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A comparative study of the difference in research performance in biomedical fields among selected Western and Asian countries

XIAOJUN HU,[a] RONALD ROUSSEAU[b,c]

[a] *Medical Information Center, Zhejiang University School of Medicine, Hangzhou, 310058 China*
[b] *KHBO (Association K.U.Leuven), Industrial Sciences and Technology,*
Zeedijk 101, B-8400 Oostende, Belgium
[c] *K. U. Leuven, Steunpunt O&O Indicatoren and Dept. MSI, Leuven, Belgium*

In this study, a series of relative indicators are used to compare the difference in research performance in biomedical fields between ten selected Western and Asian countries. Based on Thomson's Essential Science Indicators (ESI) 1996–2006, the output of papers and their citations in ten biomedical fields are compared at multiple levels using relative indicators. Chart diagrams and hierarchical clustering are applied to represent the data. The results confirm that there are many differences in intra- and interdisciplinary scientific activities between the West and the East. In most biomedical fields Asian countries perform below world average.

Introduction

This investigation starts from two focal points. On the one hand scientific research nowadays is dominated by the life sciences. On the other hand competition in science between countries and regions has increased.

Scientometric techniques, including the study of research output in the form of scientific papers, and the resulting citations have been increasingly applied to monitor scientific performance. The resulting indicators have been used for research evaluation and for research and university management. Over recent decades, the biomedical sciences have become the leading sciences, weighing heavily in measurements of national competitiveness [ADAMS, 1998]. The use of scientometric techniques and rankings based on many kinds of indicators has led to more interregional competition not only among Europe and the United States of America [HORTA & VELOSO, 2007; SHELTON & HOLDRIDGE, 2004], but also between the West and upcoming Asian countries [GLÄNZEL & AL. 2008; ROUSSEAU, 2008]. Sometimes even another division is made, namely between the 'young' Pacific Rim and the old Atlantic countries and regions. The foundation of the APRU (Association of Pacific Rim Universities,

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Address for correspondence:
RONALD ROUSSEAU
E-mail: ronald.rousseau@khbo.be

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including top universities from California, Australia, Japan, Taiwan, Singapore and China) is a clear symbol of this new geographic power. In this context it is stated that Asia is "squeezing" the West's lead in scientific output [VON BUBNOFF, 2005].

Combining these two focal points, namely the rise of Asia among scientific countries and the rise of the life sciences among the sciences we investigate the research performance of some selected Asian countries in the field of biomedicine (but we include chemistry), and compare with some Western countries. What can be said about the relative strong and weak points of their scientific research in biomedical fields compared to world standards? As a country's research impact in a given field is related to its innovative capacity [LIM, 2004; ZITT & BASSECOULARD, 2008] answering these questions provides useful information for science policy makers.

The present study aims at contributing to the discussion by using relative indicators as measures for interregional scientific evaluation. Based on a set of such indicators, the structure of a country's contribution in biomedicine and the relative impact of research outputs of each country versus the world's standards can be objectively assessed, distinctions between regions can be identified, and evidence can be provided for future strategies and prioritization of research. We use this opportunity to include a brief discussion about some scientometric indicators, namely the activity index (AI), the attractivity index (AAI) and normalized mean citation rate (NMCR). Precise definitions of these indicators follow in the next section.

Data collection

Ten countries are investigated: the United States of America, France, the United Kingdom, Germany, Italy, Japan, South Korea, China, Singapore and India. The first four are considered to be the top in the West, contrasted with one of medium strength – Italy [ADAMS, 1998], while the latter five countries are considered to be among the scientific leaders in Asia [LEYDESDORFF & ZHOU, 2005; ZHOU & LEYDESDORFF, 2006; SHELTON & AL. 2007; GLÄNZEL & AL., 2008]. The ISO 3166-1 country codes of these ten countries are given in Table 1. In order to determine national performance in scientific contribution and relative impacts versus world standards among selected biomedical fields, we categorized biomedical research (including chemistry) into ten fields, listed in Table 2, according to the ESI (Essential Science Indicators) standard. Numbers of citations and papers (and citations per paper for each country) in the ten broad subfields, the total number of citations and papers in the world, and the world baseline in each respective field were extracted from ESI 1996–2006.

Table 1. ISO 3166-1 country codes
of countries studied in this article

China	CN
France	FR
Germany	DE
India	IN
Italy	IT
Japan	JP
Singapore	SG
South Korea	KR
United Kingdom	GB
United States of America	US

Table 2. Biomedical fields (including chemistry)
studied in this article

1	Molecular biology & genetics
2	Immunology
3	Neuroscience & behaviour
4	Biology & biochemistry
5	Microbiology
6	Clinical medicine
7	Pharmacology & toxicology
8	Psychiatry/psychology
9	Chemistry
10	Plant & animal science

Methods

Selection of indicators

Among the many existing indicators and relative indicators [VINKLER; 1998] we selected the Activity Index (AI), the Attractivity Index (AAI) and the Normalized Mean Citation Rate (NMCR) for this study. These indicators are defined as follows.

The activity index (AI). The activity index of country C in field F, denoted as AI(C,F), was introduced by FRAME [1977]. It characterizes the relative research effort a country devotes to a given field F and is defined as:

$$\mathrm{AI(C,F)} = \frac{\text{the country's share in the world's publication output in the given field F}}{\text{the country's share in the world's publication output in all science fields}} \quad (1)$$

It can be shown [SCHUBERT & BRAUN, 1986; EGGHE & ROUSSEAU, 2002] that AI can be rewritten as:

$$\mathrm{AI(C,F)} = \frac{\text{the given field's share in the country's publication output}}{\text{the given field's share in the world's publication output}} \quad (2)$$

AI = 1 indicates that the country's research effort in the given field corresponds precisely to the world average. If for a given field a country's AI is larger than 1 this indicates that the country publishes more in the given field than world average (as measured through the database used). One may say that, if AI > 1, the country spends more energy and money to the given field than world average, or stated otherwise: AI > 1 reflects a specialization by this country in the field under study. We note that AI, see [SCHUBERT & AL., 1989; HORTA & VELOSO, 2007] is a version of the economists' revealed comparative advantage index. AI(C,F) – 1 is called the relative specialization rate of country C in the field F [GLÄNZEL, 2001]. The activity index has been used in many publications. We single out for mention the articles by [GLÄNZEL & AL., 2008; GUAN & MA, 2004].

The attractivity index (AAI) [SCHUBERT & BRAUN, 1986]. The attractivity index of country C in field F, denoted as AAI(C,F), characterizes the relative impact (as measured using citations) of the country's publications in the given field F. Its definition is:

$$AAI(C,F) = \frac{\text{the country's share in citations attracted by publications in the given field F}}{\text{the country's share in citations attracted by publications in all science fields}} \quad (3)$$

Also the AAI has another interpretation [SCHUBERT & BRAUN, 1986; EGGHE & ROUSSEAU, 2002]:

$$AAI(C,F) = \frac{\text{the given field's share in citations attracted by the country's publications}}{\text{the given field's share in citations attracted by all the publications of the world}} \quad (4)$$

AAI = 1 indicates that the country's citation impact in the given field corresponds precisely to the world average. If AAI > 1 for a certain country and a given field then this indicates that the publications of this country in the given field attract relatively more citations than world average. This index is sometimes also referred to as the relative citation impact [HORTA & VELOSO, 2007]. Also this index has been used in many applications such as [GÓMEZ & AL., 1995; SCHUBERT & BRAUN, 1986].

The ratio of the observed number of citations over the number of publications (using a given publication-citation window, for a certain unit) is called the mean observed citation rate, denoted as MOCR. This unit can be a research group, a university, a part of a university (by restricting publications to a specific field of science), a country, restricted to a certain subfield or not, and so on. In any case, there is always a set of articles associated to the unit under study. Now, one may consider all articles published in the same journals as the articles of the unit under study and the number of citations received by these articles (over the same time window). Also for this larger set a mean observed citation rate can be calculated. Seen from the perspective of the unit under scrutiny it is called the mean expected citation rate and denoted as MECR. This indicator has been introduced by SCHUBERT & AL. [1983]. It is also used by CWTS (Leiden) using the notation CpP/JCSm [DE BRUIN & AL., 1993]. Further, one can also calculate an expected citation rate per publication with respect to the fields in which the unit publishes. The normalised mean citation rate (NMCR) is the weighted average of the mean citation rates of the subfields to which the articles of the unit under study belong. Also this indicator has been introduced by the Budapest group [BRAUN & GLÄNZEL, 1990] and is called the *Crown Indicator* (also denoted as CpP/FCSm) by the Leiden group [VAN RAAN, 2004]. Recently a bounded version of the NMCR is preferred by applying the linear fractional transformation $x \to \frac{x-1}{x+1}$. In order to distinguish between the NMCR and the transformed one, we will denote the transformed one by tNMCR. This linear fractional transformation shifts the neutral point from 1 to 0 and yields values between –1 (inclusive, when the unit did not receive a single citation) and +1 (not inclusive).

The denominator of NMCR (FCS in the CWTS form) must be determined based on some definition of a (sub)field and using a database. Clearly the NMCR changes if one of these (or both) change, yielding another baseline or neutral value. This baseline can be chosen depending on the circumstances: it can be a world standard, a national standard or an institutional standard. In this article it will be a world standard, as determined from Thomson/Reuters' Essential Science Indicators (ESI). In the ESI counts are based on a journal set categorized into 22 broad fields. Fields are defined by a unique grouping of journals with no journal being assigned to more than one field. We do realize that the ESI is not the best possible source for this type of studies as collaborative papers are assigned to each collaborating unit separately. Yet, we also like to mention that the ESI covers 12,307 journals, more than twice that in the Web of Science and ESI data have already been used in several scientometric studies, see e.g. [MUST, 2006; BORNMANN & AL., 2007]. Hence, we do not think results on the macro level are heavily distorted. Moreover, completely distortion-free scientometrics does not exist as results always depend on the used database and on the relative weighting of publications and citations.

Finally, we would like to mention that one of us introduced the superiority coefficient [HU, 2007]. This coefficient is essentially equal to NMCR – 1. Subtracting the value one shifts the neutral value from 1 to 0, but still yields a potentially unlimited value. For this reason we now prefer the tNMCR.

Data processing

(1) The AI and AAI of each country in each field are calculated according to their definitions, resulting in two times (once for AI, once for AAI) 10×10 = 200 values. Two–dimensional relational charts [SCHUBERT & BRAUN, 1986] per field with AI on the horizontal axis and AAI on the vertical axis are drawn. A best fitting line is shown, illustrating the linear relation between these two indicators.

(2) To make distinctions in research impact between fields in assessing national performance across the selected Western and Asian countries, all data were extracted

from ESI 1996–2006 and processed according to consistent criteria. The tNMCR of each country in each biomedical field is calculated using the world standard extracted from the ESI as baseline (the indicator denoted as FCS by the Leiden group). This leads to one hundred values (ten fields and ten countries).

(3) Hierarchical clustering is applied to identify and classify all evaluated fields (ten fields in ten countries leading to a total of 100 fields) based on their tNMCR values.

Results

We obtained the AI, AAI, and tNMCR values for each of the evaluated countries by simply processing the data according to their defining equations. Their values reflect (some aspect of) the scientific structure and the differences in relative research impact in biomedical fields versus the world standards between the West and Asia during the period 1996–2006.

Relative scientific structure by country in each biomedical field

Figure 1 shows the relational charts of AAI versus AI per field. The diagrams display the relation between a country's relative "effort" (number of publications) and "return" (citations) in a given biomedical field. We note that when AI = 0, then by definition, also AAI is zero. Yet, we applied general regression (not requiring the regression to pass through the origin) as a logical requirement (AI=0 leads to AAI = 0) is not an observed value. Following Eisenhauer's advice [EISENHAUER, 2003] we performed a t-test whether the OLS regression line passes through the origin.

For the general linear regression line p-values for the null hypothesis of no correlation were always below 0.01, except for microbiology, where it was still below 0.05. This indicates that in all cases a linear relation between AI and AAI is statistically acceptable. The hypothesis that the best fitting line passes through the origin was rejected for Plant & Animal Science (p=0.0007) and barely accepted for Pharmacology & Toxicology (p=0.03).

These maps can be viewed from three different points of view. The first one is considering the lines AAI = 1, AI = 1. These divide the plane into four quadrants, as explained in Table 3. Intuitively quadrant I is the best, while quadrant III refers to a poor performance. Table 3 indicates how often each country belongs to each of the quadrants. The second way of viewing these maps is to determine if a country is situated above (positive evaluation) or below (negative evaluation) the regression line. How often this is the case is shown in column a of Table 4. The third way, preferred by SCHUBERT & BRAUN [1986], consists in considering the ratio AAI/AI and see if this is larger than 1 or not. This is then related to the "cost-effectiveness" of a country in a particular field or subfield. These results are shown in column b of Table 4.

Table 3 Number of times a country belongs to each of the four quadrants

II: AI < 1, AAI ≥ 1				I: AI ≥ 1, AAI ≥ 1			
US	0	JP	1	US	7	JP	3
GB	2	SG	3	GB	5	SG	0
DE	0	KR	0	DE	4	KR	2
FR	0	CN	0	FR	4	CN	1
IT	0	IN	0	IT	4	IN	3
III AI < 1, AAI < 1				**IV AI ≥ 1, AAI < 1**			
US	3	JP	3	US	0	JP	3
GB	1	SG	7	GB	2	SG	0
DE	4	KR	6	DE	2	KR	2
FR	4	CN	9	FR	2	CN	0
IT	4	IN	7	IT	2	IN	0

Table 4. Number of times a country scores better than the trend (a) or has AAI > AI (b)

	a	b		a	b
US	6	1	JP	2	1
GB	8	3	SG	6	3
DE	6	2	KR	3	2
FR	6	4	CN	6	4
IT	4	2	IN	4	2

Comments on the tables. Most countries belong either to the first or to the third quadrant. This corresponds to the fact that there is an increasing regression line between the variables (AI and AAI). The first quadrant is largely occupied by Western countries, while the third quadrant is largely occupied by Asian countries. We recall that AI and AAI are proportions, relating a country's "effort" and "citation results" to the world average. Intuitively it seems that the larger AAI and AI, the better. Moreover, a large AAI/AI ratio seems even better. We will, however, show that the real impact (visibility) of the country's publications cannot directly be derived from the AAI/AI ratio.

Some specific comments. In most cases the United States (US) and the United Kingdom (GB) can be found in the upper right corner of the graphs in Fig.1. The field of Psychiatry/Psychology is an extreme example. In Plant & Animal Science India occupies the right upper corner, while the United Kingdom and the United States occupy a middle position. The field of chemistry is the most special in this respect. It has India and China on the right hand side and the United States and the United Kingdom on the left-hand side. Moreover all countries are "cost-effective". i.e. have AAI > AI. That this is possible will be explained further on.

In fields where a country has AI and AAI below 1, one should wonder if this is the government's policy or not (as it is, for most countries, impossible to try to be a world leader in every field, a government may decide that a particular field is not a priority). If, however, such a 'poor' field, is not one that is deliberately somewhat neglected, then, perhaps, that country's research in that field deserves extra attention, i.e. deserves extra financial support. For China this is the case for nine of the ten biomedical fields, chemistry (not really a biomedical field) being the only exception.

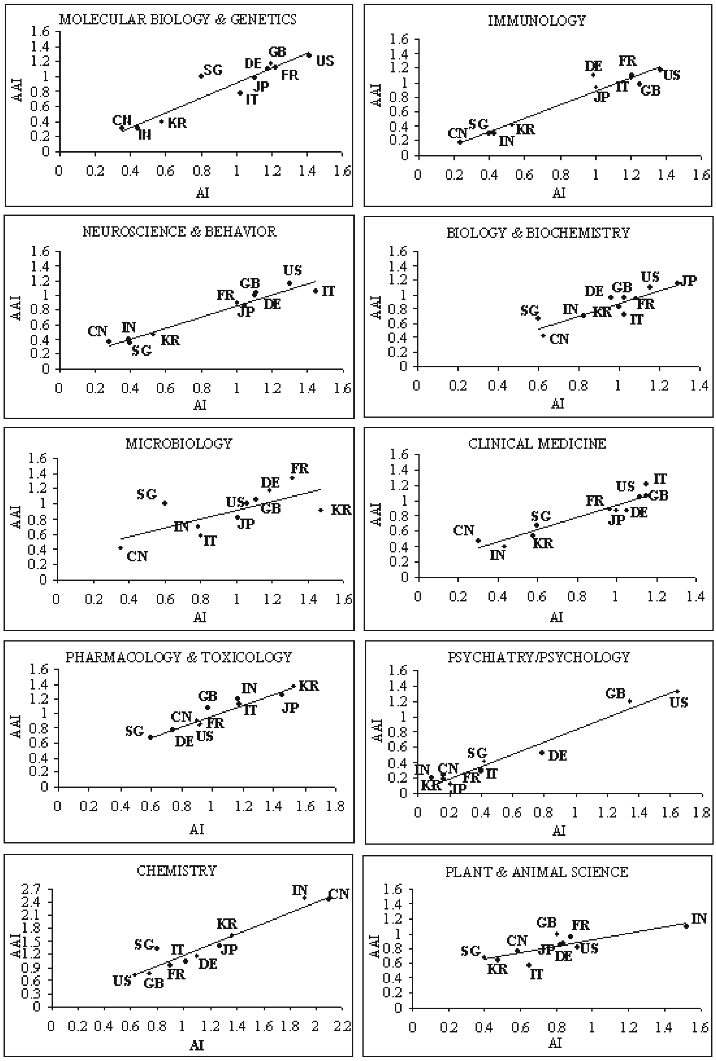

Figure 1. Relations between AI and AAI among ten countries in each biomedical field
(for country codes, see Table 1)

Differences in research impact in biomedical fields versus world standards

Based on the world baseline of citations per paper in a specific field according to ESI, we calculated the tNMCR in ten biomedical fields for ten countries during the period 1996–2006. These values show large differences in research level (impact) between the West and Asia (Table 5).

Most fields in the West, namely 37 out of 50, have a tNMCR-value larger than zero. In sharp contrast, 49 out of 50 fields in Asian countries have tNMCR < 0. The only exception is Chemistry in Japan. Not only does the West leads science in general (though it is losing its edge somewhat, [LEYDESDORFF & ZHOU, 2005; GLÄNZEL & AL., 2008]), these findings confirm that a Western lead is certainly true in the biomedical fields [WU, 2004]. Clearly for Asian countries there is, despite increased funding [WELLS, 2007; CYRANOSKI, 2001] still a lot of room for improvement in research in biomedical fields.

Differences in ranking of intra- and interdisciplinary research impact

Table 5 shows tNMCR-values for the ten countries in ten biomedical fields. A value above world average is shown in bold. The pattern in this table clearly shows strong and weak cells: the strong ones mostly on the left (Western countries, in particular the United States (US) and the United Kingdom (GB)), the weak ones mostly on the right (Asian countries, in particular India and China). The top four are the USA, the United Kingdom, Germany and France, the United States leads in eight out of ten fields. Exceptions are: Pharmacology & Toxicology, and Plant & Animal Science, where the United Kingdom leads. In most fields the United Kingdom ends second, followed by Germany. Germany's best field is Chemistry; it exceeds the world baseline in most other fields too, except for Clinical Medicine and Psychiatry/Psychology.

France's tNMCRs fluctuate around world baseline; its best field being Plant & Animal Science, while its performance according to this indicator is lowest for Psychiatry/Psychology.

Results for Italy show lower values than those of the other Western countries. Only three fields exceed the world baseline and most fields yield tNMCR-values that are lower than France's, Clinical Medicine and Psychiatry/Psychology, being exceptions.

Although Japan's results are best among Asian countries it is for nine out of ten fields below world average. Only for Chemistry it ends above world average. In Molecular Biology & Genetics, Immunology, Biology & Biochemistry and Plant &Animal Science it has a higher tNMCR value than Italy.

Singapore's tNMCR-values for Molecular Biology & Genetics, Biology & Biochemistry, Microbiology, Psychiatry/Psychology are slightly above Japan's, while the other ones are below. South Korea's Neuroscience & Behavior, Psychiatry/Psychology slightly exceed Singapore's, while the other ones are lower.

China and India perform the poorest of this selected group of countries. In five fields China ends before India while in the other five the other relation holds.

Table 5. tNMCRs in biomedical fields of ten countries during 1996–2006

Country Field	US	GB	DE	FR	IT	JP	SG	KR	CN	IN
Molecular Biology & Genetics	0.149	0.120	0.039	0.009	**–0.122**	**–0.098**	**–0.071**	**–0.439**	**–0.466**	**–0.543**
Immunology	0.122	0.021	0.030	0.015	**–0.034**	**–0.027**	**–0.354**	**–0.383**	**–0.523**	**–0.478**
Neuroscience & Behavior	0.139	0.112	0.019	**–0.009**	**–0.134**	**–0.148**	**–0.327**	**–0.300**	**–0.361**	**–0.448**
Biology & Biochemistry	0.174	0.097	0.065	**–0.026**	**–0.145**	**–0.098**	**–0.097**	**–0.359**	**–0.567**	**–0.493**
Microbiology	0.173	0.110	0.064	0.054	**–0.147**	**–0.156**	**–0.126**	**–0.443**	**–0.358**	**–0.422**
Clinical Medicine	0.165	0.093	**–0.029**	**–0.007**	0.051	**–0.100**	**–0.208**	**–0.261**	**–0.260**	**–0.418**
Pharmacology & Toxicolody	0.158	0.182	0.021	0.051	**–0.005**	**–0.119**	**–0.186**	**–0.265**	**–0.432**	**–0.367**
Psychiatry/ Psychology	0.093	0.075	**–0.131**	**–0.117**	0.014	**–0.333**	**–0.282**	**–0.212**	**–0.329**	**–0.237**
Chemistry	0.246	0.137	0.095	0.058	0.054	0.004	**–0.056**	**–0.171**	**–0.365**	**–0.280**
Plant & Animal Science	0.136	0.234	0.086	0.090	**–0.054**	**–0.034**	**–0.055**	**–0.128**	**–0.311**	**–0.529**
Average	0.155	0.118	0.026	0.012	**–0.052**	**–0.111**	**–0.176**	**–0.296**	**–0.397**	**–0.422**

Hierarchical clustering of all evaluated fields by impact

Because the tNMRC-values of the ten fields in ten countries show quite some scattering, a clustering procedure has been applied combining "customizing applet settings" and "between-groups linkage" in SPSS. This led to the following eight clusters, summarized in Table 6.

Table 6. Clustering results of fields in terms of the tNMCR-value of research impact among Western and Asian countries (see Table 2 for field codes)

Field code	US	GB	DE	FR	IT	JP	SG	KR	CN	IN
1	II	II	III	III	IV	IV	III	VII	VII	VIII
2	II	II	III	III	III	III	VI	VI	VIII	VII
3	II	II	III	III	IV	IV	VI	VI	VI	VII
4	II	II	III	III	IV	IV	IV	VI	VIII	VII
5	II	II	III	III	IV	IV	IV	VII	VI	VII
6	II	II	III	III	III	IV	V	V	V	VII
7	II	II	III	III	III	IV	V	V	VII	VI
8	II	III	IV	IV	III	VI	V	V	VI	V
9	I	II	II	III	III	III	III	V	VI	V
10	II	I	II	II	III	III	III	IV	VI	VIII

Cluster I, characterized by $tNMCR > 0.233716$. This cluster consists of two fields, namely USA Chemistry and the United Kingdom (GB) Plant & Animal Science.

Cluster II: characterized by $0.085923 < tNMCR < 0.182339$ and consisting of twenty fields: 9 from the USA, 8 from the United Kingdom, 2 from Germany and 1 from France.

Cluster III: characterized by $-0.07124 < tNMCR < 0.074503$. It consists of twenty-eight fields: 8 fields from France, 7 from Germany, 6 from Italy, 3 from Japan, 3 from Singapore and 1 from the United Kingdom.

Cluster IV: characterized by $-0.15607 < tNMCR < -0.09709$. The cluster is formed by fifteen fields: 6 fields from Japan, 4 from Italy, 2 from Singapore, 1 from Germany, 1 from France, and 1 from South Korea,

Cluster V: characterized by –0.28205 < *tNMCR* < –0.17096. Ten fields are brought together here: 4 from South Korea, 3 from Singapore, 2 from India and 1 from China.

Cluster VI: characterized by –0.38313 < *tNMCR* < –0.30039. It contains twelve fields: 5 from China, 3 from South Korea, 2 from Singapore, 1 from Japan and 1 from India.

Cluster VII: characterized by –0.49254 < *tNMCR* < –0.41884. The cluster consists of nine fields: 5 from India, 2 from China and 2 from South Korea.

Cluster VIII: characterized by *tNMCR* < –0.52323. The four fields in the last cluster come from India (2 fields) and China (2 fields).

The cluster to which a field (in a country) belongs provides an indication of the stage of its development. When comparing two fields (in the same or in different countries) the difference in cluster number is an indication of the difference in their position on the international scene.

Relative international research performance in biomedicine. National and interregional competitiveness can be measured by (but is not limited to) scientific impact as well as by the quantity of the research output. There clearly is a large gap between the West and Asia in research quantity as well as research impact. The United States has the largest output and the highest impact of the ten countries. The United Kingdom ranks second in impact. Except for Japan and Singapore, Asian countries are low in impact, mostly in grades V to VII, reflecting that research impact in biomedicine still has a lot of room for improvement.

Research resources and research structure

In most biomedical fields Asian countries have a lower-than-average AI and AAI score. This stands in contrast with the West, where AAI as well as AI are usually higher-than-average. Therefore, most biomedical fields of Asian countries need special attention and support in their countries' "scientific investment".

Although Asian nations have been increasing their scientific output in recent years, their research level in biomedical fields still has to improve considerably in order to meet world standards (de facto determined by Western countries). Most fields in Asian countries fall below those in the West. This is particularly true for India, China and even South Korea. The results shown above suggest that Asian countries, especially India, China and South Korea should consider emphasizing research quality and impact, and not focus on research quantity alone [JIN & ROUSSEAU, 2005]. Intensifying collaboration with the West by inviting outstanding scientists in the appropriate fields is a possible way to go, as long as the Asian co-author does not force himself/herself as the leading author.

The clustering results of fields in terms of relative citations per paper (impact or research impact) versus the world standards among Western and Asian countries provides not only information but also an incentive to the involved Asian countries for trying to improve science policy measures, including better decision making and co-operator selection. An intermediate goal for India and China would be to reach the levels of Singapore, Japan and Italy in research impact.

Some thought-provoking findings

What is the relation between relative research structures and relative research quality (impact)? According to the original definition AI = 1 indicates that the country's research effort in the given field corresponds precisely to world average. Similarly, AAI = 1 indicates that the country's citation impact in the given field corresponds precisely to the world average. Somewhat surprisingly, however, the real scores of research visibility (as measured through tNMCR) sometimes indicate otherwise. A typical example is the field of Chemistry in China. Here AAI = 2.47 and AI = 2.093, yielding high values for both indicators. Moreover the ratio AAI/AI > 1, yet China's tNMCR value for Chemistry is the lowest of the ten countries (–0.365). Similar observations can be made for Chemistry in India (AAI = 2.5, AI = 1.913, tNMCR = –0.280), Plant & Animal Science in India (AAI = 1.1, AI = 1.522, tNMCR = –0.529), Microbiology in South Korea (AAI = 0.909, AI = 1.474, tNMCR = –0.443), and Pharmacology & Toxicology in South Korea (AAI = 1.364, AI = 1.526, tNMCR = –0.265). While the AAI (0.705) and AI (0.638) of the United States' Chemistry is the lowest among ten countries, its tNMRC (0.246) is the highest of ten countries. These findings suggest that the relative national research structures in the given field do not reflect the real research impact by world standards. This will be studied theoretically in the next section.

Another interesting point for Asian policy-makers is the case of Singapore. Although its AAI and AI values for most biomedical fields are lower-than-average, the relative impact of citations per paper (research impact) and its distribution of national performance is better than other Asian countries' except for Japan, suggesting that Singapore has the advantage in management culture and structure [WANG & AL., 2007].

On the mathematical relation between AAI/AI and NMCR

We recall the definitions of AI, AAI and MNCR of country C in field F.

$$AAI(C,F) = \frac{\frac{CIT(C,F)}{CIT(W,F)}}{\frac{CIT(C,S)}{CIT(W,S)}}$$, C: country; F: field; W: world; S: all sciences

$$AI(C,F) = \frac{\frac{PUBL(C,F)}{PUBL(W,F)}}{\frac{PUBL(C,S)}{PUBL(W,S)}}$$

$$(NMCR)(C,F) = \frac{\frac{CIT(C,F)}{PUBL(C,F)}}{\frac{CIT(W,F)}{PUBL(W,F)}}$$

The meaning of the used notations is given below and refers always to a given database (e.g. WoS or Scopus) and a given citation and publication window (the same citation window in all cases and the same publication period in all cases):

CIT(C,F) denotes the number of citations received by country C in field F;

CIT(W,F) denotes the total number of citations (in the whole world) received by all articles in field F;

CIT(C,S) denotes the total number of citations received by publications from country C in all fields;

CIT(W,S) denotes the total number of citations (in the whole world) in all fields;

PUBL(C,F) denotes the number of publications from country C in field F;

PUBL(W,F) denotes the number of publications from all countries in field F;

PUBL(C,S) denotes the number of publications from country C in all fields;

PUBL(W,S) denotes the number of publications from all countries in all fields.

Then AAI/AI can be expressed as a function of NMCR as follows:

$$\begin{aligned}\frac{AAI}{AI}(C,F) &= [NMCR(C,F)].\frac{CIT(W,S)}{CIT(C,S)}.\frac{PUBL(C,S)}{PUBL(W,S)} \\ &= [NMCR(C,F)].\frac{\text{PUBL share of country C (wrt world) in all sciences}}{\text{CIT share of country C (wrt world) in all sciences}} \\ &= \frac{NMCR(C,F)}{NMCR(C)} \qquad (6)\end{aligned}$$

Here we have denoted by NMCR(C) the ratio of the citation share of country C over the publication share of country C (over all fields).

Expression (6) clearly shows that (AAI/AI)(C,F) and NMCR(C,F) (hence also tNMCR), although related, clearly measure something totally different. From this observation it follows that it is possible that for a group of countries and one particular field all countries have a AAI/AI ratio larger than one, as we saw for the field of chemistry. A fictitious example illustrating the difference between AAI/AI and NMCR is given in the Appendix.

Discussion and conclusion

This study recalled the definition of the activity index (AI), the attractivity index (AAI), the normalized mean citation rate (NMCR) and the transformed normalized mean citation rate (tNMCR). A mathematical relation between these indicators was derived.

We further applied these relative indicators to compare interregional differences in research performance in biomedical fields, providing objective evidence as well as new insights for policy makers. Relative indicators such as the AI and the AAI reflect relative positions with respect to reference standards, but cannot reflect their real research visibility (quality?) in a given field. They can, moreover, not be used for cross-field comparisons. We claim, however, that this information can be obtained from the tNMCR and its equivalent formulations such as the superiority coefficient (SC).

Do Asian countries want to beat Western countries in the science race? Probably yes, as scientific results form the base for future economic growth. Moreover, many Asian countries still bear a high burden of diseases, poverty and poverty related diseases. Also environmental problems leading on the one hand to water scarcity, dust storms and droughts, and on the other to floodings and powerful typhoons need solutions for which the contribution of top scientists will be of the utmost importance. Politicians, administrators and scientists responsible for drafting science policy blueprints have to make difficult decisions. Will they stimulate research similar to Western research, or opt for research related to the own region, preferring to solve local problems? [THORSTEINSDÓTTIR & AL., 2006]. In the opinion of the authors of this article the answer is easy: when Eastern countries solve so-called 'local' scientific problems, they are actually on the forefront of scientific research and are solving global problems. One way to realize this aim is to stop brain drain and attract more top scientists working in the West to do research in Asian institutions [LIU & ZHANG, 2007]. Collaboration between Asian countries and between countries all over the world will not be an option but a necessity. Finding the best institute or research group to collaborate with is another important problem. A suggestion is given in [YANG & JIN, 2006] but much more research on this interesting topic should be done.

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Appendix

It is assumed that a country (C) decides to increase its number of publications in a given field F. Thanks to some monetary incentives the number of publications in this field doubles. Yet, while publishing more the impact calculated as the number of citations per publication, stays the same. What happens to this country's AAI/AI and tNMCR? We assume that for all other countries and all other fields publication and citation numbers stay the same. We have the following data (Table 7) before and after the decision to increase publications in field F.

Table 7. Fictitious data illustrating the calculation of AAI, AI, NMCR and tNMCR

	Before	After
PUB(C,F)	100	200
PUB(C,S)	10,000	10,100
PUBL(W,F)	10,000	10,100
PUBL(W,S)	800,000	800,100
CIT(C,F)	50	100
CIT(C,S)	20,000	20,050
CIT(W,F)	10,000	10,050
CIT(W,S)	1,600,000	1,600,050

	Before	After
AAI(C,F)	0.4	0.794
AI(C,F)	0.8	1.569
(AAI/AI)(C,F)	0.5	0.506
NMCR(C,F)	0.5	0.502
tNMCR(C,F)	–0.333	–0.332

This calculation shows that, although the MOCR of country C in field F (=CIT(C,F)/PUB(C,F)) has stayed the same, AAI/AI as well as NMRC have increased, but that the relative increase of AAI/AI is 1.2% and that of NMCR is only 0.4%.