27. Wang, M. H., Yu, T. C. and Ho, Y. S., A bibliometric analysis of the performance of Water Research. *Scientometrics*, 2010, **84**, 813–820.
28. Chuang, K. Y., Wang, M. H. and Ho, Y. S., High-impact papers presented in the subject category of water resources in the Essential Science Indicators database of the Institute for Scientific Information. *Scientometrics*, 2011, **87**, 551–562.
29. Beasley, R. P., Lin, C. C., Hwang, L. Y. and Chien, C. S., Hepatocellular carcinoma and hepatitis B virus: a prospective-study of 22707 men in Taiwan. *Lancet*, 1981, **318**, 1129–1133.
30. Gisvold, S. E., Citation analysis and journal impact factors – is the tail wagging the dog? *Acta Anaesthesiol. Scand.*, 1999, **43**, 971–973.
31. Glänzel, W., National characteristics in international scientific co-authorship relations. *Scientometrics*, 2001, **51**, 69–115.
32. Kauffman, H. E., Reddy, A. P. K., Hsieh, S. P. Y. and Merca, S. D., An improved technique for evaluating resistance of rice varieties to *Xanthomonas oryzae. Plant Dis. Rep.*, 1973, **57**, 537–541.
33. Jin, S., Tiefel, T. H., Mccormack, M., Fastnacht, R. A., Ramesh, R. and Chen, L. H., Thousandfold change in resistivity in magnetoresistive La–Ca–Mn–O films. *Science*, 1994, **264**, 413–415.
34. Hsu, C. W. and Lin, C. J., A comparison of methods for multiclass support vector machines. *IEEE Trans. Neural Networks*, 2002, **13**, 415–425.

35. Cheng, Y. J., Yang, S. H. and Hsu, C. S., Synthesis of conjugated polymers for organic solar cell applications. *Chem. Rev.*, 2009, **109**, 5868–5923.

36. Chang, S. S., Shih, C. W., Chen, C. D., Lai, W. C. and Wang, C. R. C., The shape transition of gold nanorods. *Langmuir*, 1999, **15**, 701–709.

37. Tsai, W. H., Moment-preserving thresholding: a new approach. *Comput. Vision Graph. Image Proc.*, 1985, **29**, 377–393.

38. Yu, Y. Y., Chang, S. S., Lee, C. L. and Wang, C. R. C., Gold nanorods: electrochemical synthesis and optical properties. *J. Phys. Chem. B*, 1997, **101**, 6661–6664.

39. Wei, F. C., Jain, V., Suominen, S. and Chen, H. C., Confusion among perforator flaps: what is a true perforator flap? *Plast. Reconstr. Surg.*, 2001, **107**, 874–876.

40. Schein, M., Paladugu, R., Sutija, V. G. and Wise, L., What American surgeons read: a survey of a thousand Fellows of the American College of Surgeons. *Curr. Surg.*, 2000, **57**, 252–258.

41. Bennett, D. M. and Taylor, D. M., Unethical practices in authorship of scientific papers. *Emerg. Med.*, 2003, **15**, 263–270.

42. Singh, S., Criteria for authorship. *Indian J. Dermatol. Venereol. Leprol.*, 2009, **75**, 211–213.

43. Chuang, K. Y., Wang, M. H. and Ho, Y. S., High-impact papers published in journals listed in the field of chemical engineering. *Malays. J. Libr. Sci.*, 2013, **18**, 47–63.

44. Herbertz, H. and Müller-Hill, B., Quality and efficiency of basic research in molecular biology: a bibliometric analysis of thirteen excellent research institutes. *Res. Policy*, 1995, **24**, 959–979.

45. Reisenberg, D. and Lundberg, G. D., The order of authorship: who's on first? *JAMA*, 1990, **264**, 1857.

46. Burman, K. D., Hanging from the masthead – reflections on authorship. *Ann. Intern. Med.*, 1982, **97**, 602–605.

47. Paladugu, R., Schein, M., Gardezi, S. and Wise, L., One hundred citation classics in general surgical journals. *World J. Surg.*, 2002, **26**, 1099–1105.

48. Gibbs, R. A. *et al.*, The international HapMap project. *Nature*, 2003, **426**, 789–796.

49. Piccart-Gebhart, M. J. *et al.*, Trastuzumab after adjuvant chemotherapy in HER2-positive breast cancer. *N. Engl. J. Med.*, 2005, **353**, 1659–1672.

50. Ksiazek, T. G. *et al.*, A novel coronavirus associated with severe acute respiratory syndrome. *N. Engl. J. Med.*, 2003, **348**, 1953–1966.

51. Laibinis, P. E., Whitesides, G. M., Allara, D. L., Tao, Y. T., Parikh, A. N. and Nuzzo, R. G., Comparison of the structures and wetting properties of self-assembled monolayers of *n*-alkanethiols on the coinage metal surfaces, Cu, Ag, Au. *J. Am. Chem. Soc.*, 1991, **113**, 7152–7167.

52. Bentley, S. D. *et al.*, Complete genome sequence of the model actinomycete *Streptomyces coelicolor* A3(2). *Nature*, 2002, **417**, 141–147.

53. Lai, C. L. *et al.*, A one-year trial of lamivudine for chronic hepatitis B. *N. Engl. J. Med.*, 1998, **339**, 61–68.

54. Matsumoto, T. *et al.*, The map-based sequence of the rice genome. *Nature*, 2005, **436**, 793–800.

55. Mok, T. S. *et al.*, Gefitinib or carboplatin–paclitaxel in pulmonary adenocarcinoma. *N. Engl. J. Med.*, 2009, **361**, 947–957.

56. Lai, H. L. *et al.*, Global QCD analysis of parton structure of the nucleon: CTEQ5 parton distributions. *Eur. Phys. J. C*, 2000, **12**, 375–392.

57. Adcox, K. *et al.*, Formation of dense partonic matter in relativistic nucleus–nucleus collisions at RHIC: experimental evaluation by the PHENIX Collaboration. *Nucl. Phys. A*, 2005, **757**, 184–283.

58. Liu, L. F. and Wang, J. C., Supercoiling of the DNA template during transcription. *Proc. Natl. Acad. Sci. USA*, 1987, **84**, 7024–7027.