Analysis of academic papers in the field of material science among universities and colleges in Taiwan, Hong Kong, Singapore, and China

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Abstract - **The purpose of this article is to discuss the quality and quantity performance of academic papers in material science among universities and colleges in Taiwan, Hong Kong, Singapore, and China. As for the quantity evaluation, we judge by the numbers of papers in material science published in the last 11 years and Activity Index; as for quality evaluation, we judge by the numbers of citations, citations per paper, highly cited papers and CPP/FCSm. By doing this, we can analyze the academic performance for each schools and the statistics data of those papers in the field of material science among Taiwan, Hong Kong, Singapore, and China. Furthermore, we could compare the general performance of material science by Taiwan, Hong Kong, Singapore, and China to look into each development feature in this field.**

Index Terms - Chinese world, Highly cited papers, Material science, Research Performance.

INTRODUCTION

Research outputs from colleges and universities are representative of academic research achievements. Papers published in international academic journals and periodicals under peer reviews, they are the proof of academic professionalism. Assessment of academic performances of universities sheds lights to the research outputs and academic prestige of individual universities, and even helps to estimate the reasonability of budgets utilization and development potentials. Therefore, articles published on reputable academic journals and their otther statistics from citations databases, such as WOS, JCR and ESI, can be considered as indicators to both quantity and quality performance of academic achievements of individual universities. For example, Huang, Chang, and Chen [1] used ISI Essential Science Indicators (ESI) database to investigate the academic performance of research-oriented universities in Taiwan.

Meanwhile, the field of material science is booming and attracting more and more attentions. It has gained an important position in applied sciences, and has features of relatively independent domain. This paper extends the above -mentioned concept in academic assessment and use bibliometrics as the basis to evaluate the academic researches in material science, with focus on universities in Taiwan, Hong Kong, Singapore, and China.

METHODOLOGY

This article utilizes bibliometrics to compare and analyze the publication of quality papers in material science by the leading universities in Taiwan, Hong Kong, Singapore, and China. The main inquiry tool is the ESI database by ISI. This paper covers a period of 11 years, from 1996 to December 31, 2006. The specification of years in ESI is based on the "database year" in which the time papers are indexed into the system, rather than the "publication year" of the papers.

ESI divides the papers from over 11,000 journals indexed by SCI/SSCI into 22 fields. It calculates the number of papers, the total citations and the citations per paper with respect to top 1% scientists and institutions, as well as top 50% countries and periodicals. ESI provides a quick way to gain an understanding of the publications of contemporary scientific papers, quality literatures and research front.

Research objects of this article cover universities and colleges in Taiwan, Hong Kong, Singapore and China, with citations counting of material science ranged before 1%, the threshold to be collected in ESI. There are 9 universities in Taiwan, National Cheng Kung University, National Tsing Hua University, National Taiwan University, National Chiao Tung University, National Central University, National Taiwan University of Science and Technology, National Sun Yat-Sen University, National ChungHsing University, Feng Chia University; 5 universities in Hong Kong, City University of Hong Kong, Hong Kong Polytechnic University, Hong Kong University of Science and Technology, University of Hong Kong, Chinese University of Hong Kong; 2 universities in Singapore, National University of Singapore, Nanyang Technological University; and 20 universities in China, Tsinghua University, University of Science and Technology of China, Jilin University, Zhejiang University, Shanghai Jiao Tong University, Peking University, Nanjing University, Xian Jiaotong University, University of Science and Technology Beijing, Shandong University, Wuhan University of Technology, Dalian University of Technology, Sichuan University, Huazhong University of Science and Technology, Beihang University, South China University of Technology, Tianjin University, Zhongshan University, Tongji University, Lanzhou University.

The explanations of the ranking indicators used in this article are explained below.

- **Papers:** It refers to the number of papers published by a given institution over the 11 years covered by ESI, and indicates the output of academic research of each institution. Since one outstanding paper is worth more than several mediocre papers, it is not a fair criterion to consider merely the number of papers in the assessment of research excellence. In other words, using the number of papers as an indicator may limit in-depth view of the quality of academic research. The assessment based on the quantity and growth, without considering the quality, would be unfair.
- **Citations:** It refers to the times all the papers published by a given institution were cited over the 11 years covered by ESI, and reflects the level of the influences on future scientific developments. However, there are problems and limitations associated with the number of citations as an indicator for evaluation. The institution with higher output of papers tends to report higher number of times cited, thus, this indicator cannot reflect the individual performance of papers. Also, the citations of any paper may come with various considerations and purposes. In other words, there is no definite correlation between the number of citations and the quality of the paper.
- **Citations Per Paper:** It is the average mean of the total number of citations divided by the number of papers. This indicator can evaluate the level of usefulness or influence of each paper. Misinterpretations are likely if the focus of assessment is only on the citations per paper. It should be evaluated in the contexts of the number of papers and citations.
- **Highly Cited Papers:** Over the 11 years covered by ESI, all papers classified into 22 fields. Those with top 1% of citation rates compared with papers published in the same field and same publication year, are deemed highly cited papers. This definition may eliminate the influences of time and fields on citations since papers published earlier in the field of applied science may be cited more frequently.
- **Activity Index:** Activity Index is defined as the outcome of comparison between the ratio of the number of papers published by a certain institution in a certain field to that of all fields, and to that on a global basis. The purpose of Activity Index is to measure whether the institution is particularly outstanding in that field in relation to other fields.
  The formula is as follows:
  (Papers by one institution in one field / Papers by one institution in all fields) / (Papers in one field worldwide / Papers of all fields worldwide)
  If Activity Index is greater than 1.0, it means that the institution has higher output of papers than the world level; if less than 1.0, then it is lower than the world level. Activity Index shows the ratio of papers in comparison to the world standard.
- **CPP/FCSm:** CPP/FCSm is defined as the ratio of citation per paper by a certain institution in a certain field to citation per paper of all the papers in that field worldwide. This indicator measures the relative influence. It shows the percentage of citations by each institution on a global basis
  The formula is as follows:
  (Citations by one institution in one field /Papers by one institution in one field) / (Citations in one field worldwide / Papers in one field worldwide)
  If the value of CPP/FCSm is between 0.8 and 1.2, it means the quality of papers is in par with the world level. If the value is greater than 1.2, it is superior to the world level. CPP/FCSm shows a ratio in relation with the world level in the same field since it is on a global basis. This prevents the problem of comparing with the citations in different fields. However, the limitation of CPP/FCSm is advantageous to institutions with fewer paper of high quality, while neglects the issue of low quantity.

RESULTS

Among the universities that pass the top 1% threshold value in terms of citations on ESI in material science, China accounts for 56% of them with a total of 20 universities on the list, followed by 9 universities in Taiwan (25%), 5 universities in Hong Kong (14%), 2 universities in Singapore (6%). In terms of the percentage of the total number of universities in each country, Singapore ranks the first with 2 out of its 3 universities on the list [2], followed by Hong Kong with 5 out of 8[3], Taiwan with 9 out of 94 [4], China with 20 out of 644 universities and colleges[5].

This article, through ESI database, analyzes the number of papers and citations in material science by the selected 36 universities in Taiwan, Hong Kong, Singapore, and China. This study examines the overall performances in both quality and quantity of academic papers of individual universities and probes into highly cited papers in the contexts of the world level. Explanations are as follows (see Table1 and Table2 for detailed statistics).

I. Quantity of Papers from Individual Universities in Material Science

Over the period of 11 years covered in this study, among the 36 universities in the four regions, Tsinghua University in China performs the best in the number of papers published in material science. The top five universities are all from China or Singapore. They are Tsinghua University, Nanyang Technological University, Shanghai Jiao Tong University, National University of Singapore, and University of Science and Technology Beijing. A total of 17 universities are among the top 100. Singapore has the highest ratio, with 2 of its universities followed by China with 10 out of 20, Hong Kong with 2 out of 5, Taiwan with 3 out of 9.

In terms of Activity Index (to indicate the quantity of papers of individual universities), almost all universities have values of above 1.0, i.e. while exceeding the level of world value in material science. The only three exceptions are Peking University, University of Hong Kong and Chinese University of Hong Kong. The Activity Indices of University of Science and Technology Beijing, and Wuhan University of Technology are both over 15, ranking the first and second, respectively. Also, both universities are only included in this

single field on ESI, indicating the importance of material science in the universities. All the top 7 are universities in China. Among the top 10, only Feng Chia University is in Taiwan and all the 9 universities are in China. This shows that universities in China have strong performers in the number of papers in material science.

Among the 36 universities, University of Science and Technology Beijing has the highest numbers of papers in material science compared with all other fields, reaching 67%. It is followed by Wuhan University of Technology (65%), National Taiwan University (34%) and Beihang University (33%). The universities in Hong Kong have lower ratio. The rate of Chinese University of Hong Kong is only 1.9%, University of Hong Kong is only 2.9%. Hong Kong Polytechnic University has the highest ratio among all universities in Hong Kong, but has merely 13%, relatively lower than the universities in other regions. This reveals that material science is not an important field in the development agenda among the universities in Hong Kong.

Generally speaking, the universities in China and Singapore have higher output of papers in material science, compared with universities in other two regions. The number of papers produced by the universities in China shows their relative focus in material science, particularly University of Science and Technology Beijing and Wuhan University of Technology. They are outstanding in terms of the most focused group in material science with its number of papers produced and the level of concentration of their efforts among all universities in this study.

II. Quality of Papers from Individual Universities in Material Science

In terms of the numbers of citations over the 11 years, Tsinghua University in China is the highest among the 36 universities in this study. It ranks the 19th in material science. The top five performers among 36 universities are Tsinghua University in China, National University of Singapore and Nanyang Technological University in Singapore, University of Science and Technology of China in China and National Cheng Kung University in Taiwan. A total of 8 universities are included in the top 100 worldwide for citations in material science. They are 2 universities in Singapore (the highest), 3 universities in Taiwan (the second highest), and 1 university in Hong Kong and 2 universities in China (the lowest).

In terms of the ratio of citations in material science and citations in all fields, universities in China have the highest ratio. That of Wuhan University of Technology is 54%, which is the highest of all the 36 universities, followed by University of Science and Technology Beijing (54%). Universities in China and Taiwan have higher ratio, and that in Hong Kong have the lowest. The ratios of Chinese University of Hong Kong and University of Hong Kong are even all below 2%.

In terms of citations per paper, universities in Hong Kong have the highest ratio, with City University of Hong Kong ranking the first and Hong Kong University of Science and Technology ranking the second. They are followed by University of Science and Technology of China in China, National University of Singapore in Singapore and Peking University in China. Universities in Taiwan are rather average in this field, with only National Central University ranking the sixth. Universities in China have the highest output of papers, yet their citations per paper are in the lower half of ranking. The last 14 universities in this category are all universities in China.

In terms of CPP/FCSm, the ranking is similar to the citations per paper. The only difference is that Hong Kong Polytechnic University is one position higher in this ranking. Therefore, a total of 15 universities in China are on the bottom of ranking. There are only 5 universities among 36 universities with CPP/FCSm higher than the world level and these 5 universities are also the top five in terms of citations per paper. In addition, National Central University in Taiwan has a value of 1.17, close to the world level of 1.2.

Universities in China have higher citations simply because of the large quantity of papers. However, universities in Hong Kong and Singapore are better in citations per paper. The overall ranking of universities in Taiwan is higher than that of Universities in China; yet few universities in China are more cited than that in Taiwan.

III. Highly Cited Papers from Individual Universities in Material Science

In terms of highly cited papers in material science of these 36 universities, National University of Singapore ranks the highest with a total of 47 papers, followed by Tsinghua University's 32, University of Science and Technology of China's 29 and City University of Hong Kong's 24. Two thirds of the 20 universities, i.e. 12 out of 20, have less than 10 highly cited papers; 17 out of 20 universities have less than 5 highly cited papers in material science. The lowest is National ChungHsing University, with zero highly cited paper.

This article also explores the percentage of highly cited papers in material science among all papers in material science of individual universities. University of Science and Technology of China and National University of Singapore are at the top ranking in this category, with ratios of 2.32% for both, followed by City University of Hong Kong (2.23%) and Peking University (2.12%). Nearly 40% (i.e. 14) of the universities have higher than 1% of highly cited papers ratio. Among the 5 universities in Hong Kong, 4 of them have a ratio higher than 1%. The universities in Hong Kong are among top ranking in this category, followed by the universities in Singapore with 1 out of 2 universities having a ratio higher than 1%.

In terms of the highly cited paper ratio of material science (i.e. the number of highly cited papers in material science divided by the number of highly cited papers in all field), universities in China and Taiwan have higher performance. Wuhan University of Technology and Tongji University in China rank the first and second, respectively, with their ratios exceeding 45%. Among all the universities in Taiwan, National Tsing Hua University performs the best by ranking the third with a ratio of 35%. The same ratios for universities in Hong Kong and Singapore further prove that material science is not a key field there, as their ratios are lower than that in China and Taiwan.

TABLE I

INDICATORS OF ACADEMIC PAPERS PUBLISHED FROM 1996 TO 2006 BY 36 UNIVERSITIES

Institutions	Country/Region	Papers	Papers Rank	Papers in MS / Papers in All Fd.	Citations	Citations Rank	Citations in MS/ Citations in All Fd.	Citations Per Papers	Citations Per Papers Rank	Activity Index	CPP/ FCSm	Highly Cited Papers	Highly Cited Papers Ratio	Papers in MS/ Highly Cited Papers in All	ESI field
TSING HUA UNIV	CN	4,022	4	19.43%	14,043	19	20.24%	3.49	501	4.48	0.72	32	0.80%	25.20%	5
NANYANG TECHNOL UNIV	SG	2,219	16	16.80%	9,581	42	20.43%	4.32	454	3.87	0.89	5	0.23%	9.80%	6
SHANGHAI JIAO TONG UNIV	CN	2,136	17	20.62%	4,860	116	18.25%	2.28	541	4.76	0.47	5	0.23%	8.47%	4
NATL UNIV SINGAPORE	SG	2,027	22	8.05%	12,791	26	7.50%	6.31	273	1.86	1.31	47	2.32%	18.15%	16
UNIV SCI & TECHNOL BEIJING	CN	1,939	24	67.14%	3,119	203	52.61%	1.61	550	15.48	0.33	1	0.05%	25.00%	1
NATL CHENG KUNG UNIV	TW	1,701	26	12.92%	7,330	64	10.67%	4.31	455	2.98	0.89	5	0.29%	7.94%	7
ZHEJIANG UNIV	CN	1,585	31	9.93%	4,973	112	9.79%	3.14	519	2.29	0.65	10	0.63%	16.39%	8
XIAN JIAOTONG UNIV	CN	1,442	35	26.85%	3,464	184	26.29%	2.4	538	6.19	0.50	2	0.14%	13.33%	2
NATL TSING HUA UNIV	TW	1,378	40	14.38%	6,817	67	13.12%	4.95	401	3.31	1.02	18	1.31%	35.29%	5
SHANDONG UNIV	CN	1,331	47	16.96%	2,884	215	11.68%	2.17	543	3.91	0.45	4	0.30%	12.90%	4
HONG KONG POLYTECH UNIV	HK	1,318	49	13.21%	4,602	125	11.47%	3.49	500	3.04	0.72	4	0.30%	10.00%	7
NATL TAIWAN UNIV	TW	1,268	56	34.28%	6,488	74	45.41%	5.12	382	1.22	1.06	17	1.34%	12.23%	13
UNIV SCI & TECHNOL CHINA	CN	1,249	58	9.68%	7,917	56	12.02%	6.34	269	2.23	1.31	29	2.32%	22.14%	5
WUHAN UNIV TECHNOL	CN	1,217	62	65.18%	2,209	283	53.77%	1.82	548	15.03	0.38	6	0.49%	60.00%	1
JILIN UNIV	CN	1,094	73	14.03%	5,544	102	18.11%	5.07	387	3.24	1.05	12	1.10%	32.43%	4
CITY UNIV HONG KONG	HK	1,078	75	10.93%	7,106	65	14.81%	6.59	246	2.52	1.36	24	2.23%	24.74%	10
NANJING UNIV	CN	907	96	6.33%	4,338	139	6.79%	4.78	416	1.46	0.99	14	1.54%	23.33%	5
DALIAN UNIV TECHNOL	CN	834	104	17.58%	2,042	304	14.88%	2.45	536	4.05	0.51	5	0.60%	23.81%	3
TIANJIN UNIV	CN	803	110	15.72%	1,444	415	12.69%	1.8	549	3.63	0.37	2	0.25%	20.00%	3
HUAZHONG UNIV SCI & TECHNOL	CN	766	119	12.52%	1,613	381	10.86%	2.11	544	2.89	0.44	1	0.13%	4.55%	3
NATL CHIAO TUNG UNIV	TW	751	120	8.13%	3,891	160	10.85%	5.18	378	1.87	1.07	12	1.60%	26.09%	5
BEIJING UNIV	CN	707	133	3.95%	4,441	135	4.99%	6.28	278	0.91	1.30	15	2.12%	9.15%	9
BEIHANG UNIV	CN	702	134	33.43%	1,538	395	31.36%	2.19	542	7.71	0.45	1	0.14%	12.50%	2
SICHUAN UNIV	CN	641	149	11.56%	1,849	330	12.63%	2.88	528	2.67	0.60	3	0.47%	13.64%	3
HONG KONG UNIV SCI & TECHNOL	HK	628	154	4.39%	4,021	153	6.29%	6.4	262	1.51	1.32	10	1.59%	7.30%	10
S CHINA UNIV TECHNOL	CN	583	179	21.84%	1,450	414	20.75%	2.49	535	5.03	0.51	4	0.69%	30.77%	1
NATL TAIWAN UNIV SCI & TECHNOL	TW	500	216	13.52%	1,988	309	13.91%	3.98	475	3.12	0.82	2	0.40%	25.00%	4
TONGJI UNIV	CN	490	221	16.55%	1,199	482	14.21%	2.45	537	3.82	0.51	5	1.02%	45.45%	2
NATL CENT UNIV	TW	488	222	8.73%	2,755	225	9.44%	5.65	335	2.01	1.17	4	0.82%	10.26%	5
UNIV HONG KONG	HK	487	223	2.87%	2,144	288	1.57%	4.4	450	0.66	0.91	5	1.03%	3.03%	14
NATL SUN YAT SEN UNIV	TW	439	239	8.41%	1,675	363	7.79%	3.82	486	1.94	0.79	2	0.46%	10.00%	4
LANZHOU UNIV	CN	355	307	8.77%	1,143	496	5.53%	3.22	516	1.48	0.67	1	0.28%	6.67%	3
NATL CHUNGHSING UNIV	TW	308	343	6.91%	1,215	477	5.77%	3.94	479	1.59	0.82	0	0.00%	0.00%	5
FENG CHIA UNIV	TW	307	345	18.49%	1,133	500	20.46%	3.69	489	4.26	0.76	1	0.33%	12.50%	2
CHINESE UNIV HONG KONG	HK	276	380	1.87%	1,389	431	1.23%	5.03	390	0.43	1.04	4	1.45%	2.88%	14
ZHONGSHAN UNIV	CN	255	408	6.30%	1,339	442	6.48%	5.25	369	1.45	1.09	4	1.57%	18.18%	3

*Institutions are sorted by Papers

** MS=Material Science; All Fd.=All Field.

TABLE II
INDICATORS OF ACADEMIC PAPERS PUBLISHED FROM 1996 TO 2006 BY 4 REGIONS

Country /Region	Schools	Papers	Average Papers	Papers Rank	Papers in MS / Papers in All Fd.	Citations	Average Citations	Average Citations Rank	Citations in MS/ Citations in All Fd.	Citations Per Papers	Average Citations Per Papers Rank	Average Activity Index	Average CPP/FCSm	Highly Cited Papers	Highly Cited Papers Ratio	Highly Cited Papers in MS/ Highly Cited Papers in All Fd.	Average ESI field
CN	20	23,058	1153	116	14.71%	71,409	3570	261	12.77%	3.1	487	4.63	0.66	156	0.68%	18.51%	3.55
TW	9	7,140	793	179	12.68%	33,292	3699	278	12.69%	4.66	431	2.48	0.93	61	0.85%	16.05%	5.56
HK	5	3,787	757	176	5.74%	19,262	3852	212	4.80%	5.09	370	1.63	1.07	47	1.24%	8.13%	11.00
SG	2	4,246	2123	19	11.06%	22,372	11186	34	10.29%	5.27	364	2.87	1.10	52	1.22%	16.77%	11.00

CONCLUSIONS

This article analyzes the academic performance in both quality and quantity of the 36 universities in Taiwan, Hong Kong, Singapore, and China which cross the threshold of material science by searching through ESI database. The indicators for quantity are the number of papers published and Activity Index; those for quality are the total citations, citations per paper, highly cited papers and CPP/FCSm. The total number and average of all indicators of four regions are in Table II, and the conclusions are as follows.

Universities in China have higher outputs of papers in material science than those in Taiwan and Hong Kong, especially Tsinghua University in China with the highest output among all the universities in this study. However, the universities in China do not have high citations per paper, with 13 universities are on the bottom of ranking. Also, the average of citations per paper of the 20 universities of China is 3.1, the lowest of the four regions. All these numbers indicate that Universities in China need to improve the quality of their papers in material science.

On the other hand, the 10 Universities in China are more focused in few fields, with an average of 3.55 fields pass the ESI thresholds. However, the ratio of the number of papers in material science to the number of papers in all fields is at an average of 14.71%, the ratio of highly cited paper in material science to those in all fields is 18.51, and the average Activity Index is as high as 4.63%. All the figures are the highest among the four regions. This indicates that material science is an important subject to universities in China with considerable focus in the development of teaching and research. If the trend continues, it is expected that universities in China can shortly enhance the quality of their papers.

Among all universities in Taiwan, National Cheng Kung University has the highest output of papers and citations in material science; while National Central University has the highest citations per paper. The ratio of highly cited papers in material science to all fields, National Tsing Hua University has the highest ratio, even among the 36 universities in the four regions. On average, universities in Taiwan are listed in 5.56 fields in ESI, and have an average ratio of 12.68% in the number of papers in material science to the number of papers in all fields, an average ratio 12.69% in citations per paper in material science to those in all fields, and 16.05% in the highly cited papers in material science to those in all fields. These figures show that Taiwan is not as focused in material science as China, yet it still has advantages in both education and research in material science.

Universities in Hong Kong have relatively high citations per paper and highly cited papers ratio in material science. Overall, the quality of their papers in material science is very high, indicating that Hong Kong is a small, yet competent player in the education of material science. The focus is on quality, rather than quantity (i.e. the number of papers). City University of Hong Kong has citations ranking the 65th, 6.59 citations per paper and a CPP/FCSm value of 1.36. It has 24 highly cited papers in material science and a highly cited paper ratio of 24.74% in material science to all fields. All these figures are the highest among the five chosen universities of Hong Kong. On average, universities in Hong Kong are listed in 11 fields in ESI. In addition, universities in Hong Kong are also competitive in other fields and there is no skew of focus in material science.

Both universities in Singapore have excellent achievement in researches of material science, with higher overall averages among the four regions. Nanyang Technological University ranks the second in the number of papers. National University of Singapore has the highest highly cited papers and the highly cited paper ratio in material science, among all the 36 universities in this study. Nanyang Technological University is listed in a total of 6 fields in ESI. In terms of the ratio of papers and citations in material science to all fields, it demonstrates a strong focus in material science. National University of Singapore is listed in a total of 16 fields in ESI, the highest among all the universities in the four regions, indicating that it has diversified developments and no particular focus is placed on the education or research of material science. However, the overall performance of its papers in material science is still superior to other universities in four regions.

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