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Network structure, distribution and the growth of Chinese international research collaboration

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Abstract The paper studied 211,946 articles indexed in Thomson Reuters's Web of Science from January 1st 2002 to December 31st 2011, in order to describe the growth and distribution of Chinese international research collaboration (IRC), from the perspective of amount, authors, countries, discipline fields and journals. By applying bibliometric and social network methods, this study provided the collaboration network of countries and fields. The main results were as follow: the number of article increased faster comparing with the stable growth in average annual of IRC degree; the articles collaborated with SAC are 80 % more than all IRC's; as to the fields, collaboration in Social science is at disadvantage, while the largest field is physics and the fastest field is molecular biology and genetics; mathematics, physics, multidisciplinary and space science had more in fluencies than others in corresponding respective journals; as to the network, USA, as the largest and most important partner, had 30 % IRC articles, and collaborated with China in all 22 ESI fields.

Keywords International research collaboration (IRC) · Collaboration network · China · Field · Journal · Country

Introduction

International research collaboration (IRC), namely international collaboration in scientific research, can promote the knowledge and cultural exchanges among countries. There are

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rapid development of science and technology in China from 2002 to 2011. According to the previous literature outputs, China has become more important for international scientific research. Thus, to study the feature and network of Chinese scientific research is meaningful and valuable.

Collaborative articles are ideal objects for studying the IRC, just as surveyed by Franceschet and Costantini (2010, p. 541), "co-authorship in publications is widely considered as a reliable proxy for scientific collaboration". Over the past decade the amount of IRC articles has been increasing faster. it was described as a "exponential growth" (He 2009; Leydesdorff and Sun 2009) or "five-fold" increases (Mattson et al. 2010).The reasons for that can be explained as following, first is the tendency of "Big Science" (Price 1986), another is the benefits and merits of research collaboration, including sharing, transferring knowledge and research equipment, connecting scholars to a large scientific network, expediting the research process, and increasing the visibility of articles (Gazni et al. 2012).

Growth mode is a popular research topic. Moreover the collaborative network can show the collaboration clearly. Based on the structure of the network, the certain "core countries" had been identified in many studies (Leydesdorff and Wagner 2008; Schubert and Sooryamoorthy 2010). (Rousseau 2000; Goldfinch et al. 2003; Onyancha and Maluleka 2011) found that developing and underdeveloped countries are benefited more from co-authorship with the core countries (typically the USA and a select group of European countries). Recently, the percentage and network of international collaboration had been examined on a wide scale (Gazni et al. 2012). In addition from the perspective of journals or discipline fields, the more feature of collaboration could be revealed, such as journal preference or main fields. (Gonzalez-Alcaide 2010) found that fewer papers published in five English language journals, which were focused on basic research but they have a higher level of international participation and outstanding citation rates. In this paper, we hope to reveal the main fields and key journals of Chinese IRC in macro level.

But there are few articles mapping the IRC of China, especially from the perspective journals and fields. Based on the data from the SCI-E, the collaboration with G7 (USA, United Kingdom, Japan, Germany, France, Canada, and Italy) in 12 science fields was studied from 1996 and 2005, in which showed exponential growth of outputs, and the trend of main countries and fields (He 2009). Also, it was studied that international scientific and technological (S & T) collaboration of China from 2004 to 2008 through the perspective of paper and patent. It showed the continuously increasing of China' total papers and patents and the USA being the most important international scientific collaboration (ISC) partners and China's international technological collaboration (ITC) was mainly carried out with USA and Taiwan (Zheng et al. 2012). Recently China's ISC was studied from three categories of collaborating countries, institutions and individuals (Wang et al. 2013), in which the USA, in first place, takes up more than 40 % of all co-authored papers, and Chinese immigrant scientists were playing an important role in China's ISC. But the related data was restricted in 1 year (2010) of SCI-E, so the time window was a little bit too short.

This paper aim to solve the following questions, how lager is the Chinese IRC scale, with what countries and fields dose China mainly collaborated in recent decade. Other questions are to be considered, Such as on which journals are the articles mainly published, and how the network of countries and fields is connected with. To those ends, This paper studied 211,946 articles indexed in Thomson Reuters's Web of Science (WoS) from January 1st 2002 to December 31st 2011, and demonstrated the features of Chinese IRC from perspective of amount, countries, fields, journals, and network.

By studying the number of papers, we found a stable increase of Chinese IRC, with average annual growth of 23 % (Table 1). By analysing the distribution of IRC articles, we get the major cooperative group of countries, which were USA, Japan, England, Germany, Canada and Australia. By comparison to the countries, we found China prefers to collaborate with SAC (Table 2). According to the 22 fields of Essential Science Indicators (ESI) and five broad fields (Nagaoka et al. 2010), we further researched the articles distribution characteristics in different broad fields, and found that Physical sciences has the largest proportion but with the smallest increase ratio, Social sciences has a less proportion but a higher increase ratio in 5 broad fields (Table 4). And then the "key" journals were listed in all fields (Table 6). From the 2-mode network of countries and fields, we found that China had the most collaborative articles with USA, and Physics was the biggest collaboration field. But some countries only collaborated with China in one main field (Fig. 2).

Data and methods

Data source and processing

ISIs WoS is considered as a large, mature and professional bibliographic database. This study used three database of the science citation index expanded (SCI-Expanded), Social sciences citation index (SSCI) and Arts & humanities citation index (A & HCI), retrieved previous literatures in the span from 2002 to 2011 using "People's Republic of China" as the address. Then we filtered data by category of "articles" and download by countries or regions which had frequently collaborated with China. By dropping imperfect information and repeated ones, finally we selected 211,946 out of 283,575 downloaded articles, with complete information including fields such as AU, AF, C1, SO, SN, PY and UT.[1] Then the data processing had been accomplished by excel and access etc.

A dataset was built including all the 211,946 selected articles. These articles were distributed in 8,242 journals (according to their ISSNs revised partly) and 177 countries and regions. Total frequency of authors was 1,711,251, and that of institutions and countries was up to 797,410 and 490,601 respectively. The average number of authors per article was 8.07, and that of institutions and countries was 3.76 and 2.31 respectively. In addition, the maximum number of authors in one article was up to 2,423, and that of affiliated institution and countries or regions was up to 178 and 52 respectively. Their definition and time-variation would be elaborated in "*The changes over the last decade*".

Solution to multiple affiliated authors problem

It is common that one author is affiliated with more than one institution or country in an article, which has a great influence on the analysis results. According to the statistical description of all articles, there are 15,300 articles in which the number of institutions is greater than the number of authors. Moreover the figure increases rapidly from 666 in 2002 to 2,988 in 2011. But that is not all. Because in some articles, of which institutions' number is not more than authors' number, maybe author is affiliated more than one institution or country. The situation is similar as to the country.

[1] AU—author(s) first and last name(s), AF—author(s) full name, C1—Author(s) affiliation(s), SO—Journal name, SN—Journal ISSN, PY—Publish year, UT—WOS ID.

Table 1 The proportionality indicators of Chinese scientific collaboration

Year	Average numbers per article			Ratios			IRC (%)
	Author	Institution	Country	Author/institution	Author/country	Institution/country	
2002	8.78	3.58	2.29	2.45	3.83	1.56	24.41
2003	8.04	3.51	2.27	2.29	3.54	1.55	23.60
2004	9.86	3.81	2.32	2.59	4.25	1.64	22.84
2005	10.33	3.97	2.35	2.60	4.40	1.69	21.69
2006	9.44	3.86	2.31	2.45	4.09	1.67	21.15
2007	8.06	3.73	2.31	2.16	3.49	1.61	21.65
2008	7.34	3.66	2.30	2.01	3.19	1.59	22.53
2009	7.02	3.65	2.29	1.92	3.06	1.59	22.92
2010	7.58	3.80	2.33	2.00	3.25	1.63	24.24
2011	7.42	3.87	2.33	1.92	3.18	1.66	24.22
Total	8.07	3.76	2.31	2.15	3.49	1.63	23

Table 2 Comparison of collaborative countries of China (I)

Groups	Countries		Collaborations		Category of countries			
	Numbers	%	Numbers	%	SAC (%)	SPC (%)	SDC (%)	SLC (%)
≥10,000	7	10.6	187,056	67	100	0	0	0
≥1,000	26	39.4	77,901	28	58	31	4	8
≥100	33	50	13,202	5	9	33	30	27
Total	66	–	278,159	–	38	29	17	17

Thus this paper takes account into all affiliated institutions and countries, assuming them contribution are equal. But repeated institutions or countries in one article is counted only once. For example, if an article has four authors affiliated with three institutions which belong to two countries, then the number of authors, institutions and countries are four, three and two respectively. The collaboration takes place not only among authors but also among institutions or countries. So an article, with one author affiliated with two institutions that belongs to two countries, is considered as one IRC.

Unify journal's ISSN

In the last decade, maybe for the reasons of renaming, publication ceasing, etc., some journals have more than one name or ISSN number. So the paper has unified different ISSNs of a same journal to the new one, referring to the journal citation reports (JCR) of ISI. The following related analysis are based on the ISSN, namely SN field, so journals that have more than one name but only one ISSN number would remain unchanged.

Mapping articles to 22 and five fields

In ESI there are 22 fields, and Japanese scholar Nagaoka et al. (2010) further classified them into five broad fields (Table 4). The science watch website provides a list of ISI journals and corresponding classification (updated to March 2012). However, the records of that were incomplete therefore a great number of articles have no corresponding fields. Based on JCR, this study added 250 records for the website's list. Each added record was classified into a field under the following rules: If a journal belongs to multiple subjects, take the first subject; if "multidisciplinary" is used for a journal category, take the "multidisciplinary"; if their subject is not covered by the 22 ESI fields, a similar one is matched according to the subject(s) of journal.

Categorizing countries

The nationalities (or regions) of authors were extracted automatically from the author affiliations (C1) field. The name of countries and regions that used in this paper is strictly based on the information that author provided for the respect sake. A country or region would only count once if some authors in one article are from the same country. For the expression easy sake, the country or region are collectively referred to as country in the paper, such as Northern Ireland etc.

The development of science and technology is related with economic development. According to the development speed of science and technology Wagner et al. (2001) divided 150 countries into four categories including scientifically advanced countries (SAC), scientifically proficient countries (SPC), scientifically developing countries (SDC), and scientifically lagging countries (SLC). In this paper, some regions and their categories were added according to the research, such as Cyprus and Qatar etc.

Visualization software

UCINET is a social network analysis program which works in tandem with freeware program called NETDRAW for visualizing networks. This study applied UCINET 6.186 and NetDraw 2.076 to draw 2-mode collaboration network of major countries and fields.

Results and discussion

The changes over the last decade

Four indicators to measure the scale of collaboration were compared: number of collaboration articles, total frequency of authors, total frequency of institutions and that of countries. The collaboration article was defined as the article which is accomplished by authors affiliated with China and other country (countries). The total frequency of authors, institutions and countries respectively was the total number of authors, institutions and countries in each article. Institution or country which repeated in one article was counted just once.

As we can see from Fig. 1, the four indicators are increasing, with the average annual growth rate of 16.73, 14.57, 17.76 and 16.96 % respectively. The total frequency of authors fluctuates lightly. The growth of the four indicators was accelerating in nearly 3 years, especially the number of authors.

The other proportionality indicators are as follows: average number of authors per article, average number of institutions per article, average number of countries per article, and ratio of author/organization, author/national, institutions/countries, as well as the

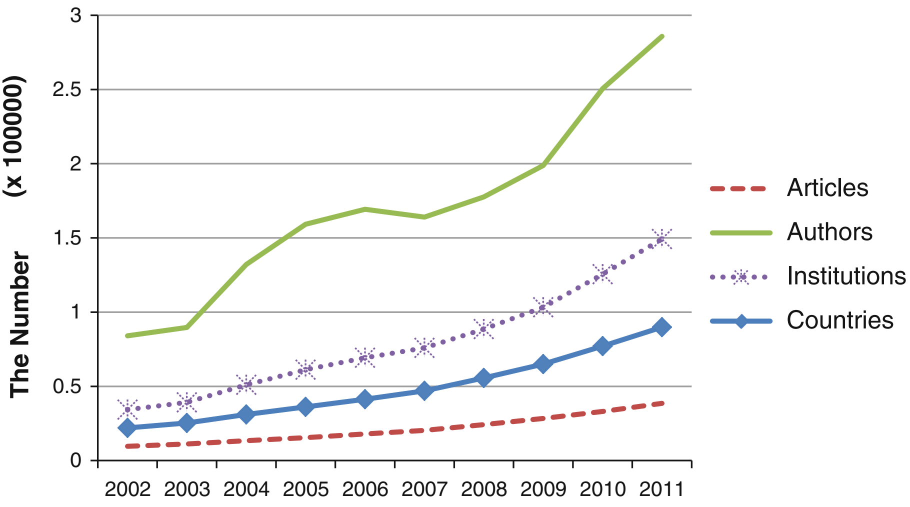

Fig. 1 The frequencies of articles, authors, institutions and countries in Chinese IRC articles

percentage of IRC article, which reflects the collaboration strength. The percentage of international collaboration articles defined as the ratio of number of Chinese IRC articles and the total number of articles published or participating published by Chinese authors. The average number of authors per article, average number of institutions per article, and average number of countries per article are calculated as total frequency of authors, institutions and countries divided respectively by the number of collaboration articles. Then author/organization, author/countries, institutions/countries are the ratios between the corresponding frequencies.

Table 1 presents a stable percentage of IRC articles in the last decade, with the fluctuation less than 2 % and an average of 23 %. The other six indicators were measured based on the Chinese IRC articles. All the indicators share similar trends over 10 years which are relatively stable, decrease after increase, and peak between 2003 and 2007. As a result of the increasing number of institutions and countries and the number of authors that affiliated more than one institution or country in an article, the indicator of author/institutions and author/countries decrease overall.

International collaboration by countries

There are 178 countries that have collaborated with China. And the total collaboration frequencies are 283,575 according to countries. The numbers maybe are slightly less than the actual value because not all articles could be indexed from SCI-E. There are 66 countries have collaborated with China for 278,159, which account 99.1 % of the total frequencies (Table 2). In this section, analysis was based mainly on the top 66 countries, each country had collaborated more than 100 papers with China.

According to the number of articles, the 66 countries could be classified into three groups. In the first group there were seven countries which are USA, Japan, England, Germany, Canada, Australia and France, the collaboration frequency with each of them is no less than 10,000. USA is a primary collaboration partner, which accounts for 30 % of the all articles. The second group consisted of 26 countries, such as Singapore, South

Table 3 Comparison of collaborative countries of China (II)

Groups	Average annual		Annual growth				
	Numbers	Growth (%)	Max. (%)	Countries	Min. (%)	Countries	SD
≥10,000	26,722	16.1	34.9	Canada (2004)	2.8	Japan (2007)	0.072
≥1,000	2,996	16.2	93.1	Czech Republic (2004)	−33.1	Malaysia (2008)	0.171
≥100	400	24	400	Lithuania (2003)	−85.7	Iceland (2003)	0.645
Total	4,215	20.1	400	–	−85.7	–	0.476

Korea, etc., with the frequency between 1,000 and 10,000. The third group comprised 33 countries, with the frequency between 100 and 1,000, such as Pakistan, Portugal, etc. The indicators are compared in Table 2 below.

Wang et al. (2013) listed top seven countries collaborate with China in 2010, which are USA, Japan, Germany, Canada, UK, Australia and South Korea. Apart from USA and Japan, the rank was different with our results for different time periods.

From Table 2 shows extraordinary disparities among three groups. The frequency of collaboration with the top seven countries in first group accounted for 67 % of the all, and the third group of 33 countries accounted only for 5 %. With respect to scientific development level, all countries are divided into four categories: SAC, SPC, SDC and SLC (Wagner et al. 2001). Great differences are found among three groups. There were seven SACs (100 %) in group one while almost 60 % SDCs and SLCs in group three. In the light of 82 % articles are collaborated with the SACs, it could be confirmed that China prefers to collaborate with SACs.

Collaboration frequency with the first group is steadily growing at annual rate of 16.1 %, with a minimum standard deviation of 0.072 (See Table 3). By contrast, the third group increases faster, but the fluctuation is far greater than the other two groups, reflecting that a long-term and stable collaboration with countries in group three have not yet been established. As a SPC, China is apt to collaboration with those SPCs, which are geographical proximity, such as Singapore, Korea and India.

International collaboration by fields

A journal list was downloaded from the science watch website, and 250 records were added. But it wasn't enough. Providing every article was matched, the list would be even longer. To complete it is a time-consuming and inefficient job. Our solution was to ensure that the number of unmatched articles was lower than 20 for each journal. Although there were 3,820 articles in 735 omitted journals (5.2 articles on average). It had little influence on the result. The following analysis was based on the new list which contained 10,979 journal records. And 7,507 journals in the list were used to match. At last 208,126 articles were matched to 22 ESI fields via ISSN and further matched to five broad fields.

In Table 4, all five broad fields are listed in descending order of frequency, and the 22 ESI fields are listed in descending order of the rate in same broad field. The number of articles increases substantially. In particular, the medicine articles increases 4.4 times, followed by Social sciences. In the recent decade, physics sciences broad field has published most IRC articles, and took up overwhelming advantageous in 5 broad fields. There was a plain decline from 69.3 % in the year of 2002 to 61.6 % in 2011.

Table 4 Chinese scientific collaboration changed rate in fields

Broad fields	Growth (times), annual growth (%)	Fields	Article number	Annual growth (%)
Physical sciences	3.57, 15.18	Environment/ecology	7,248	22.39
		Computer science	9,013	20.80
		Engineering	24,819	18.16
		Geosciences	10,731	16.34
		Chemistry	24,813	15.35
		Materials science	15,020	14.00
		Space science	2,870	12.76
		Mathematics	9,408	11.95
		Physics	29,948	11.13
Life sciences	4.88, 19.25	Molecular biology and Genetics	1,564	25.84
		Immunology	4,039	24.75
		Agricultural Sciences	3,070	24.10
		Pharmacology and toxicology	2,988	21.11
		Microbiology	3,738	21.00
		Neuroscience and behavior	9,845	19.25
		Biology and biochemistry	9,621	18.52
		Plant and animal science	1,564	13.89
Medicine	5.4, 20.62	Clinical medicine	22,504	20.95
		Psychiatry/psychology	2,096	17.33
Social sciences	5.38, 20.55	Social sciences, general	3,539	22.46
		Economics and business	3,420	18.69
Multidisciplinary	3.5, 14.93	Multidisciplinary	2,569	14.93

Among the fields, physics stay the top with nearly 30,000 articles, followed by engineering, chemistry, clinical medicine, materials science and geosciences. The average annual growth rates of all fields are more than 11 %, and molecular biology and genetics have the highest growth rate of 25.84 % (Table 4). Further study shows that computer science has dropped significantly in 2006 then rise gradually. Meanwhile, geosciences and materials science stay stalled in 2008 and 2006.

International collaboration by journals

Above all, we defined the journal published IRC articles as published-journal (P-J), and the journal with the most IRC articles as the IRC core-journal (C-J). The total number of journals and the number of P-J in each field are showed in Table 5. Base on the statistic data of the percentage of P-J to total journals, the distribution of journals with different amount of articles and the percentage of C-J articles to the total articles of its field, and the influence of each field were studied. According to article quantity, statistical grouping method was used for discipline fields to count the journal amount: 1–9, 10–19···0.190–199,200-maximum. The interval was select through several experiments. The shorter the interval was, the more even the distribution was. But if the interval was too big, the distribution wouldn't be shown clearly. Three groups of them are listed in Table 5 for the need of compare. The first two columns cumulate more than 40 % for

Table 5 Published-journal (P-J) percentage and article amount distributions

Field	Total number	P-J numbers	Percentage of P-J (%)	Distribution of P-J		
				$x < 10$ (%)	$10 \leq x < 20$ (%)	$201 \leq x$ (%)
Agricultural sciences	290	183	63.10	55.19	14.75	1.09
Biology and biochemistry	434	340	78.34	41.76	19.41	1.18
Chemistry	549	427	77.78	35.36	13.11	6.79
Clinical medicine	1,976	1,314	66.50	57.91	18.65	0.53
Computer science	347	292	84.15	46.23	18.15	0.68
Economics and business	536	396	73.88	71.46	17.42	0.00
Engineering	879	703	79.98	36.42	17.07	2.42
Environment/ecology	327	247	75.54	46.96	18.62	2.02
Geosciences	393	310	78.88	46.77	13.87	3.23
Immunology	94	73	77.66	43.84	24.66	1.37
Materials science	322	250	77.64	38.40	13.60	8.80
Mathematics	450	407	90.44	45.70	18.67	1.23
Microbiology	122	80	65.57	35.00	17.50	2.50
Molecular biology and genetics	278	221	79.50	40.72	19.91	0.00
Multidisciplinary	36	27	75.00	29.63	14.81	14.81
Neuroscience and behaviour	244	189	77.46	58.20	16.93	1.06
Pharmacology and toxicology	212	132	62.26	50.00	18.18	0.00
Physics	318	272	85.53	33.70	12.82	13.55
Plant and animal science	810	553	68.27	55.70	18.26	0.36
Psychiatry/Psychology	533	306	57.41	81.05	12.09	0.00
Social sciences, general	1,772	741	41.82	89.47	6.61	0.00
Space science	57	44	77.19	45.45	9.09	6.82
Total	10,979	7,507	68.38	53.77	15.94	2.05

each of 22 fields, and the last columns show the big different between them. The other columns are meaningless to analyse, and thus are not listed in the paper.

Except for Social sciences and general, the percentages of P-J in all fields are more than 50 %. In particular, mathematics has the maximum percentage of 90.44 %, followed by Physics (=85.53 %).These reflect a greater impact within their fields to some extent.

As to distribution of P-Js, more than half of them publish IRC articles below 10. P-Js of "Social sciences, general" field has the maximum percentage (=89.47 %), followed by those of Psychiatry/Psychology field (=81.05 %). Contrarily the P-Js which publish IRC articles over 200 in Multidisciplinary and Physics fields has the higher percentage of 14.81 and 13.55 % respectively. These revealed the core journal(s) maybe existed in some fields.

Furthermore the abbreviate name of C-Js and the percentage of their articles in same field are listed in Table 6. A journal could be regarded as "core journal" or "key journal" in their corresponding fields if the percentages of IRC articles that published in it are more than 30 %, such as Proc Nat Acad Sci USA for Multidisciplinary and Astrophys J for Space Science. J Power Sources publishes IRC articles beyond most of other C-Js', but the percentage is the lowest. This can be explained by the even distribution of articles in engineering field. These findings above illustrate different distribution features of articles

Table 6 The maximum percentage of article quantity in identical journal (by fields)

Field	Abbreviation	ISSN	Numbers	%
Multidisciplinary	Proc Nat Acad Sci USA	0027-8424	797	31.02
Space science	Astrophys J	0004-637X	876	30.52
Immunology	J Immunol	0022-1767	269	17.20
Computer science	Lect N Bioinformat Lect Note Comput Sci	0302-9743	1459	16.19
Geosciences	J Geophys Res-Atmos	0148-0227	1,098	10.23
Agricultural sciences	J Agr Food Chem	0021-8561	403	9.98
Microbiology	J Virol	0022-538X	285	9.54
Biology and biochemistry	J Biol Chem	0021-9258	871	8.85
Neuroscience and behavior	Brain res	0006-8993	305	8.16
Environment/ecology	Environ Sci Technol	0013-936X	560	7.73
Physics	Appl Phys Lett	0003-6951	2,110	7.05
Psychiatry/psychology	Am J Physiol-Heart C	0363-6135	145	6.92
Pharmacology and toxicology	Acta Pharmacol Sin	1671-4083	189	6.16
Clinical medicine	Plos One	1932-6203	1,189	5.28
Materials science	J Alloys Compounds	0925-8388	705	4.69
Mathematics	J Math Anal Appl	0022-247X	409	4.35
Molecular Biology and genetics	BMC Genomics	1471-2164	195	3.71
Social sciences, general	Energ policy	0301-4215	124	3.50
Economics and business	China Econ Rev	1043-951X	106	3.10
Plant and animal science	Zootaxa	1175-5326	288	2.99
Chemistry	J Chem Phys	0021-9606	712	2.87
Engineering	J Power Sources	0378-7753	454	1.83

in difference journals and fields. There are publications concentrates in certain journals and some scatters in various journals. However, articles scattered distributions great may result a lower impact in their field than others.

International collaboration 2-mode network of countries and fields

For further analysis of the characteristics of IRC between other countries and China, a 2-mode network of main countries and fields is drawn using UCINET 6.186 and NetDraw 2.076 (Fig. 2). The main 39 countries are selected with IRC articles no less than 200 in any field.

From the network (Fig. 2), the difference is visible. As to fields (red circles), physics is the main field in which the most countries collaborated with China and simultaneously has the largest number of IRC articles, followed by clinical medicine and chemistry, with 23 and 19 collaborative ones respectively among 39 countries. On the contrary, Immunology field only has USA which has collaborated with China for more than 200 times. As to countries, there are 15 out of 39 countries that collaborated only in a field with China, of which 11 countries are in Physics field, three countries (Thailand, New Zealand and Finland) in Clinical Medicine field, one (Wales) in Engineering field. Only USA has collaborated in all 22 ESI fields with China for more than 200 times.

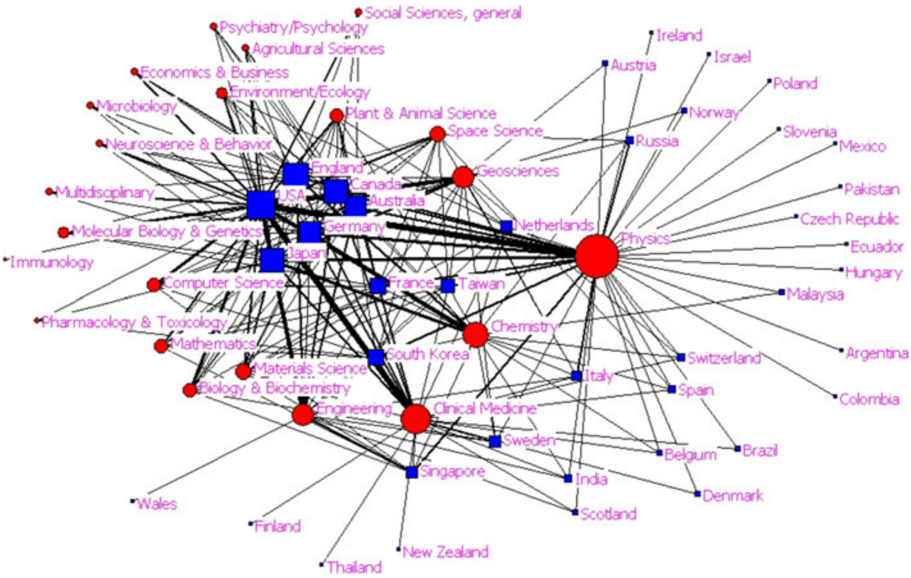

Fig. 2 Network of main countries and fields (threshold = 200)

Table 7 The parallel of major collaborator fields between the two results

Countries	Collaborator fields in the results of (He 2009)	Collaborator fields in this paper
UAS	Biosciences (BIOS), clinical and experimental Medicine (CLIN), neuroscience and behavior (NEUR), multidisciplinary sciences (MULT)	Clinical medicine,physics
Japan	Biomedical research (BIOM), chemistry (CHEM)	Physics, chemistry
England	Biology (BIOL)	Engineering, physics
Germany	–	Physics, chemistry
France	Geosciences and space sciences (GEOS)	Physics, chemistry
Canada	Agriculture and environment (AGRI), engineering (ENGN), mathematics (MATH)	Engineering, physics
Australia	–	Physics, geosciences
Italy	Physics (PHYS)	Physics, clinical Medicine

The bigger green squares represented countries of USA, Japan, England, Germany, Canada and Australia respectively in Fig. 2. These countries together form a group as a core of the network. USA, as the foremost partner, mainly collaborates with China in fields of clinical medicine, physics, engineering, geosciences and chemistry, etc.

Unlike G7, the group includes Australia but without Italy. Compared with the results of He (2009), we can see the distinct differences between them (see Table 7). Physics is the major field for the eight countries to collaborate with China in this study. In addition the same IRC fields are Clinical Medicine with USA, Chemistry with Japan and Engineering with Canada. The different results lie in the inconsistent span of time. But it reflects the changes of Chinese IRC with time.

Conclusion

This paper presented the macroeconomic situation of Chinese IRC from perspective of amount, countries, fields, journals, and network of countries and fields. All the data used in this paper were indexed from WoS. This study applied bibliometric and social network methods. Major results include that the number of IRC articles was increasing greatly, with a stable percentage of 23 %. Among top 66 collaborative countries, China prefers to collaborate with SACs, accounting for more than 80 % of all IRC articles. The increasing rates between fields are different. In five broad fields, “Physical sciences” has the largest proportion but with the smallest increase ratio, “Social sciences” has a less proportion but a higher increase ratio. Among the 22 ESI fields, Physics stay the top with 29,948 articles, but the Medicine articles increases most quickly with 4.4 times. The distribution of articles in different journal is different too, even though in same field, reflecting the diversification of field impact. The P-Js of Mathematics has the maximum percentage of 90.44 %, followed by Physics (=85.53 %), which reflect a greater impact within their fields to some extent. From the maximum percentage of article quantity in identical journal, the core-Journal had been found, such as Proc Nat Acad Sci USA for Multidisciplinary and Astrophys J for Space Science. From the network of main countries and fields, the core of countries had been shown, namely USA, Japan, England, Germany, Canada and Australia. Moreover we found that USA is one of the most important partner, who collaborated with China for more than 200 times in any one of 22 fields, and Physics was the most popular collaborative field, in which 35 countries collaborated with China for more than 200 times. These results could give answers to questions that mentioned in this paper. Finally, we hope these results can be useful for highlighting the Chinese international collaborative behaviour.

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