

In-depth analysis on China's international cooperation in science

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Abstract It has been about 30 years since China adopted an open-up and reform policy for global competition and collaboration. This opening-up policy is accompanied by a spectacular growth of the country's economy as well as visibility in the world's scientific literature. Also China's competitiveness in scientific research has grown, and is mirroring the development of the country's economy. On the other hand, international collaboration of most countries dramatically increased during the last two decades and accompanied the growth of science in emerging economies. Thus the question arises of whether growth of competitiveness in research is accompanied by an intensification of collaboration in China as well. In the present study we analyse the dynamics and the national characteristics of China's co-operation in a global context. We also study research profile and citation impact of international collaboration with respect to the corresponding domestic 'standards'.

Keywords China · International collaboration · Subject profiles · Subject normalisation

Introduction

The spectacular rise of the emerging economies (e.g., O'Neill 2005) has become a favourite topic of the recent literature on science and technology policy. The centre of gravity of growth in science and technology has actually moved away from the US and Japan, passing the European Union towards China, as has shown in many literatures

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(Leydesdorff and Zhou 2005; Zhou and Leydesdorff 2006, 2008; Zhou et al. 2009; Kostoff et al. 2007; Glänzel et al. 2008; Rousseau 2008). This development has already measurable effect on the balance of power as measured by scientific production. Nonetheless, countries of other world regions are undergoing dramatic growth and thus contributing to the global changes as well. In fact, scientific literature reports on the impressive developments in South America (e.g., Zanotto 2002, Glänzel et al. 2006, Leta et al. 2006, Zitt et al. 2006), but also within the EU and in its direct neighbourhood (Glänzel 2008). The spectacular development often goes with an intensifying international collaboration.

Since the adoption of the Opening-up policy in 1978, China has achieved a spectacular growth in both economy as well as visibility in the world's scientific literature. Recently China has overtaken France in economy and, at least according to the publication output indexed in the Web of Science, in scientific research as well (Glänzel et al. 2008). Since 2006 China holds position two just behind the US in terms of publication activity (Zhou and Leydesdorff 2008). International collaboration has also been expanded and strengthened. In 30 years after the adoption of the opening-up policy, China has established S&T collaboration relations with more than 150 countries or regions, and has signed inter-governmental S&T cooperation agreement with over 90 countries. When internationally co-authored publications in most countries dramatically increased during the last two decades (Schubert and Braun 1990; Glänzel and Schubert 2004), whether growth of competitiveness in research is accompanied by an intensification of collaboration in China as well? Which countries are China's major scientific partners, and which fields are active in international collaboration? What is the role of international collaboration in China? All these questions will be investigated in a global context. In addition, research profile and citation impact of international collaboration with respect to the domestic 'standards' will also be explored.

Methods

The study is mainly based on publications from 1997 to 2007 in the Science Citation Index Expanded (SCIE) version of the Institute of Thomson Scientific (Philadelphia, PA, USA). All documents recorded as article, letter, note, proceedings paper or review will be taken into account. The papers were assigned to countries based on the corporate address given in the by-line of publication. All countries indicated in the address field are thus taken into consideration.

Publications are assigned to 12 major subject fields according to the classification scheme developed by Glänzel and Schubert (2003) which, in turn, is based on ISI's Subject Categories. The 12 major fields include: Agriculture & Environment, Biology (Organism & Supra-organismic level), Biosciences (General, Cellular & Subcellular Biology, Genetics), Biomedical research, Clinical & Experimental Medicine I (General & Internal Medicine), Clinical & Experimental Medicine II (Non-Internal Medicine Specialties), Neuroscience & Behaviour, Chemistry, Physics, Geosciences & Space Sciences, Engineering and, finally, Mathematics.

The set of bibliometric indicators developed at the ISSRU (Budapest) and the ECOOM (Leuven) (see, e.g., Glänzel et al. 2003) is used to gauge publication activity and citation impact against both the Chinese national and the world standard. In particular, the effect of collaboration on the national disciplinary research profile, on citation impact and its change in time is studied.

Results

Comparative analysis between Chinese internationally co-authored and domestic publications is conducted. The first section deals with publication activity with major focus on the evolution, main players, and field diversity of publications. The second part explores citation impact based on different indicators which will be introduced in relevant sections.

Publication profile

After reviewing the development of publications of China in comparison with other leading nations, we investigated major players and active fields in international collaboration.

An overview

China takes the second position only after the USA in 2007 in terms of the percentages of world share of scientific publications based on the SCIE (Zhou and Leydesdorff 2008). The rapid growth of China would be more prominent if it is compared with the emerging countries (Fig. 1). South Korea had experienced slight growth before 2004 and keeps a stable share afterwards.

When Chinese publications increase remarkably, how is the situation of internationally co-authored papers? We separate the Chinese publications into two sets: set one includes all the Chinese publications and set two only counts the internationally co-authored papers. Detail information is shown in Fig. 2. Both numbers of the two sets increase obviously. But the increasing rate of set two is lower than that of set one. In other words, the number of China's internationally co-authored publications grows slower than its total number of publications.

In order to investigate the situation in other countries, we list the share of internationally co-authored publications of relevant countries in Table 1. Most countries' shares of international collaborations have been increased steadily. Only those of the emerging countries including China, Brazil, and Turkey decrease. This phenomenon implies that the growth rate of international collaboration in the emerging countries is lower than that of these countries' non-internationally co-authored publications. The situation in many other countries is the other way round.

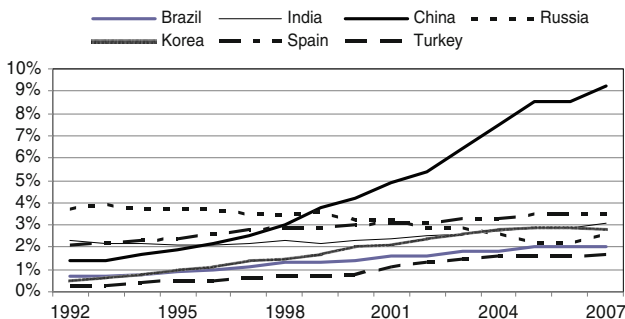


Fig. 1 Percentages of world share of publications of several selected countries (1992–2007)

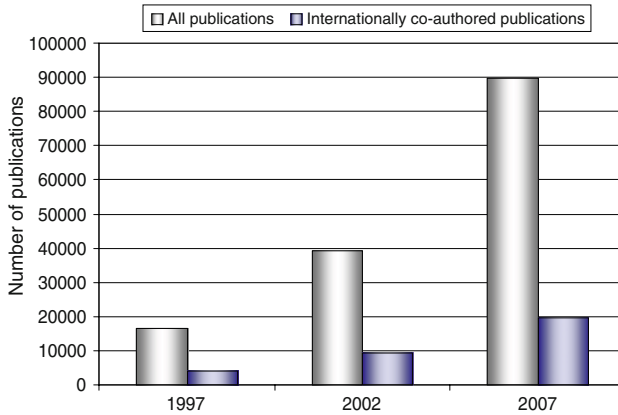


Fig. 2 China's total versus internationally co-authored publications

Table 1 National share of internationally co-authored publications (in %)

Country/region	1997	2002	2007
Switzerland	46.7	56.8	63.4
Sweden	38.5	48.1	54.3
Netherlands	36.3	46.0	50.7
France	33.3	42.4	49.4
Germany	31.9	41.4	48.0
UK	27.7	38.2	45.5
Canada	31.5	40.8	45.0
Australia	27.6	39.0	44.3
Italy	32.0	37.0	40.3
Spain	28.6	34.9	40.2
Russia	25.7	34.7	34.1
Brazil	34.4	32.7	30.2
EU15	19.6	25.6	29.4
USA	18.0	24.8	28.9
Korea	24.4	25.1	27.6
Japan	15.0	19.8	24.0
China	24.4	23.7	21.9
India	12.3	18.7	19.9
Turkey	17.3	17.7	16.1

Many EU member countries have high share of internationally co-authored papers. This is quite plausible. European integration encourages individual mobility of researchers within the European Union. On the other hand, the auspices of the European Commission are maybe the most important factor for stimulating the process of regional international scientific collaboration. Many multinational research projects are only possible in the framework of the large European programmes, above all, the European Framework Programmes. International collaboration among the EU countries has thus become very

intensive. But if considering the EU as an entity, its collaboration share with none EU countries is less significant (cf. Table 1).

The top six countries with high national share of internationally co-authored publications are from the EU, including Switzerland, Sweden, The Netherlands, France, Germany, and the UK. Switzerland is one of the most active countries in international collaboration. Over 60% of Swiss publications in 2007 are internationally co-authored. Sweden and The Netherlands are also active in this regard, with over 50% of their total publications are internationally-co-authored.

The national publication shares of international collaboration of Canada and Australia are also high. The largest producers of scientific publications, the USA and the EU have lower shares of international collaboration, but this is to a large extent due to the size effect described by Schubert and Braun (1990).

Compared to the EU countries and North American countries, all the major Asian countries including China, Japan, South Korea, and India have low rate of international collaboration.

Major domestic players

This section aims at finding out Chinese regions that are active in international collaboration. Details are shown in Table 2.

Among the 33 provinces, only three including Beijing, Shanghai, and Hong Kong are the most active. Almost half of China's international collaborations happened in the three regions. While nine regions including Jiangxi, Guizhou, and so on take no national share in this regard. If we use national share of internationally co-authored publications as a

Table 2 Share of international collaboration (in %) of regions with more than 1%

Province	2000	2001	2002	2003	2004	2005	2006
Beijing	26.4	26.5	26.5	24.5	24.6	24.4	24.6
Hong Kong	18.5	17.3	15.9	15.6	13.6	12.2	11.1
Shanghai	9.7	8.9	8.7	9.5	9.8	10.1	10.7
Jiangsu	6.3	6.4	6.6	6.3	6.6	6.5	6.6
Hubei	4.3	3.6	4.5	4.5	4.5	4.8	5.0
Guangdong	3.1	3.1	3.7	3.6	4.2	4.3	4.4
Liaoning	3.6	3.7	4.3	4.2	4.0	4.2	4.3
Zhejiang	3.0	2.6	3.4	3.8	4.2	4.4	4.2
Shandong	2.6	2.1	2.6	3.2	3.1	3.2	3.0
Anhui	3.3	2.9	2.8	3.0	3.3	3.0	2.9
Shaanxi	2.5	2.7	2.9	2.9	2.6	2.6	2.7
Tianjin	2.0	2.0	2.0	2.0	2.3	2.5	2.5
Sichuan	2.1	1.9	2.2	2.2	2.2	2.0	2.4
Hunan	1.2	1.7	1.7	1.9	2.3	2.1	2.2
Jilin	2.3	2.1	1.8	2.1	2.2	2.4	2.1
Heilongjiang	1.1	1.4	1.4	1.5	1.8	1.8	1.7
Fujian	1.4	1.5	1.7	1.6	1.5	1.6	1.4
Gansu	1.6	1.3	1.7	1.8	1.5	1.4	1.4
Yunnan	1.1	1.1	1.2	1.3	1.0	1.2	1.3

measurement of national visibility in international collaboration we will find that such visibility of most Chinese regions is extremely low or even zero.

International partners

Two indicators will be applied to measure China's international collaboration relations, which are (1) strength of mutual collaboration links and (2) (unidirectional) collaboration affinity (Glänzel 2000, 2001; Glänzel and Schubert 2001).

Salton's measure is used to define indicator of strength of mutual collaboration link between two countries, which is the number of joint publications divided by the square root of the product of the number (i.e., the geometric mean) of total publication outputs of the two countries. This indicator takes the publication size of two collaborated countries into account. Co-authorship affinity measures the relative roles of a country to another country and to the world in terms of publications. If C_j is the total number of internationally co-authored publications of country j , then

$$S_i = C_{ij}/C_j.$$

where S_i is the share of country i in the total number of internationally co-authored papers of country j . C_{ij} is the number of joint publications between countries i and j . If the total number of publications of country i and the world are P_i and P_w , respectively, the share of a partner country i in the "rest of the world" total is $W_i = P_i/(P_w - P_j)$. If S_i is higher than W_i , country i is more important to country j than to the world in terms of publications.

(Unidirectional) affinity Countries with relatively higher share in China's internationally co-authored publications in 1997 and 2007 are shown in Table 3.

Among China's international partners, the USA, Japan, Germany, the UK, and Canada take major part of China's international publications. Over 71% of China's internationally co-authored publications are jointly written with authors from the five countries. Although

Table 3 Important contributors to China's internationally co-authored publications

	1997		2007	
	Share (%)	Rank	Share (%)	Rank
USA	29.1	1	39.4	1
Japan	16.4	2	13.3	2
Germany	10.9	3	9.5	4
UK	8.6	4	8.6	3
Canada	6.2	5	7.7	5
France	5.7	6	7.4	7
Italy	4.4	7	5.2	12
Australia	3.5	8	4.8	6
South Korea	3.4	9	4.7	8
Netherlands	3.1	10	2.4	11
Singapore	2.4	11	2.2	9
Russia	2.3	12	2.0	13
Spain	2.2	13	1.9	15
Sweden	2.2	14	1.7	10
Switzerland	2.1	15	1.2	14

the shares of the five countries have changed 10 years later, the five are still the most important contributors to Chinese internationally co-authored publications. Furthermore, collaborative relations between China and the five countries have been strengthened in 2007 since their collective contribution to China's internationally co-authored publications has surpassed 78%. The USA takes the biggest share in China's internationally co-authored publications and collaboration between the two countries was further strengthened in 2007. It must be noticed that the collaboration links of each country pair are treated separately, co-publication counts and shares are not additive, and thus cannot be summed up to the total over any part of the world.

The status in terms of joint publications of relevant countries with China changed in the 2 years (i.e., 1997 and 2007). In 1997, the USA and the UK were more important contributors to world total publication output than they were to China's internationally co-authored publications, while the status of Japan and Germany are the opposite. By 2007, the importance of the USA, Singapore and Australia to China has been increased sharply, but that of Japan and Italy has been decreased notably. Even so, Japan is still more important to China than to the world. China's top five important partners (i.e., the USA, Japan, the UK, Germany, and Canada) are also more affinitive to China than they are to the world. Above all the relation between China and Singapore is worth of mentioning. Singapore's share in China's internationally co-authored papers is about 7 times of its world share of publications, which is the highest among those of any countries (Table 4).

Mutual collaboration strength A country with bigger number of publications may have more chances to jointly publish with a selected country, therefore, may take higher share in the selected country's internationally co-authored publications. This prevents from looking

Table 4 Co-authorship affinity of China ranked by percentage share of partner countries in China's total internationally co-authored publications in 1997 and 2007

	1997		2007		
	W	C	W	C	
USA	33.41	29.07	32.68	39.36	USA
Japan	8.93	16.44	8.37	13.29	Japan
Germany	8.35	10.94	9.01	9.55	UK
UK	9.01	8.64	8.49	8.63	Germany
Canada	4.40	6.15	5.10	7.74	Canada
France	6.28	5.71	3.25	7.36	Australia
Italy	3.99	4.36	6.02	5.24	France
Australia	2.64	3.54	3.06	4.80	South Korea
South Korea	1.15	3.41	0.73	4.71	Singapore
Netherlands	2.50	3.09	1.94	2.39	Sweden
Singapore	0.31	2.39	2.75	2.21	Netherlands
Russia	3.77	2.27	5.02	1.97	Italy
Spain	2.70	2.24	2.87	1.91	Russia
Sweden	1.91	2.19	2.05	1.65	Switzerland
Switzerland	1.75	2.12	3.86	1.24	Spain

W = Share of partner countries in the world total minus that of China, C = Share of partner countries in China's total internationally co-authored publications

into the collaboration strength between two countries. For instance, as the largest producer of world scientific publications, the USA can easily take a big share in another country's internationally co-authored publications even the number of joint publications with the country only takes a very small share in the internationally co-authored publications of the USA. In other words, the USA is important to the selected country, but it is not true vice versa. If both countries' total numbers of publications are taken into consideration, the relative mutual collaboration strength can be reflected. Figures 3 and 4 are mutual collaboration strength between China and other important countries. The values are based on Salton's measure.

There were eight countries with visible mutual collaboration strength with China in 1997 (Fig. 3). Hong Kong was the only region with the strongest mutual collaboration with China. In this picture, Hong Kong is considered as an independent region but not in Fig. 4 since it is part of China after 1997.

Most countries collaborating with China in 1997 are still China's partners 10 years later. Mutual collaboration strength with the USA, Japan, Australia and Singapore has been enhanced and become the strongest. In the meantime mutual collaboration strength with countries Sweden, France, and Malaysia has also been reinforced (Fig. 4). Compared to 1997, China's collaboration relation with Cyprus becomes at least weaker since Cyprus does not appear in the collaboration map in 2007.

The USA and Japan are China's most important partners in terms of mutual collaboration strength and unidirectional collaboration affinity. Collaboration relation between China and Singapore is unusually strong when taking Singapore's general productivity into account.

Active fields in international collaboration

In order to investigate the national publication profiles of international collaboration, we applied the Relative Specialisation Index (RSI) which is defined in the REIST-2 (1997) and

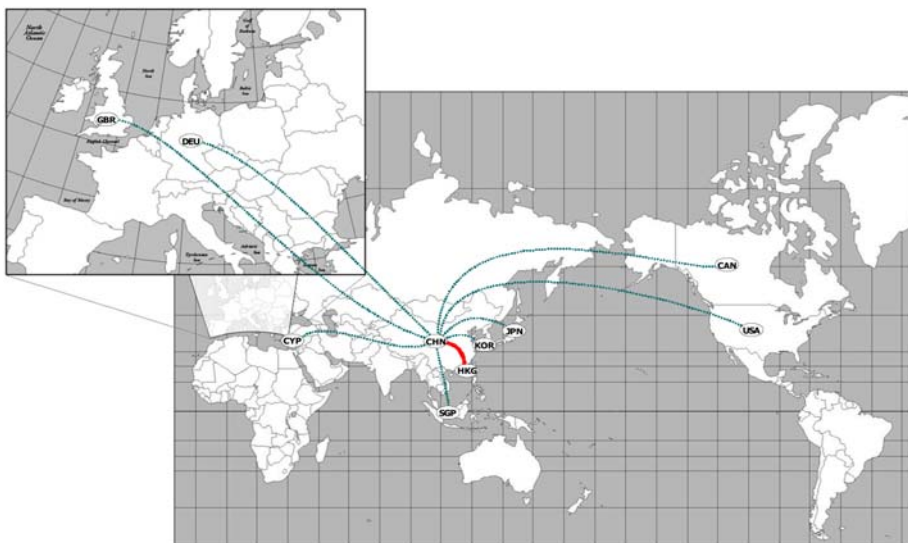


Fig. 3 Countries with relatively stronger mutual collaboration strength with China in 1997 ($0.010 \leq$ value of dotted line < 0.025 ; value of solid line ≥ 0.025)



Fig. 4 Countries with relatively stronger mutual collaboration strength with China in 2007 ($0.010 \leq$ value of dotted line < 0.025 ; value of solid line ≥ 0.025)

is closely related to the Activity Index (AI). AI was originally introduced by Frame (1977) which is a version of the economists' Comparative Advantage Index. Definitions of the AI and the RSI are expressed as follows.

$$AI = \frac{\text{the world share of the given country in the publications in the given field}}{\text{the overall world share of the given country in publications}}$$

or, equivalently,

$$AI = \frac{\text{the share of the given field in the publications of the given country}}{\text{the share of the given field in the world total of publications}}$$

and finally

$$RSI = \frac{AI - 1}{AI + 1}.$$

RSI shows in how far the national publication profile is in line with or deviates from the world standard of subject distribution of publication activity. By definition, the values of RSI range between -1 and $+1$. $RSI < 0$ means a lower-than-average activity; $RSI > 0$ indicates a higher-than-average activity; and $RSI = 0$ reflects a completely balanced situation. $RSI \equiv 0$ for all fields corresponds to the "world standard" (cf., REIST-2 1997).

Earlier studies (e.g., REIST-2 1997) distinguished the following four basic paradigmatic patterns in publication profiles:

- (1) The 'western model' with clinical medicine and biomedical researcher as dominating fields,
- (2) The characteristic patten of the former socialist countries with excessive activity in chemistry and physics,

- (3) The ‘bio-environment model’ with biology and earth and space sciences in the main focus,
- (4) The ‘Japanese model’ with engineering and chemistry being predominant.

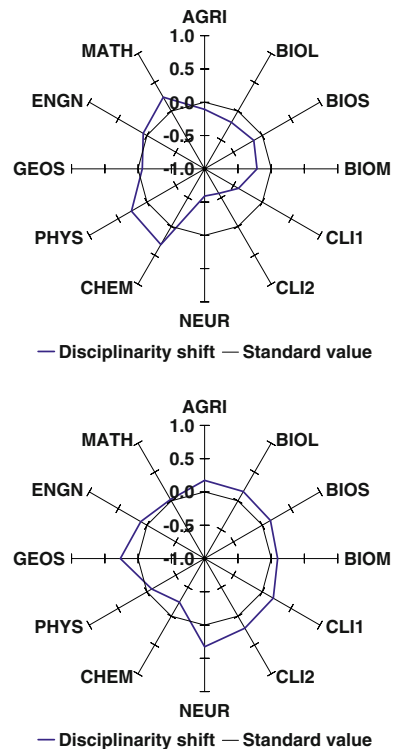
The AI and RSI indicators can also be used to analyze the profile shift of national publication activity in collaborative research from the national standard. In particular, Glänzel (2001) has shown that the relative specialisation of internationally co-authored publications often deviates from the domestic one and that in principle four cases occur in this deviation or disciplinary shift, particularly,

- (1) no significant deviation between the two profiles in the country,
- (2) increase of national peculiarities through international co-publications,
- (3) weakened national characteristics, and
- (4) deviation that cannot be classified in any other category.

The upper diagram in Fig. 5 shows that China’s subject profile clearly follows the basic paradigmatic pattern of the former socialist countries with pronounced activity in chemistry and physics and less activity in the life sciences (cf., REIST-2 1997), but in addition, China is also active in mathematics.

In terms of the deviation of disciplinary shift in international collaboration, the Chinese situation applies to the third case summarized by Glänzel (2001): international collaboration compensates China’s field activity: the more active fields in domestic research the less active in international collaboration, vice versa (Fig. 5). International collaboration in chemistry, physics, and mathematics is less active compared to that in neuroscience and

Fig. 5 Shift of China’s relative publication activity due to international collaboration in 2007 based on Frame’s Activity Index (top: all publications, bottom: international publication)



behaviour, clinical and experimental medicine, biomedical research, biosciences, biology, geosciences and space sciences, and agriculture.

Citation impact

As citation culture differs among disciplines, we select relative indicators to measure citation impact. These indicators are either journal based or field based therefore can better reflect the real situation. Relevant indicators and their definitions are listed below:

- Mean Observed Citation Rate (MOCR). MOCR is defined as the ratio of citation count to publication count (Braun et al. 1985).
- Mean Expected Citation Rate (MECR) is a journal-based citation measure which expresses one expected citation rate of a publication set. The expected citation rate of a single paper is defined as the mean citation rate of all papers published in the same journal in the same year. Here a 3-year citation window to one source year is used. MECR is then defined as the average of the individual expected citation rates over the given publication set. This indicator can preferably be standardized through dividing MECR by the Field-Expected Citation Rate (FECR) which is calculated in the same manner as MECR but instead of the journal citation impact the average impact of the corresponding subfields is used (Glänzel et al. 2008). This ratio expresses if papers are, on an average, published in journals with higher or lower citation impact than the corresponding subfield citation standards. Therefore, we can consider this indicator also a measure of relative “visibility”. It should be mentioned that a version of this relative measure, namely, FCSm/JCSm is used at CWTS in Leiden (Moed et al. 1995).
- Relative Citation Rate (RCR). RCR is defined as the ratio of the two previous measures, that is, $RCR = MOCR/MECR$. It should be stressed that in this study, a 3-year citation window to one source year is used for the calculation of both the numerator and denominator of RCR. $RCR = 0$ corresponds to uncitedness; $RCR < 1$ (or $RCR > 1$) means lower (or higher)-than-average citation rate. $RCR = 1$ if the set of papers in question attracts just the number of citations expected on the basis of the citation impact of the journals where the papers have been published (Braun et al. 1985]. Again, a version of this relative measure, namely, CPP/JCSm is used at CWTS (Moed et al. 1995).
- Normalised Mean Citation Rate (NMCR) is defined analogously to the RCR as the ratio of the Mean Observed Citation Rate to the weighted average of the mean citation rates of subfields, that is, $NMCR = MOCR/FECR$. This indicator is a second relative citation rate; in contrast to the RCR, NMCR gauges citation rates of the papers against the standards set by the specific subfields. Its neutral value is 1 and $NMCR > 1$ (or < 1) indicates higher (lower)-than-average citation rate than expected on the basis of the average citation rates of the underlying subfields. NMCR has been introduced by Braun and Glänzel (1990) in the context of national publication strategy. A similar measure (CPP/FCSm) is used at CWTS (Moed et al. 1995).

The overall situation

The two indicators of both total Chinese publications and internationally co-authored publications in 3 years (i.e., 1997, 2001, and 2005) have been investigated (Fig. 6).

Both the RCR and the NMCR of Chinese total and internationally co-authored publications have increased after each 5-year interval. The relative citation impact of

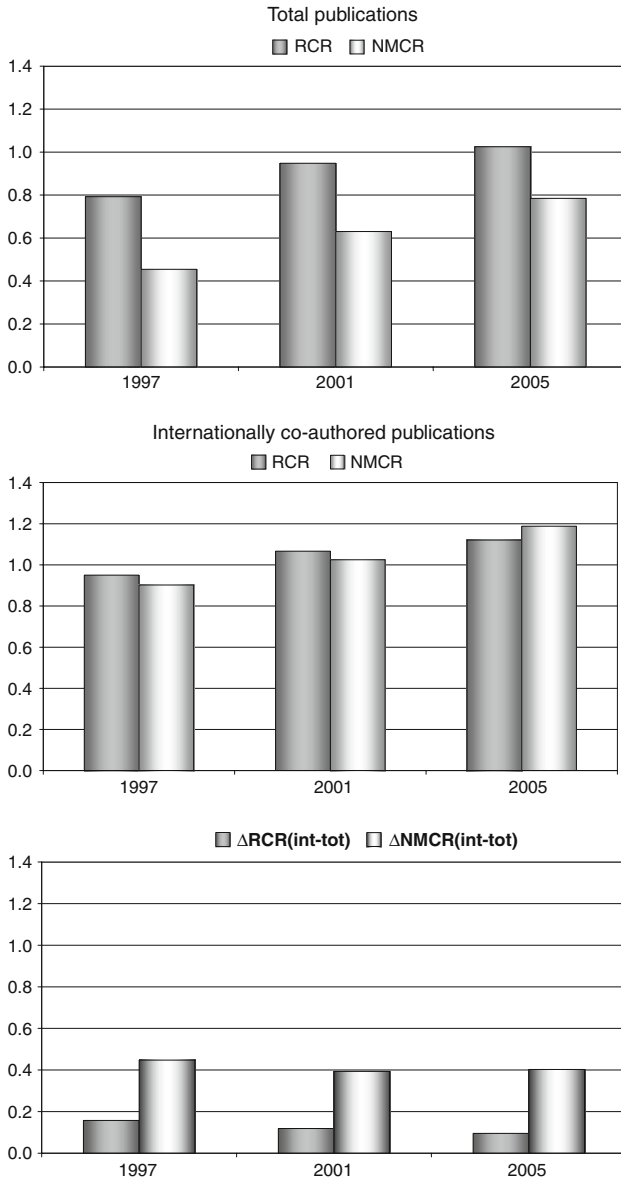


Fig. 6 The RCR and NMCR of China's total vs. internationally co-authored publications

internationally co-authored publications is higher than that of Chinese total publications. In other words, international collaboration increases China's citation impact. The raising effect to the RCR keeps going down from 1997 to 2005, while the raising effect to the NMCR has also been weakened from 1997 to 2001 and later on keeps stable till 2005. This phenomenon implies that the increase function of international collaboration to the RCR and the NMCR of Chinese publications has been lowered since 2001 while China's domestic citation impact keeps rising.

Fig. 7 Change of the RCR between China's total and internationally co-authored publications

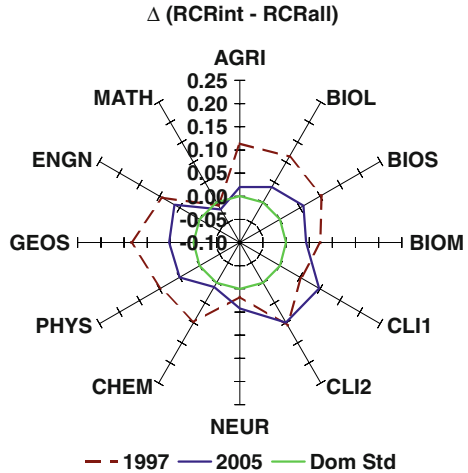
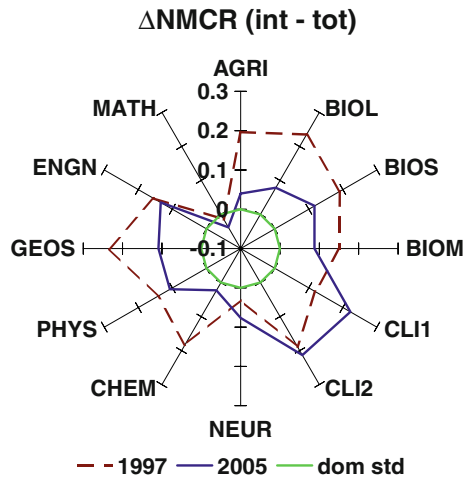


Fig. 8 Change of the NMCR between internationally co-authored and China's total publications



Publication profiles

Figure 7 shows the difference of the relative citation rate (RCR) of publication profiles of China's total and internationally co-authored publications. In both 1997 and 2005, the RCRs of internationally co-authored publications in most subject categories are higher than those of China's total publications. Collaboration in mathematics is an exception since the RCR of the China's total is higher than that of international collaboration. This is again an example that international collaboration does not always pay off (Glänzel and Schubert 2001). The raising effect of international collaboration in most subjects has weakened from 1997 to 2005 except the fields in clinical & experimental medicine and neuroscience & behaviour.

International collaboration also raises the value of the NMCR of Chinese publications, except in mathematics whose citation impact is lowered by international collaboration and

the lowering effect became stronger in 2005. However, the citation raising effect of international collaboration in many subject categories has decreased remarkably 8 years later. The subjects in which China is extremely inactive, namely, clinical & experimental medicine and neuroscience & behaviour still increasingly benefit from international collaboration (Fig. 8).

Conclusions

International collaboration measured by scientific publications has been increased obviously in China. But the growing speed of the number of internationally co-authored publications does not catch up with that of China's total publications. In other words, the growth of China's research output measured by publication activity does not go with intensification of international collaboration. When national share of internationally co-authored publications increase in most countries, for example, the EU countries and the North American countries, that of China, Brazil, and Turkey decreases. This may imply that the growth rate of international collaboration in the emerging countries is lower than that of these countries' non-internationally co-authored publications. The situation in many other countries is the other way round.

The EU countries have high national share of internationally co-authored publications. But the intensity of collaboration differs between within and outside the EU: collaboration within the EU is more significant than that with non-EU countries. International collaboration also takes high share in national publications in Australia and Canada but is not high in the USA. All the selected Asian countries (i.e., South Korea, Japan, China, and India) have less share of international collaboration in their publication activity.

International collaboration partly contributes to China's scientific output. International collaboration compensates China's deficiency of field activity. China follows the basic paradigmatic pattern of the former socialist countries with pronounced activity in chemistry and physics and less activity in the life sciences (REIST-2 1997), in the meantime research activity is also remarkable in mathematics. Publication activities in China's international collaboration are the opposite with clear activities in neuroscience and behaviour, clinical and experimental medicine, biomedical research, biosciences, biology, geosciences and space sciences, and agriculture.

Distribution of international collaboration among Chinese regions is highly skewed: almost half of international collaboration is conducted only in three regions (i.e., Beijing, Shanghai, and Hong Kong). National visibility of international collaboration in many regions is extremely low or even zero.

The USA, Japan, the UK, Germany, and Canada are China's most important partners, among which the USA and Japan take the lead. Mutual collaboration link between China and Australia or Singapore has been enhanced. The relation between China and Singapore is unusual. Although Singapore has low international visibility in world share of publications, its share in China's internationally co-authored publications is rather high.

Citation impact of China's overall publications and internationally co-authored publications has increased considerably, although the share of internationally co-authored papers decreased over the last 10 years. This applies to both journal- and subject-normalised mean citation rates (RCR and NMCR, respectively). International collaboration increases China's overall citation impact. But such raising effect is weakening.

The citation impact of international collaboration differs among subject categories. Internationally co-authored publications in most subject categories attract on average more

citations than domestic papers. This applies above all to the medical sciences. The situation in mathematics is unique since international collaboration lowers China's citation impact, and the lowering effect becomes even stronger 8 years later. The citation raising effect of international collaboration in subject categories in which China is less active continues to grow.

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