Scientific research competitiveness of world universities in computer science

RUIMIN MA, CHAOQUN NI, JUNPING QIU

Research Center for Chinese Science Evaluation, Wuhan University, Wuhan (P. R. China)

This article evaluates the scientific research competitiveness of world universities in computer science. The data source is the Essential Science Indicator (ESI) database with a time span of more than 10 years, from 01/01/1996 to 08/31/2006. We establish a hierarchical indicator system including four primary indicators which consist of scientific research production, influence, innovation and development and six secondary indicators which consist of the number of papers, total citations, highly cited papers, hot papers, average citations per paper and the ration of highly cited papers to papers. Then we assign them with proper weights. Based on these, we obtain the rankings of university and country/territory competitiveness in computer science. We hope this paper can contribute to the further study in the evaluation of a certain subject or a whole university.

Introduction

In general, countries that have more world-class universities develop more prosperously. Scientific research level of universities in a country, considered to be an important part of comprehensive national strength, reflects the development level of technology, education and culture of this country to some extent. As a result, the research performance of universities is given increasingly more attention for its important role in country development. Both the research managers in universities and

the policy makers of governments refer to the outcomes of any research evaluation to help them supervise the R&D activities in universities [HUANG & AL., 2006]. Under such a situation, a large variety of research evaluation projects are popularly launched by some private or public entities. Until now, three of most accepted research evaluation results are: "Global Universities Ranking" by US News (US News &World Report), "World University Rankings" by THES (The Times Higher Education Supplement), and "Academic Ranking of World Universities" by SHJTU (Shanghai Jiao Tong University).

US News first published Global Universities Ranking in 1983 and is known as one of the most authoritative research evaluation projects for its accurate data source, reasonable indicators and appropriate calculation method [NATIONAL SCIENCE COUNCIL, 2003]. It adopts not only subjective data, for instance, academic reputation, but also objective date such as faculty resources as indicators. Then it calculates every university's score and obtains ranking of every specific category separately at the same time. Different from US News, THES and SHJTU both use Essential Science Indicators of Thomson Scientific (ESI) as the most significant data source. They adopt number of papers and highly cited papers as main indicators to measure research outputs of universities. However, World University Rankings by THES takes peer review as the most important indicator and assigns it a weight of 40%, which seems to overemphasize on the reputation of a university. On the other hand, Academic Ranking of World Universities by SHJTU emphasizes particularly on scientific research and ignores social scientific research [THE TIMES HIGHER EDUCATION SUPPLEMENT, 2006; SHANGHAI JIAO TONG UNIVERSITY, 2006].

The outcomes of various research evaluation projects have caused quite a stir all over the world, though the methods they use are considered to have assets and liabilities [VAN RAAN, 2005]. Nevertheless, bibliometric methods have been widely used in research evaluation projects to reveal the research capacity and competitiveness of universities and even regarded as a powerful support tool for peer review system (e.g. [NEDERHOF, 2005; WALLIN, 2005; GARCIA & SANZ-MENENDEZ, 2005]). In most cases, bibliometric methods are based on the ESI database, which provides comparatively precise data such as the number of papers, the number of citations, the number of highly cited papers, etc. (e.g. [VAN LEEUWEN & AL., 2003; CALVINO, 2006]). Some experts make use of ESI to evaluate the research performance of universities (e.g. [HUANG & AL., 2006; NEDERHOF & AL., 1993; VAN RAAN, 1999]) or just one special field (e.g. [POMFRET & WANG, 2003; RINIA & AL., 2002; VAN RAAN, 2006]).

This paper mainly targets on the research performance of computer science from a global perspective, emphasizing both quantitative and qualitative aspects of research activities of universities, which amounts to a total number of 233. The data of this study is derived from ESI of Thomson Scientific. We construct a hierarchical indicator system, making scientific research production, scientific research influence, scientific

research innovation, scientific research development as the primary indicators and the number of papers, the number of total citations, the number of highly cited papers, the number of hot papers, the number of average citations per paper, and the ratio of highly cited papers to papers as the corresponding secondary indicators. At the same time, every indicator is assigned a proper weight. At last, we obtain the ranking of scientific research competitiveness in the field of computer science and have a comparison between not only universities but also countries.

Methods

Data source

All data we use in this study is gathered from Essential Science Indicators (ESI) of Thomson Scientific with a time span of more than 10 years, from 01/01/1996 to 08/31/2006. ESI is a database providing high quality papers and considered to be one of the most authoritative databases for statistical using. This database is updated every two-month so as to ensure that the articles published recently are included. But we must emphasize that a paper owned by multi-universities is calculated repeatedly for per owner in ESI, so does other indicators such as total citations, highly cited papers, etc.

Objects

Universities entering our ranking in computer science should be in accordance with the following two requirements:
One is that the total citations of these universities should be among the top 1% of all the institutions (including universities, companies, etc.) in computer science, or they can't enter the ESI subject ranking so that we can't make evaluation for them.
On the basis of the first requirement, considering the fairness of the result, the other requirement is that universities selected should achieve a certain number of publications. We set a minimum threshold of papers at the number of 100, which means that some universities, despite high impact figure (average citations per paper), are excluded from the ranking because they published comparatively few papers in this field. Given a smaller number of publications, one or two highly cited papers can artificially inflate a university's apparent impact, which may lead to the result not precise enough [SCIENCE WATCH, 2005]. For example, Medical College of Wisconsin only published 10 papers included by ESI in the past 11 years but had publication citations at the number of 851 times, which meant that Medical College of Wisconsin' s average citations per paper is 85, which is fairly high and abnormal in this field.
Taking the standards above into account comprehensively, finally, 233 universities are selected for evaluation. But we must emphasize that all universities' names are from

ESI database and we don't change them at all. ESI partly distinguishes different universities in the same university system, for example, for California university system, ESI provides us UNIV CALIF BERKELEY, UNIV CALIF LOS ANGELES etc. with corresponding data. But for Texas university system, ESI provides us the whole system data and doesn't make any partition.

Indicators

This study constructs a hierarchical indicator system that consists of four primary indicators and six secondary indicators. Because our evaluation ranking is composite and we also need to assign each indicator with proper weights. Different evaluation systems have different indicators and corresponding weights. For example, US News emphasizes the ratio indicators; THES emphasizes peer review (reputation) and sets it 40% weights. We give the weights on each indicator on the basis of the comparative importance between them, and we also ask some scholars for their comments on the weights at the same time. In the end, we get the indicator system as shown in Table 1.

Scientific research production can be measured by one secondary indicator, the number of papers a university published in computer science within a certain time span, which is considered one of the most significant indicators and assigned a weight of 30%. This indicator may reveal a university's contribution to the global academic intercourse. As papers indexed by ESI are all peer reviewed and published on the journals influencing widely around the world, they are always the comparative high-quality papers.

Scientific research influence can be measured by two secondary indicators, the number of total citations and highly cited papers. They are assigned weights of 30% and 20% separately. As for a university, the greater the number of total citations is, the more researchers all over the world are influenced by it. According to the definition by ESI, highly cited papers are the top cited ones over the last 10 years whose rankings are based on meeting a threshold of the top 1% by field and year based on total citations received [THOMSON SCIENTIFIC, 2007]. So these highly cited papers in this field can have effect on the researchers more widely and are more likely to be the classic ones in future.

Scientific research innovation measures a university's innovational ability in computer science and can be reflected by the number of hot papers. Hot papers are the ones published in the past two years that receive more citations during the past two months relative to other papers in the same field [THOMSON SCIENTIFIC, 2007]. It is a momentous indicator but only assigned a weight of 10%, since it depends too much on the statistic time according to its definition.

Scientific research development reflects the possibility of a university to produce more excellent research papers and can be measured by two secondary indicators, the

number of average citations per paper and the ratio of highly cited papers to papers (hereafter Hi/P). They are both assigned a weight of 5% separately. Average citations per paper reveal its average impact and higher ratio means that these papers of a university are high quality on average. Hi/P stands for a potential ability of a university, because if Hi/P of a university is higher, it means that this university has a permanent ability to produce more highly cited papers. At the same time, these two indicators can balance the size influence of different universities and allow smaller universities to compete more equitably with larger ones.

Table 1. The indicator system

Primary Indicator	Secondary Indicator	Weights (%)
Scientific Research Production	Papers	30
Scientific Research Influence	Total Citations	30
	Highly Cited Papers	20
Scientific Research Innovation	Hot Papers	10
Scientific Research Development	Hi/P	5
	Average Citations Per Paper	5

Results

General situation

On the basis of the indicators and their respective weights, we get the rankings of 233 universities in computer science. These universities have totally published 127418 papers, got 468244 citations, and owned 1856 highly cited papers and 57 hot papers. The country/territory distribution of them is shown in Figure 1.

As Figure 1 shows, there are 27 countries/territories in total. USA is dominant and owns 87 of all the 233 universities. The followings of top 5 are UK (20), Germany (25), Canada (15), and Italy (12). Each of them has more than 10 universities and the proportion of them to all is 64%. To some extent, this indicates the strong scientific research strength of these 5 countries. In the following section, we will analyze the scientific research competitiveness of 27 countries/territories in details.
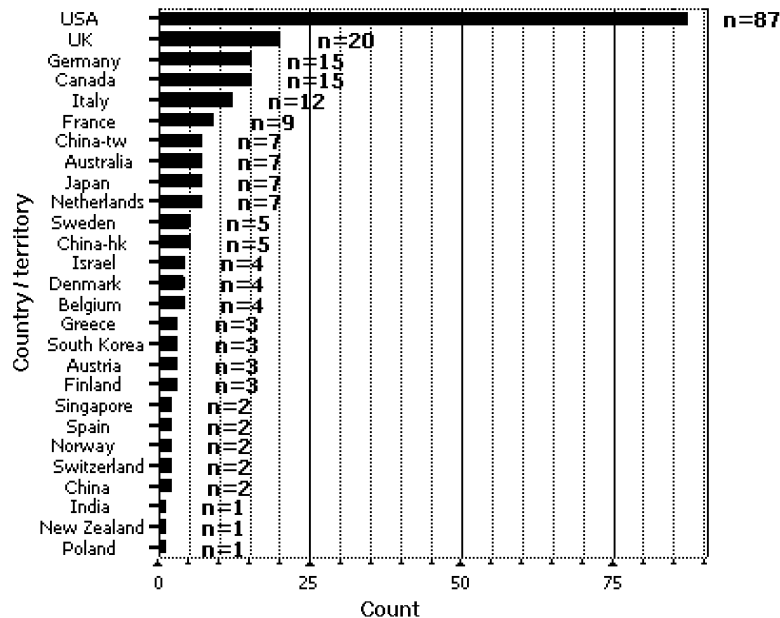
Figure 1. Country/territory distributions of 233 universities

Country/territory competitiveness

We sum up the number of all universities within per country in each indicator and also give the same weights on each indicator as Table 1 gives. In the end, we obtain the 27 countries/territories scientific research competitiveness as Table 2 shows. In order to discover per indicator's performance, we standardize per indicator by transforming it as the following steps: first, the value of per indicator divides by the maximum of this indicator; secondly, each result of the first step multiplies 100, which leads to the maximum score of per indicator being 100. "S" stands for the score of per indicator per country/territory; "R" stands for the ranking of per indicator per country/territory. From Table 2, we can analyze each indicator's performance of each country/territory and find the advantages and weaknesses easily.

Combining Figure 1 and Table 2, we find that the most excellent country/territory is USA. It is dominant among all countries/territories. The total score of USA is 80 points higher than that of UK that ranks the 2nd. This result is very amazing. The rest of top 5 are UK, Canada, Denmark, and Israel in sequence. USA ranks the 1st in North America, so does UK in Europe, Israel in Asia, and Australia in Oceania.

250   *Scientometrics 76 (2008)*

Table 2. Country/territory competitiveness in computer science

Rank	Total score	Country/ territory	Production		Influence						Innovation		Development					
			Paper		S	R	Total citations		High		Hot		S	R	Average citations		Hi/P	
			S	R			S	R	S	R	S	R			S	R	S	R
1	100.00	USA	100.00	1	100.00	1	100.00	1	100.00	1	100.00	1	86.81	2	82.00	2	65.60	2
2	17.91	UK	16.73	2	12.02	2	12.63	2	11.10	2	11.40	2	62.07	6	61.80	6	43.60	5
3	14.12	Canada	14.67	3	8.22	3	8.97	3	7.10	3	11.40	2	48.17	9	50.00	8	31.80	9
4	11.58	Denmark	2.90	19	3.26	9	2.47	15	4.45	6	2.90	7	100.00	1	69.80	4	100.00	1
5	11.47	Israel	6.17	11	5.16	6	5.13	6	5.20	4	5.70	4	72.67	4	68.00	5	55.40	3
6	11.05	Germany	13.23	4	6.20	4	7.10	5	4.85	5	2.90	7	40.05	15	43.80	14	24.20	15
7	10.30	Italy	12.03	5	5.60	5	7.20	4	3.20	8	2.90	7	39.22	16	49.00	9	17.60	16
8	9.82	Switzerland	2.57	21	2.56	14	3.13	14	1.75	14	2.90	7	85.16	3	100.00	1	44.60	4
9	9.71	France	6.87	10	4.70	7	4.97	7	4.35	7	0.00	8	59.36	7	59.20	7	41.60	6
10	8.62	Sweden	3.90	16	3.06	11	3.47	11	2.45	10	0.00	8	66.90	5	72.80	3	40.80	7
11	7.87	Australia	6.10	12	3.12	10	3.57	10	2.45	10	5.70	4	43.58	11	48.00	10	26.20	14
12	7.82	Netherlands	6.90	9	3.56	8	3.97	8	2.95	9	0.00	8	44.29	10	47.20	12	28.00	11
13	6.86	Belgium	3.63	17	2.10	16	2.10	17	2.10	12	2.90	7	50.06	8	47.40	11	37.60	8
14	6.61	Japan	8.97	6	2.88	12	3.40	12	2.10	12	0.00	8	27.33	21	31.00	23	15.20	18
15	6.53	China-hk	7.50	8	2.82	13	3.60	9	1.65	15	0.00	8	31.80	19	39.60	18	14.40	20
16	5.96	China-tw	8.13	7	2.26	15	3.37	13	0.60	18	2.90	7	22.85	22	33.80	21	5.00	25
17	5.33	Finland	2.07	24	1.00	19	1.07	22	0.85	17	5.70	4	41.22	13	42.60	16	27.60	13
18	4.91	Austria	2.50	22	1.18	18	1.27	18	1.05	16	0.00	8	40.64	14	41.60	17	27.60	12
19	4.33	Singapore	5.43	13	1.46	17	2.20	16	0.35	22	0.00	8	21.91	23	33.00	22	4.20	27
20	4.10	Spain	2.60	20	0.98	20	1.23	19	0.60	18	0.00	8	32.04	18	39.00	19	15.40	17
21	4.05	New Zealand	0.60	27	0.28	26	0.30	27	0.25	23	0.00	8	42.64	12	43.20	15	29.20	10
22	3.67	Norway	1.17	25	0.50	25	0.67	25	0.25	23	0.00	8	34.98	17	45.00	13	14.60	19
23	3.66	South Korea	3.97	15	0.90	21	1.17	20	0.50	20	2.90	7	19.20	26	24.00	26	8.60	21
24	3.16	China	3.97	14	0.68	23	0.80	24	0.50	20	2.90	7	14.84	27	16.60	27	8.60	22
25	3.15	Greece	3.17	18	0.78	22	1.13	21	0.25	23	0.00	8	20.49	25	29.40	25	5.40	24
26	2.83	India	2.37	23	0.60	24	0.87	23	0.15	26	0.00	8	20.61	24	30.20	24	4.80	26
27	2.75	Poland	0.67	26	0.24	27	0.33	26	0.10	27	0.00	8	27.92	20	38.80	20	8.60	23

As for "Paper", the single indicator that stands for scientific research production, the top 5 are USA with 51221 papers, UK with 8569, Canada with 7520, Germany with 6779, and Italy with 6160 in sequence, which indicates the researches on computer science in these 5 countries are active and productive.

As for "Total citations", one of the indicators that stands for scientific research influence, the top 5 are USA with 251681 citation times, UK with 31754, Canada with 22544, Italy with 18132, and Germany with 17844 in sequence. As for "High", the other indictor stands for scientific research influence, the top 5 are USA with 1151 highly cited papers, UK with 128, Canada with 82, Israel with 60, and Germany with 56. Combing the two secondary indicators with weights, we can find the top 5 countries are USA, UK, Canada, Germany, and Italy. Therefore, comprehensively, we can say that the most influential countries in computer science are USA, UK, Canada, Germany and Italy. We also find this order is the same as that of the production completely, so paper production has close relationship with paper influence.

As for "Hot", the single indicator that stands for scientific research innovation, the countries whose number of hot papers exceeds 3 are USA with 35, UK with 4, and Canada with 4, which indicate their stronger creative ability. But the absolute number of hot papers is very small. There are only 4 hot papers in whole UK that ranks 2nd. These indicate that the hot paper stands for the most innovational research level in computer science and it is difficult to be obtained.

As for "Average citation", one of the indicators that stand for scientific research development, the top 5 are Switzerland with a ratio of 6, USA with 4.91, Sweden with 4.37, Denmark with 4.19, and Israel with 4.08 in sequence. As for "Hi/P", the other indicator also stands for scientific research development, the top 5 are Denmark with 3.43%, USA with 2.25%, Israel with 1.9%, Switzerland with 1.53%, and UK with 1.49%. Combining these two secondary indicators, we can get the score of the primary indicator "development" of per country/territory. The top 5 are Denmark, USA, Switzerland, Israel, and Sweden. So, comprehensively, computer science in these countries can develop more healthily and persistently.

In addition, we also find the ranking of China in the number of papers exceeds the rankings in other indicators a lot and this leads to the ranking of total score falling behind a lot. As for Denmark, Switzerland, Sweden, etc., although the ranking in the number of papers is not so good, the performances of the rankings in other indicators are excellent. Their conditions are very different from China. As Chinese people, we think it is related with the policy of evaluating a researcher's outputs in China. In the past years, almost every university encourages its researchers to publish papers that are indexed by SCI or SSCI and gives them many bonuses, which may lead to the publications of paper in China being good but the other indicators being week. Therefore, from this evaluation, the government managers of China should pay more and more attention to this phenomenon and change its policy, evaluating the outputs of researchers not only on the basis of the number of papers but also on the number of the citations in order to amend the disadvantages.

The explanations above focuses on the comparisons of different countries'/ /territories' performance in per secondary or primary indicator, but we should also pay

attention to the comparison of the different indicators' performance within each country/territory. So, then, we also obtain Figure 2 that describes per indicator's performance of per country/territory better. We use different notes to describe different indicators as the Figure 2 shows at right.
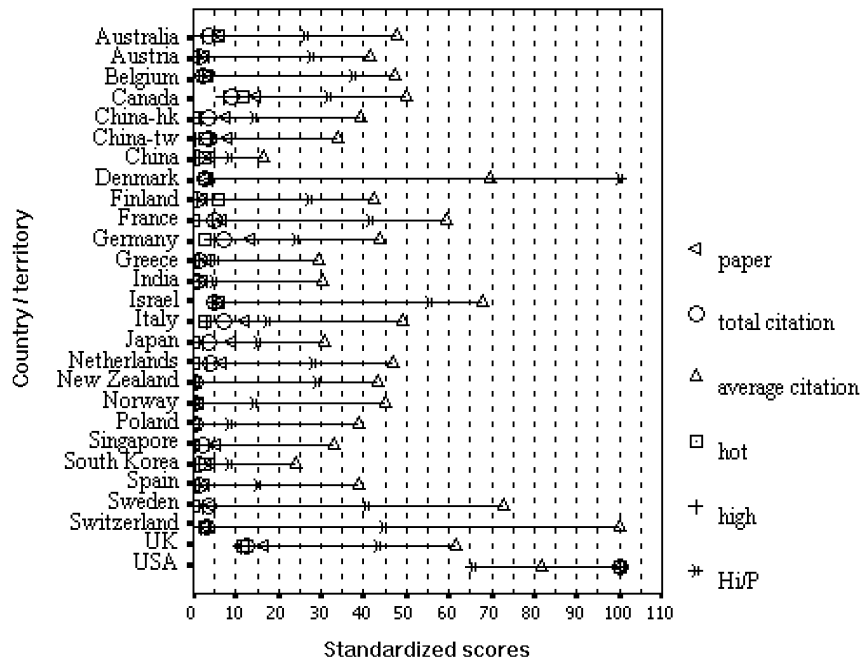

Figure 2. Standardized score of per indicator in a country/territory

In Figure 2, as for each country/territory, we can find its per indicator's standardized score ranking. In a scope of country/territory, the indicators paper, total citation, etc. rank in a descending order. For example, as for Germany, the scores of different indicators in descending order are those of average citations, Hi/P, paper, total citations, high, and hot. If we assign the indicators with same weights, then we can see that Germany has problems on the absolute number of hot papers and highly cited papers and should try its best to enhance them. In addition, we can also see easily that the score of USA in per indicator exceeds 60 and this is unique among all countries/territories. Moreover, we find the countries that have full scores in the indicator average citations and Hi/P are Switzerland and Denmark respectively and the full scores in other indicators belong to USA.

University competitiveness

Here, we mainly analyze the top 10% universities (totally 23, see Table 3) according to our comprehensive evaluation. These 23 universities are the top ones in computer science.

The country distribution of 23 universities is shown in Figure 3. We can find USA owns 17 top universities, about 74% of the top 10% universities, which indicates that the most excellent and strongest country/territory in computer science is USA without any doubt. The 2nd is Israel and it owns 2 top 10% universities. Canada, Switzerland, Singapore, and UK all own 1, respectively.
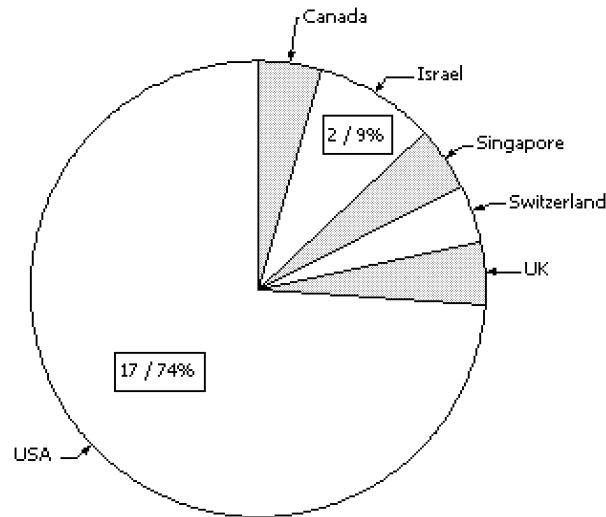

Figure 3. Country distribution of top 10% universities

As Table 3 shows, obviously, we can find that the total scores of STANFORD UNIV, MIT, and UNIV CALIF BERKELEY are very outstanding. All of them are above 90 points and rank about above 1%. The followings are UNIV TEXAS and UNIV ILLINOIS. The total scores of them are between 70 and 80. The total scores of the rest universities are below 60. The number of total papers of the 23 universities is 28188, 22 percent of that of all ranked universities; total citations, 146248, 31 percent; hot papers, 30, 53 percent; highly cited papers, 727, 39 percent; the ratio of the average citations is 5.22, 1.43 times as much as that of all the 233 ranked universities; the number of the Hi/P is 0.03, 3 times as much as that of all the 233 ranked universities.

As for indicator papers, the top 5 universities are UNIV TEXAS with 2108 papers, MIT with 2031, UNIV ILLINOIS with 1933, STANFORD UNIV 1681, and CARNEGIE MELLON UNIV with 1656. As for indicator total citations, the top 5 are UNIV CALIF BERKELEY with 13242, MIT with 12889, STANFORD UNIV with 12009, UNIV ILLINOIS with 10307, and UNIV TEXAS with 8767; As for indicator high, the top 5 are STANFORD UNIV with 82, UNIV CALIF BERKELEY with 71, MIT with 66, UNIV TEXAS with 45; Combining these two indicators and obtaining the weighted score of influence, we find that the top 5 universities in primary indicator influence are UNIV CALIF BERKELEY, STANFORD UNIV, MIT, UNIV ILLINOIS, UNIV TEXAS. As for indicator hot, universities that own more than 3 hot papers are STANFORD UNIV with 6, UNIV CALIF BERKELEY with 4, MIT with 4 and HARVARD UNIV with 4. As for indicator average citations, the top 5 are BRIGHAM YOUNG UNIV with a ratio of 27.2, UNIV ROCHESTER with 12, UNIV CALIF SANTA CRUZ with 10.2, UNIV UPPSALA with 9.78, and UNIV OXFORD with 8.93; As for indicator Hi/P, the top 5 are TECH UNIV DENMARK with 9.04%, WASHINGTON UNIV with 5.52%, UNIV BIELEFELD with 5.06%, STANFORD UNIV with 4.88%, and CALTECH with 4.87%; Combining these two indicators, the top 5 universities in primary indicator development are TECH UNIV DENMARK, BRIGHAM YOUNG UNIV, WASHINGTON UNIV, UNIV BIELEFELD, and STANFORD UNIV.

Then, we also give the rankings of top 10% universities in per secondary indicator (see Table 4), and mark the top 10% in per secondary indicator with bold type. We find the ranking of STANFORD UNIV, MIT, and UNIV CALIF BERKELEY in per indicator is in top 10%, which indicates their stronger research ability in computer science. We also find most of universities whose rankings of total scores are in top 10% have at least three indicators that rank in the scope of top 10% or the performances of one or two indicators are very excellent, NATL UNIV SINGAPORE is a typical sample whose ranking in paper is very high but others are week. As the last row of Table 4 shows, of all the universities comprehensively ranking in top 10%, most of them also rank in top 10% in per indicator. For example, 78% of the universities comprehensively ranked in top 10% also rank in top 10% in indicators total citations and high; and for indicators hot and paper, the proportions exceed 55%, which also indicates the predominance of these top 10% universities again.

Table 3. Top 10% universities in computer science

Rank	Total score	University	Country/ territory	Production	Influence				Innovation	Development			
				Paper	S	R	Total citations	High	Hot	S	R	Average citations	HI/P
1	100.00	STANFORD UNIV	USA	79.74	99.77	2	90.69	100.00	100.00	66.39	5	26.25	53.95
2	98.46	MIT	USA	96.35	95.73	3	97.33	80.49	66.67	49.06	20	23.32	35.94
3	95.49	UNIV CALIF BERKELEY	USA	78.18	100.00	1	100.00	86.59	66.67	63.89	8	29.52	47.64
4	73.74	UNIV TEXAS	USA	100.00	65.17	5	66.21	54.88	0.00	32.20	52	15.28	23.61
5	72.41	UNIV ILLINOIS	USA	91.70	67.91	4	77.84	43.90	0.00	33.27	47	19.59	20.60
6	56.56	CARNEGIE MELLON UNIV	USA	78.56	45.14	7	51.68	29.27	16.67	25.84	75	15.18	16.03
7	50.44	UNIV CALIF SAN DIEGO	USA	51.85	45.35	6	46.32	37.80	33.33	43.04	27	20.62	31.37
8	48.57	GEORGIA INST TECHNOL	USA	60.63	41.07	9	40.39	36.59	16.67	34.22	44	15.37	25.96
9	47.47	UNIV MARYLAND	USA	65.09	40.44	10	44.27	29.27	0.00	29.01	62	15.70	19.34
10	46.60	ETH ZURICH	Switzerland	50.52	43.70	8	54.30	21.95	16.67	36.01	38	24.80	18.69
11	42.04	TECHNION ISRAEL INST TECHNOL	Israel	59.58	34.61	17	40.77	20.73	0.00	25.47	79	15.79	14.97
12	41.07	PRINCETON UNIV	USA	33.02	38.43	12	37.84	34.15	33.33	58.73	11	26.45	44.49
13	40.88	UNIV WASHINGTON	USA	38.99	38.75	11	36.72	36.59	16.67	51.41	19	21.74	40.36
14	40.48	TEL AVIV UNIV	Israel	52.28	32.48	22	35.79	23.17	16.67	28.87	63	15.80	19.07
15	39.84	HARVARD UNIV	USA	30.93	30.72	25	24.06	36.59	66.67	56.99	12	17.95	50.88
16	39.37	UNIV TORONTO	Canada	47.06	32.76	21	29.72	32.93	16.67	36.99	34	14.57	30.10
17	38.83	UNIV CALIF LOS ANGELES	USA	46.44	35.49	16	34.84	31.71	0.00	38.65	33	17.32	29.37
18	38.63	UNIV MICHIGAN	USA	44.50	33.07	20	33.45	28.05	16.67	36.82	36	17.35	27.12
19	37.96	UNIV SO CALIF	USA	47.11	34.08	18	36.67	25.61	0.00	34.24	43	17.97	23.39
20	37.57	UNIV MINNESOTA	USA	39.42	36.69	13	36.72	31.71	0.00	46.45	24	21.50	34.60
21	35.85	NATL UNIV SINGAPORE	Singapore	73.72	16.89	52	26.64	0.00	0.00	6.91	218	8.34	0.00
22	35.73	COLUMBIA UNIV	USA	33.97	35.68	15	32.69	35.37	0.00	55.48	13	22.21	44.79
23	35.49	UNIV CAMBRIDGE	UK	37.57	31.06	24	29.47	29.27	16.67	42.74	28	18.11	33.51

In addition, we also compute the Spearman's correlation coefficient between two secondary indicators based on data sample of 233 universities and obtain the results as Table 5 shows.

From Table 5, we find the coefficients between indicators paper, total citations, hot, and high are significant. However, as for the two ratio indicators, average citations and Hi/P, they have significant relationships with the three quality indicators, total citations, hot and high, but the indicator paper. So the number of papers can't decide the ranking of a university, it is only a quantitative indicator. We also find the coefficients between paper and total citations, high and total citations, Hi/P and average citations, Hi/P and High, are more than 0.7. These indicate that the more papers a university published, the more total citations it could get and the more highly cited papers it could own.

Table 4. The secondary indicators' rankings of top 10% universities

Rank	University	Country/ territory	Indicators' rank					
			Paper	Total citations	Average citations	Hot	High	Hi/P
1	STANFORD UNIV	USA	**4**	**3**	**12**	**1**	**1**	**4**
2	MIT	USA	**2**	**2**	**17**	**2**	**3**	**21**
3	UNIV CALIF BERKELEY	USA	**6**	**1**	**7**	**2**	**2**	**9**
4	UNIV TEXAS	USA	**1**	**5**	60	40	**4**	45
5	UNIV ILLINOIS	USA	**3**	**4**	34	40	**5**	56
6	CARNEGIE MELLON UNIV	USA	**5**	**7**	62	**9**	18	83
7	UNIV CALIF SAN DIEGO	USA	17	**8**	30	**5**	**7**	24
8	GEORGIA INST TECHNOL	USA	**10**	**12**	58	**9**	**8**	37
9	UNIV MARYLAND	USA	**8**	**9**	57	40	18	62
10	ETH ZURICH	Switzerland	**19**	**6**	**14**	**9**	29	67
11	TECHNION ISRAEL INST TECHNOL	Israel	**11**	**11**	56	40	31	90
12	PRINCETON UNIV	USA	52	**14**	**10**	**5**	**12**	**12**
13	UNIV WASHINGTON	USA	34	**15**	24	**9**	**8**	**17**
14	TEL AVIV UNIV	Israel	**16**	**18**	55	**9**	27	66
15	HARVARD UNIV	USA	62	40	38	**2**	**8**	**7**
16	UNIV TORONTO	Canada	24	27	70	**9**	**13**	27
17	UNIV CALIF LOS ANGELES	USA	25	**20**	44	40	**14**	28
18	UNIV MICHIGAN	USA	27	**21**	43	**9**	**22**	33
19	UNIV SO CALIF	USA	**23**	**17**	37	40	25	46
20	UNIV MINNESOTA	USA	33	**15**	26	40	**14**	**22**
21	NATL UNIV SINGAPORE	Singapore	**7**	32	193	40	218	218
22	COLUMBIA UNIV	USA	46	24	**23**	40	**11**	**10**
23	UNIV CAMBRIDGE	UK	37	28	36	**9**	18	**23**
Count			13	18	6	14	18	9

Table 5. The correlation between indications

			Paper	Total citations	High	Hot	Average citations	Hi/P
Spearman's rho	Paper	Correlation Coefficient	1	0.727(**)	0.446(**)	0.232(**)	−0.029	0.032
	Total citations	Correlation Coefficient	0.727(**)	1	0.761(**)	0.282(**)	0.595(**)	0.510(**)
	High	Correlation Coefficient	0.446(**)	0.761(**)	1	0.356(**)	0.678(**)	0.881(**)
	Hot	Correlation Coefficient	0.232(**)	0.282(**)	0.356(**)	1	0.261(**)	0.311(**)
	Average citations	Correlation Coefficient	−0.029	0.595(**)	0.678(**)	0.261(**)	1	0.806(**)
	Hi/P	Correlation Coefficient	0.032	0.510(**)	0.881(**)	0.311(**)	0.806(**	1

** Correlation is significant at the 0.01 level (2-tailed).

Conclusion

We manage to evaluate the scientific research competitiveness of global universities in computer science, build the evaluation indicator system including four primary indicators and six secondary indicators based on ESI and assign them with proper weights. According to these, we get the ranking results mainly including country/territory competitiveness and university competitiveness.

In the competitiveness ranking of country/territory, USA owns most of the universities that enter our ranking and its total score ranks as the highest one with dominant advantages. The other top 5 countries are UK, Canada, Denmark, and Israel in sequence. Although the number of universities that Denmark and Israel own in computer science is not big, their scores and rankings in the indicators highly cited papers, average citations, Hi/P are excellent. In addition, China has published more papers, but the performances of other indicators are very week. This is related to Chinese evaluating policy, so it should convert its old policy that encourages quantity to a new one that focuses on the quality of papers. Surely, this conversion is suitable to other countries/territories that have the same condition as China.

In the competitiveness ranking of universities, we mainly analyze the conditions of top 10% universities. In these top 10% universities, USA owns most of the first level universities and shows its absolute predominance. The performances of STANFORD UNIV, MIT, and UNIV CALIF BERKELEY are excellent. Their scores are much higher than those of other universities and their rankings in per secondary indicator are in top 10%, which is also unique in all top 10% universities. In addition, for PRINCETON UNIV and HARVARD UNIV, although their rankings in indicator paper are low, rankings in other indicators are higher and this leads to their ranking in total score are higher. In the end, we compute the Spearman's correlation coefficient between

two secondary indicators based on data sample of 233 universities. We find the coefficients between every two indicator are significant except that between paper and average citations, and paper and Hi/P. Especially, the coefficients between paper and total citations, total citation and high, Hi/P and average citations, and high and Hi/P all exceed 0.7, which indicates the more papers one university published, the more citations it will get and the more highly cited papers it will own. This means the production (quantity) has close relationship with the quality. We should pay attention on this phenomenon at the same time.

This paper explores a method of evaluating universities scientific research competitiveness in computer science. Surely, we can extend it to other 21 subjects in ESI database. Every country/territory and university can find its relative ranking and discover its advantages and weaknesses according to related data. This is beneficial for their further development.

<div align="center">*</div>

References

CALVINO, A. M. (2006), Assessment of research performance in food science and technology: Publication behavior of five Iberian-American countries (1992–2003). *Scientometrics*, 69 (1) : 103–116.

GARCIA, C. E., SANZ-MENENDEZ, L. (2005), Competition for funding as an indicator of research competitiveness. *Scientometrics*, 64 (3) : 271–300.

HUANG, M. H., CHANG, H. W., CHEN, D. Z. (2006), Research evaluation of research-oriented universities in Taiwan from 1993 to 2003. *Scientometrics*, 67 (3) : 419–435.

NATIONAL SCIENCE COUNCIL (2003), *Evaluation of research achievement for universities and college in Taiwan.* Taipei, Taiwan: National Science Council.

NEDERHOF, A. J. (2005), Bibliometric monitoring of research performance in the social sciences and the humanities: A review. *Scientometrics*, 66 (1) : 81–100.

NEDERHOF, A. J., VAN RAAN, A. F. J. (2003), A validation study of bibliometric indicators: the comparative performance of cum laude doctorates in chemistry. *Scientometrics*, 57 (2) : 257–280.

NEDERHOF, A. J., MEIJER, R. F., MOED, H. F., VAN RAAN, A. F. J. (1993), Research performance indicators for university departments: A study of an agricultural university. *Scientometrics*, 27 (2) : 157–178.

POMFRET, R., WANG, L. C. (2003), Evaluating the research output of Australian universities' economics departments. *Australian Economic Papers*, 42 (4) : 249–256.

RINIA, E. J., VAN LEEUWEN, T. N., VAN RAAN, A. F. J. (2002), Impact measures of interdisciplinary research in physics. *Scientometrics*, 53 (2) : 241–248.

SCIENCE WATCH (2005), Canadian Universities: U. Toronto Still Tops. *Science Watch*, 16 (5) : 1–2.

SHANGHAI JIAO TONG UNIVERSITY (2006), *Academic ranking of world universities 2006.* Retrieved May 25, 2007, from http://ed.sjtu.edu.cn/rank/.

THE TIMES HIGHER EDUCATION SUPPLEMENT (2006), *World University Rankings 2006.* Retrieved May 25, 2007, from http://www.thes.co.uk/worldrankings/.

THOMSON SCIENTIFIC (2007), *ESI v2.0 Reference Card.* Retrieved April 20, 2007, from http://scientific.thomson.com/media/scpdf/esi-0805-q.pdf.

VAN LEEUWEN, T. N. (2005), The application of bibliometric analysis in the evaluation of social science research. Who benefits from it, and why it is still feasible. *Scientometrics*, 66 (1) : 133–154.

VAN LEEUWEN, T. N., VISSER, M. S., MOED, H. F., NEDERHOF, T. J., VAN RAAN, A. F. J. (2003), Holy Grail of science policy: Exploring and combining bibliometric tools in search of scientific excellence. *Scientometrics*, 57 (2) : 257–280.

VAN RAAN, A. F. J. (1999), Advanced bibliometric methods for the evaluation of universities. *Scientometrics*, 45 (3) : 417–423.

VAN RAAN, A. F. J. (2005), Fatal attraction: Conceptual and methodological problems in the ranking of universities by bibliometric methods. *Scientometrics*, 62 (1) : 133–143.

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

WALLIN, J. A. (2005), Bibliometric methods: Pitfalls and possibilities. *Basic & Clinical Pharmacology & Toxicology*, 97 (5) : 261–275.