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Academic publishing and collaboration between China and Germany in physics

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Abstract Based on publications indexed in the *Science Citation Index Expanded* (*SCIE*) of Thomson Reuters, we explored China–Germany collaboration in physics from perspectives including publication profiles, collaboration effect, as well as active institutions and active fields. We found that German researchers are more capable of publishing higher-quality papers than Chinese counterparts. Both China and Germany get benefit from collaboration in raising publication productivity. The collaboration helps improve Chinese researchers' citation impact and capability of publishing in higher-quality journals. Research capacities of German institutions are more evenly distributed than Chinese counterparts. Chinese institutions that are most active in collaborating with German counterparts are mainly those in leading positions in China, whereas those in disadvantageous situation are still isolated from the international community.

Keywords Physics · International collaboration · Publication productivity · Citation impact · China · Germany

Introduction

Collaboration plays a significant role in the progress of science and technology. As a major form of research output, co-authored publications have been import sources for exploring collaboration relations (e.g., Beaver and Rosen 1978, 1979a, b).[1] Internationally

[1] In the later text, the words *collaboration* and *co-authorship* will be treated as alternative of each other.

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co-authored publications in most countries have increased dramatically for decades, but with highly skewed distribution among countries or regions (e.g., Schubert and Braun 1990; Glänzel and Schubert 2004). In addition to common research interests, political relations, geography, culture and language may play critical roles in the establishment of collaboration relations. With the development of communication technology, however, geographical distance is no more an obstacle blocking researchers located far away from collaboration. Take China for example, USA, UK and Germany are its major partners although located far away from China (e.g., Zhou and Tian 2014; Wang et al. 2013; Zhou et al. 2013; Zhang and Guo 1997).

Nevertheless, research results of collaboration relation between countries may vary when different data sources are used. In other words, different data sources may tell different stories (Leydesdorff et al. 2014). For example, in contrast to the high contribution of international collaboration to China's total publications indexed in the Web of Science of Thomson Reuters (Guo et al. 2000; Wang et al. 2005; Zhou and Glänzel 2010), the share of international collaboration is low in China's domestic publication database—the *Chinese Scientific and Technical Papers and Citations Database* (CSTPCD) Zhang and Guo 1997; Wang et al. 2005).

With the fast growth of Chinese publications (e.g., Zhou and Leydesdorff 2006; ISTIC 2014), international collaboration of China has been investigated extensively, of which main partners and collaboration effect are hot topics (He 2009; Zhou and Glänzel 2010; Zheng et al. 2012; Wang et al. 2013; Leydesdorff et al. 2014; Zhou et al. 2013). International collaboration in specific fields such as nanotechnology (e.g., Wang et al. 2012; Tang 2013; Tang and Hu 2013; Tang and Shapira 2011; Chen et al. 2013), food and agriculture (Zhou et al. 2013), and mathematics (Zhou and Tian 2014) have also been explored. USA, Japan, Germany, UK, and Canada are major partners of China. Positive effect of international collaboration in raising China's productivity and citation impact has been proved, although such effect may vary among different fields (Wang et al. 2013; Zhou and Glänzel 2010).

Collaboration relations between USA and China are hot topics and have been explored broadly. In studying China–USA collaboration in nanotechnology, Tang and her co-authors found that collaboration output of China–USA publications in this field have kept growing and structural changes are seen in sub-fields of nanotechonolgy (Tang and Shapira 2011). China–USA collaboration may not only improve China's research quality (Tang 2013), but also help generation of new research topics (Tang and Hu, 2013). Also focused on nanotechnology, Wang et al. (2012) investigated China–USA collaboration from another perspective—the ethnic background of American scientists, and found that most American scientists were Chinese–American. The authors attributed the phenomenon partly to China's talent policies for attracting overseas Chinese to work partly in China or to collaborate with Chinese domestic researchers. Compared with studies on China–USA collaboration, research on China's collaboration with the rest leading partners such as Japan, UK, and Germany are much fewer. In their study financed by UK government on China–UK collaboration in food and agriculture, Zhou and her coauthors found that the bilateral collaboration may raise China's publication impact. Collaboration with Japan, however, did not generate such effect (Zhou et al. 2013).

Studies on collaboration relations between China and Germany are also few, among which is the work of Zhou and Bornmann (2015). They found that collaboration effect of China–Germany is similar to that of China–USA: both sides get benefit in terms of raising publication productivity. As to improvement of citation impact, however, only China is the beneficiary. In view of the important role of Germany in China's international collaboration in science, we decided to investigate further by focusing on collaboration between the two countries in a specific field. Based on the annual statistic results of the Institute of

Scientific and Technological Information of China (ISTIC), physics is among China's four most productive fields in international collaboration. Thus, we choose physics as the first discipline for investigating China–Germany collaboration reflected by publications. Issues to be analyzed include publication productivity, collaboration effect, as well as active subfields and institutions.

Data and methods

Publications in 2008–2012 are downloaded from the *Science Citation Index Expanded* (*SCIE*) of Thomson Reuters. Only document types of article and review are included. Publications in physics are defined by journals based on the subject categories of the *Journal Citation Reports* (*JCR*) of Thomson Reuters. To ensure all journals in the *JCR* being included for selecting papers in physics, another journal subject category classification system produced by the National Science Library of Chinese Academy of Sciences (*NSLC*) is used. In the *NSLC* system, all the journals covered by the *JCR* are classified into 13 subject categories including physics. Nevertheless, it is possible that not all journals in the *JCR* in the same area are classified into the same subject category in the *NSLC*. To avoid this happen, we first screen all journals in all subfields relevant to physics and match them with journals in the physics category of the *NSLC*. Only journals supposed to be in the subject category of physics of both *JCR* and NSLC will be used as seed journals for retrieving papers in physics. By the retrieval date (December 20th, 2013), respectively 381 journals in the *JCR* and 337 journals in the *NSLC* categories belong to the field of physics. Finally, 231 are covered by the two subject categories and are used to define subject attribution of papers in physics (Fig. 1).

In mapping overall development of publications of China or Germany, all publications with China or Germany in the address field are included. When investigating collaboration effect between China and Germany, however, we compare the number of publications of China and Germany collaboration with national total of either country without publications of international collaboration.

Publication quality is defined by the journal ranks of the *NSLC* which classifies journals into four zones (i.e., quartiles) based on Impact Factor (IF) value in the *Journal Citation Reports* (*JCR*). The rank order from the highest to the lowest is quartiles 1, 2, 3 and 4 (i.e., Q1, Q2, Q3 and Q4) covering journals with IF values at top 5 %, top 6–20 %, top 21–50 % and the rest set in one of the 13 subject categories defined by the *NSLC*. Collaboration effect of China and Germany is investigated from different perspectives including publication productivity (i.e., number of publications), publication quality, citations per paper, as well as active institutions. Active institutions are defined by contribution to publications

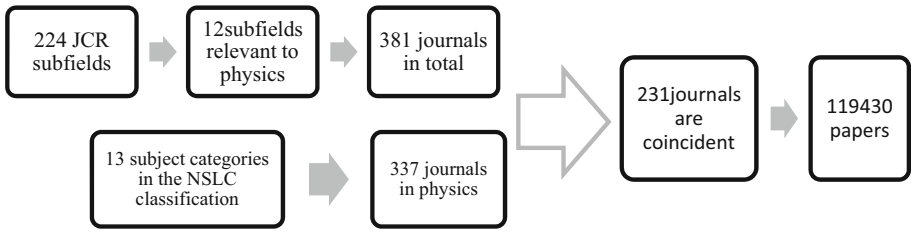

Fig. 1 Matching process of journals in physics

of China–Germany collaboration. Citations received by a publication are calculated in a 3-year window.

Results

Collaboration activities

Collaboration productivities

In physics, publication productivity of China is significantly higher than that of Germany. The gap becomes wider when publication productivity of China increased from 1.4 (in 2008) times to 1.6 times (in 2012) of that of Germany. Take productivity of the two countries in 2012 for example, China has 15,897 papers indexed in the *SCIE*, whereas that of Germany is 9830. In other words, the 6067 more papers of China are already around 62 % of German total. Furthermore, publication growth rate of Germany is also lower than that of China in the entire period under investigation (2008–2012), even though Germany has experienced a clear increase (by 355 papers) from 2010 to 2011 (Fig. 2).

With the growing productivity of China and Germany, co-authored publications between the two countries have increased exponentially. In the 5 years (i.e., 2008–2012), bilaterally co-authored publications have risen by nearly 1.3 times (Fig. 3a), and the ratio in the total of either country grew as well: respectively from 3.9 to 8.4 % in the German total, and from 2.7 to 5.2 % in the Chinese total (Fig. 3b). In terms of publication productivity, China–Germany collaborations contribute more to Germany and grow faster than to China. In the situation that publication productivity of Germany is significantly lower than that of China, it is understandable that China–Germany coauthored papers take a higher ratio in the total of Germany than in that of China.

Active collaboration subfields in physics or other disciplines involved

In the Web of Science, each paper is marked with subject categories that are assigned to the journal publishing the paper. A journal involving multiple disciplines may be assigned to more than one subject category, so is a paper in it. By aggregating words or expressions

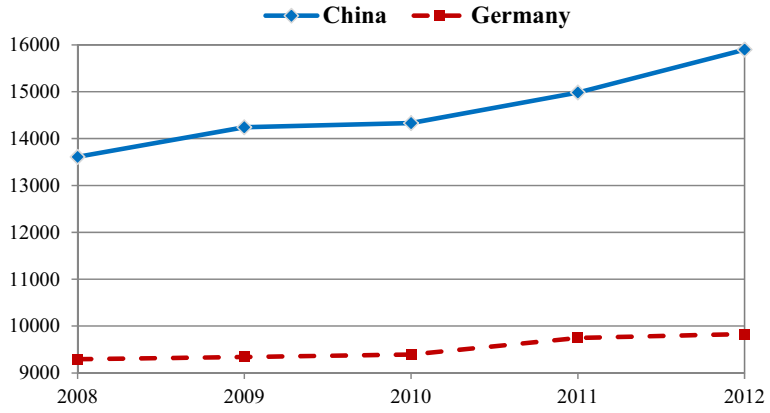

Fig. 2 Publications in 2008–2012

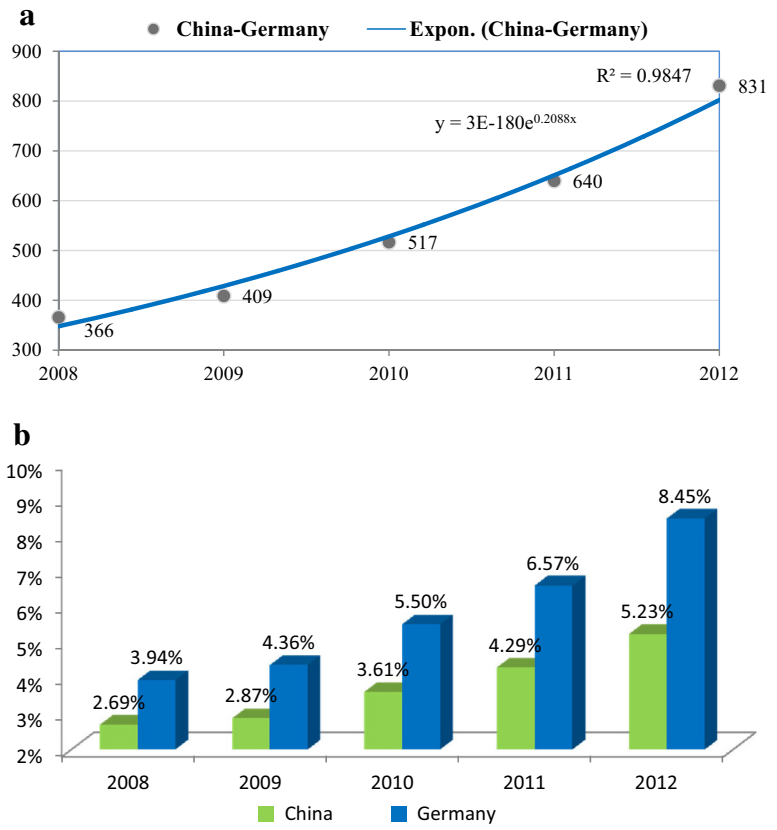

Fig. 3 **a** Publications in 2008–2012. **b** National share of China–Germany coauthored publications

defining subject category affiliation of a paper, we found that, of the 935 China–Germany co-authored papers, 809 (86.5 %) are in physics but may be in different subfields, and the rest 126 papers (13.5 %) involve other disciplines except physics (Fig. 4a, b).

Of the 809 papers in physics, most (20.6 %) are in applied physics, and next are papers in condensed matter. In other words, China–Germany collaborations reflected by publications are mainly in applied physics and condensed matter. Collaboration productivities in optics, atomic physics, molecular and chemical physics, particle and field-physics, fluid- and plasmas-physics, mathematical physics, as well as nuclear physics are similar and are significantly fewer than those in applied physics and condensed matter (Fig. 4a). Of the 126 papers involving multiple disciplines, collaboration activities of China and Germany are mainly in Astronomy and Astrophysics (24.6 %), Materials Science (20.6 %), Instruments and Instrumentation, Nuclear Science and Technology (18.3 %), as well as Mathematics (14.3 %). Collaborations in other disciplines are less active (Fig. 4b).

Active collaboration institutions

In total, 358 institutions from China (176) and Germany (182) coauthored the 935 publications in 2008–2012. Activeness of an institution in China–Germany collaboration

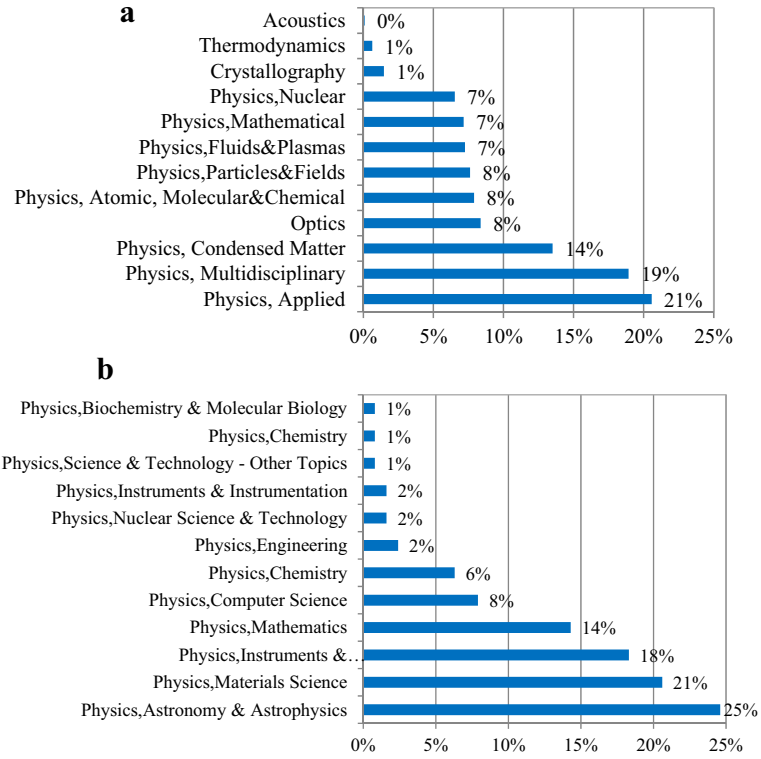

Fig. 4 Active fields of China–Germany collaboration (2008–2012). **a** Percentage of China–Germany publications in subfields of physics, **b** percentage of China–Germany publications in multiple disciplines

is defined by the number of collaborated publications. Table 1 lists the top-20 most active ones. Of the top-10 institutions six are from China and four are from Germany. Publication contributions of each German institution are significantly lower than that of Chinese. All the top-4 contributors are from China, and the Chinese Academy of Sciences (CAS) takes the absolute lead by coauthoring 302 papers with German counterparts. In other words, the CAS contributed over 1/3 of China–Germany coauthored publications. The leading German institution in China–Germany coauthored publications, however, is Ruhr University Bochum, which only coauthored 45 papers with Chinese counterparts (Table 1).

By applying the visualization tool NodeXL, collaboration relations between Chinese and German institutions are displayed in Fig. 5 based on coauthored publications. The Chinese Academy of Sciences (CAS) stands in the center with no doubt because of collaboration relations with all the top-20 institutions from both China and Germany. Major domestic partners of the CAS include the City University of Hong Kong (CUHK), Zhejiang University (ZJU), and Peking University. Collaboration relations of the later three are also broad, although less wide than that of the CAS. Foreign partners of Chinese institutions vary. For example, the CAS mainly collaborates with University of Giessen and Forschungszentrum Jülich GmbH, Zhejiang University collaborates mostly with Ruhr-Universität Bochum.

Table 1 Top 20 institutions contributing to coauthored publications between China and Germany (2008-2012)

Rank	Institutions	Country	P_{coll}	P_{coll} (%)
1	Chinese Acad Sci	China	302	32.30
2	Univ Sci Technol China	China	82	8.77
3	Peking Univ	China	76	8.13
4	Zhejiang Univ	China	71	7.59
5	Ruhr Univ	Germany	45	4.81
6	Capital Normal Univ	China	40	4.28
7	Tsinghua Univ	China	38	4.06
8	Univ Giessen	Germany	38	4.06
9	Max Planck Inst Math Sci	Germany	37	3.96
10	Goethe Univ Frankfurt	Germany	36	3.85
11	Forschungszentrum Julich	Germany	34	3.64
12	Tech Univ Dresden	Germany	31	3.32
13	Univ Heidelberg	Germany	30	3.21
14	City Univ Hong Kong	China	28	3.00
15	Shanghai Jiao Tong Univ	China	28	3.00
16	Univ Siegen	Germany	27	2.89
17	Ifw Dresden	Germany	26	2.78
18	Inst Appl Phys Computat Math	Germany	25	2.67
19	Lanzhou Univ	China	23	2.46
20	Tech Univ Munich	Germany	23	2.46

Collaboration effect

Journal quality and citation impact are applied to quantify collaboration effect by comparing China–Germany coauthored publications with the total of either country without internationally coauthored papers. Citation impact is defined by average citations per paper. A 3-year citation window is applied.

Publishing in higher-quality journals

According to the IF (impact factor) values in 2012 of journals in the Journal Citation Report of Thomson Reuters, the 337 source journals are assigned to the four NSLC ranks. Respectively 16, 44, 80 and 197 journals are in quartiles 1, 2, 3 and 4 taking 4.7, 13.1, 23.7, and 58.5 % of the total. The number of journals in the higher ranks (i.e., Q1 and Q2) especially in Q1 is small in contrast to that in the lower ranks (i.e., Q3 and Q4; Table 2). The low proportion of journals in relatively higher ranks implies fierce competition for researchers to publish in higher-quality journals. In later text, we call journals in Q1 and Q2 as higher-quality journals and those in Q3 and Q4 as lower-quality journals when necessary. Papers published on higher-quality journals are considered as of higher quality, although this is not completely true because not all papers in a higher-quality journal are of higher quality than those in a lower-quality journal. We further assume that a country (or institution or individual) with more higher-quality papers has higher research competence.

In publishing in higher-quality journals in 2008–2012, Germany performs much better than China with nearly half (48.3 %) of its total in higher-quality journals, whereas that of China is only 17.6 %. Of the 16,317 German papers, 9.4 % are published in top-journals,

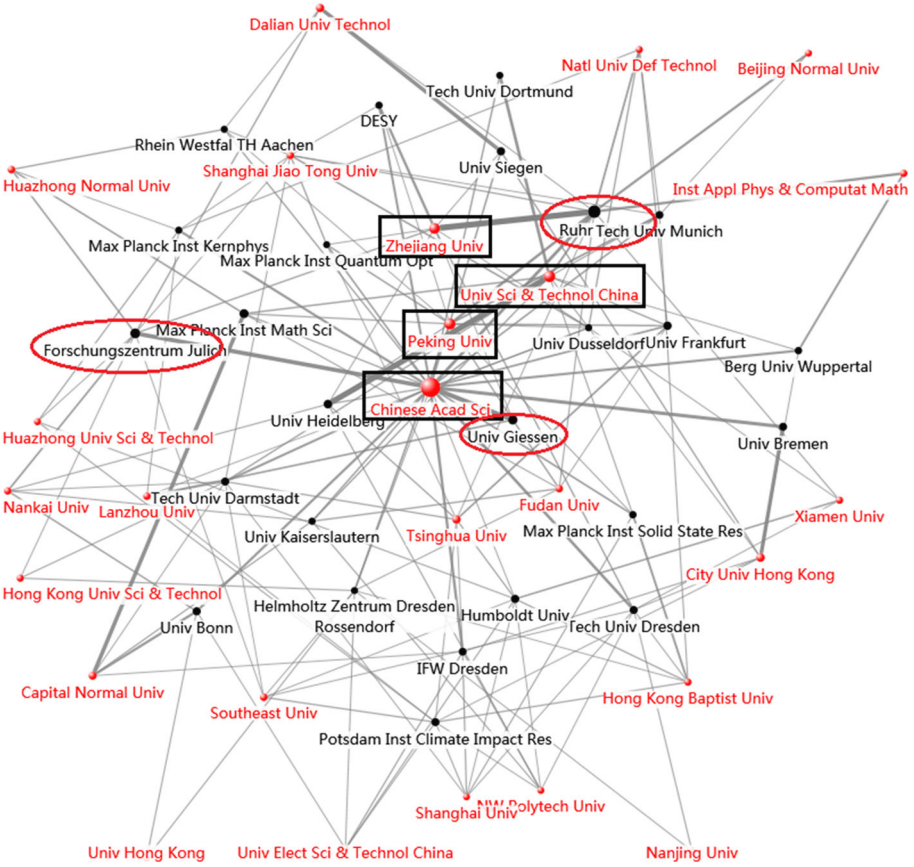

Fig. 5 Leading institutions in China–Germany collaboration (2008–2012). *Note* Institutions with *dotted line circles* are from China, and those with *solid line circles* are from Germany

Table 2 Journal distribution in the four quartiles of NSLC in 2012

Q	Impact factor	Journals	Percentage
1	≥5.966	16	4.7
2	5.966 < ≥2.535	44	13.1
3	2.535 < ≥1.433	80	23.7
4	<1.433	197	58.5

whereas that of China is only 1.3 %. Most of Chinese papers are published in lower-quality journals, and to make it worse, half (50.1 %) are in journals at the lowest rank (Q4). Germany, however, only published 19.8 % papers in journals at the lowest rank. In publishing in third-rank journals, the two countries are at the same level with similar percentages of publications (Table 3). The distribution of journal quality of China is different from that of Germany. The number of Chinese papers increases with the decrease of journal quality. In the German situation, however, most papers (80.3 %) are published in journals ranked in the middle or above (i.e., Q1, Q2 and Q3).

Collaboration between China and Germany generates leveling effect. Of the papers collaborated between the two countries, the percentage of higher-quality papers (in Q1 and Q2) is higher than that of China and lower than that of Germany. In the meantime, percentage of China–Germany co-authored papers at the lowest rank (Q4) is fewer than that of China and more than that of Germany. Little change happens in publishing in journals at the middle rank (Q3). In other words, China–Germany collaboration may raise productivity of both sides. As to publication quality, however, that of China can be raised but not so for Germany.

From 2008 to 2012, capabilities of publishing in higher-quality journals of both China and Germany have been increased. Nevertheless, Germany advances faster although with a higher percentage of papers in higher-quality journals already. For example, in publishing in journals in Q1 zone, China only increased by 0.14 % whereas that of Germany is 1.00 %. Growth rate of Germany (2.44 %) is even higher than China (0.22 %) in publishing in Q2 journals. The low growth rate of China in publishing in higher-quality journals implies how difficult for China to advance in publishing in higher-quality journals. The rapid growth of Chinese total publications in physics mainly relies on publishing lower-quality papers: The 9.49 % decrease of Chinese papers in Q3 journals and the 9.14 % increase of papers in Q4 journals is a strong proof (Table 4).

Everyone knows that to publish in a higher-quality journal is more difficult than in a lower-quality journal. As stated in its editorial page, *Nature Physics* is *to publish top-tier original research in physics through a fair and rigorous review process*. Only output of

Table 3 Publication distribution in the four NSLC ranks of journals (2008-2012)

Q	Germany		China		China–Germany	
	P	*P* (%)	*P*	*P* (%)	*P*	*P* (%)
1	1532	9.4	758	1.3	50	5.3
2	6357	39.0	9164	16.2	338	36.1
3	5195	31.8	18,252	32.3	296	31.7
4	3233	19.8	28,339	50.1	251	26.8
Total	16,317	100	56,513	100	935	100

Table 4 Percentage of publications in the four NSLC journal ranks (2008–2012)

Q	Country	2008 (%)	2012 (%)	Growth rate (%)
1	China	1.36	1.50	0.14
	Germany	9.00	10.00	1.00
	Collaboration	4.82	5.16	0.34
2	China	33.65	24.16	−9.49
	Germany	31.19	27.63	−3.56
	Collaboration	31.93	24.52	−7.41
3	China	16.42	16.64	0.22
	Germany	41.13	43.57	2.44
	Collaboration	35.54	43.23	7.69
4	China	48.56	57.70	9.14
	Germany	18.68	18.80	0.12
	Collaboration	27.71	27.10	−0.61

top-tiered research can be considered for publishing. With an impact factor (IF) value of 20.603, *Nature Physics* ranks the 3rd among journals in physics in *JCR* 2013. With more publications in higher-quality journals, a research unit (e.g., individual, institution or country) is considered as having higher research capacity.

To compare collaboration effect between China and Germany in publishing in specific journals in physics, we list five journals publishing most of papers of China, Germany, and China–Germany collaboration (Table 5). The IF values of the five journals publishing most of Chinese papers range from 0.92 of *Chinese Physics Letters* to 3.66 of *Physical Review B*. The first two journals publishing most of Chinese papers are from China. In fact, very few foreign researchers publish in the two Chinese journals. Take issue 4 of volume 24 in 2015 of *Chinese Physics B* for example, only nine out of the total (90) papers (i.e., 10 %) are from non-Chinese researchers. In other words, over 12 % of Chinese researchers communicate mainly with domestic counterparts. All the five journals publishing most of German papers in physics are from the USA, and with IF values ranging from 2.99 of *Physical Review A* to 7.73 of *Physical Review Letters*. The German researchers are completely internationalized in scholarly communication and are more capable of publishing higher-quality papers. Collaboration effect has been further proved in terms of improvement of China's capacity in publishing in higher-quality journals. The IF values of the five journals publishing most of papers of China–Germany collaboration range from 2.19 of *Journal of Applied Physics* to 4.86 of *Physical Review D*, are higher than those of publishing Chinese papers. Scholarly communication of China–Germany coauthored publications is also better internationalized than are Chinese ones.

Citation impact

In the 3 years from 2008 to 2010, citations per paper of Chinese papers are significantly lower than those of Germany. Similar to the situation of publishing in higher-quality

Table 5 Top-5 journals publishing most papers in 2008–2012

Country	Journal	*P*	*P* (%)	IF (2-years)[a]
China	Chinese Physics B (China)	4808	6.59	1.39
	Chinese Physics Letters (China)	4515	6.18	0.92
	Applied Physics Letters (USA)	4295	5.88	3.52
	Journal of Applied Physics (USA)	3954	5.42	2.19
	Physical Review B (USA)	2268	3.11	3.66
Germany	Physical Review B (USA)	6021	12.65	3.66
	Physical Review Letters (USA)	4233	8.89	7.73
	Physical Review D (USA)	2401	5.04	4.86
	Applied Physics Letters (USA)	2398	5.04	3.52
	Physical Review A (USA)	1994	4.19	2.99
China–Germany	Physical Review B (USA)	83	8.88	3.66
	Applied Physics Letters (USA)	74	7.91	3.52
	Journal of Applied Physics (USA)	68	7.27	2.19
	Physical Review A (USA)	61	6.52	2.99
	Physical Review D (USA)	45	4.81	4.86

[a] The IF value is from the 2013 version of the journal citation reports of Thomson Reuters

journals, collaborating with Germany may raise citations per paper of China. In 2009, citations per paper of China–Germany collaboration are even equal to that of Germany. To Germany, however, collaborating with China may result in decreased citations per paper, although not always so (Fig. 6).

Conclusions and discussion

In the *SCIE* of Thomson Reuters, publications in physics of China are significantly more than those of German, and the gap between the two is widening with the faster growth of Chinese publications. With a large population of researchers and PhD candidates, China still has great potential in raising publication productivity. In terms of production of higher-quality papers, however, Germany performed much better. On the contrary, over half of Chinese papers are still in journals of the lowest rank (Q4). The rapid growth of Chinese publications in physics relies heavily on lower-quality papers. On the contrary, Germany progresses faster in publishing in higher-quality journals, although advances slowly in publication productivity. To China, raising publication quantity is relatively easier than raising publication quality.

The growing number of co-authored publications of China and Germany implies a strengthened collaboration relationship between the two countries. With the faster growth of Chinese total publications, China–Germany collaboration contributes more to Germany and increases faster in terms of share of national total. Both sides get benefit from bilateral collaboration. For China, collaborating with Germany may raise both publication productivity and publication quality (i.e., citation impact), and Chinese researchers' scholarly communication scope can also be widened. For Germany, Chinese researchers may compensate its shortage of researchers and, perhaps, even research infrastructure, and thus raising publication productivity.

Of the factors responsible for the inconsistent growth of Chinese total versus higher-quality publications, three can be significant. Firstly, the performance evaluation policies of most Chinese academic institutions are still at the stage of counting number of publications indexed in the Web of Science with less emphasis on journal quality. To Chinese researchers, publishing as many *SCI/SSCI* papers as possible is more important than publishing fewer but higher quality papers. Secondly, many Chinese universities lack research infrastructure including access to publications of international counterparts, although leading Chinese universities including those listed in Table 1 do not suffer. Such

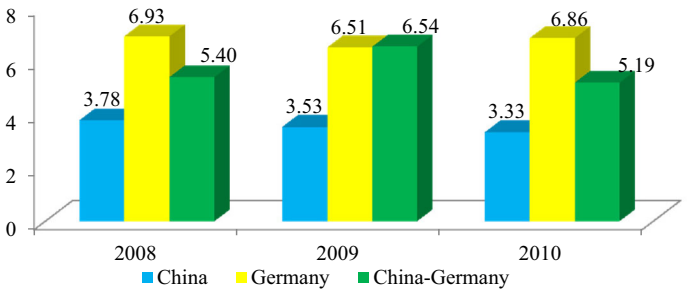

Fig. 6 Citations per paper

insufficiency or skewed distribution of research resources may result in Chinese researchers in disadvantageous institutions unable to touch advanced ideas, new theories and tools. Thirdly, as a major language in international community, English language may also affect Chinese researchers' communication skill and thus the chances of publishing in higher-quality journals (Zhou and Leydesdorff 2006).

Active Chinese institutions in China–Germany collaboration in terms of productivity of joint publications in physics are those in leading positions in China. The first two most active institutions in China–Germany collaboration, the Chinese Academy of Sciences and University of Science and Technology of China, have large size and high-rank research teams. For example, the Institute of Physics of Chinese Academy of Sciences has 269 researchers, among which 15 are academicians of sciences or engineering sciences. The School of Physical Sciences of the University of Science and Technology of China has 239 faculties, among which 11 are academicians of sciences or engineering sciences. In China, the title of academician is the top honor for a scholar and only a few with outstanding research performance can receive such an honor. The number of academicians is usually used as an indicator of an institution's research capacity. The research teams of Peking University, Zhejiang University and Tsinghua University are much smaller than those of the Institute of Physical Sciences of Chinese Academy of Sciences and the School of Physical Sciences of the University of Science and Technology of China, and so is the number of their joint publications co-authored with German researchers.

The significantly lower publications of each German institution most active in collaboration with Chinese counterparts match with the fact that the number of German institutions is more than that of China in China–Germany coauthored publications. In other words, China–Germany collaboration is more scattered among German than among Chinese institutions. Chinese institutions in collaboration with German counterparts are usually in leading positions in physics in China, but take only a small ratio of Chinese institutions. A considerable large number of Chinese academic institutions are still isolated from the international community. The scattered distribution among German institutions in collaboration with China implies research capacity among German Institutions is more evenly distributed than in China. Most German institutions are capable of collaborating with international counterparts.

Many reasons may bring researchers together for the research interests, for instance, compensating shortages of each other. The shortages can be research capacity, innovative ideas, infrastructure, human resources, fund, and so on. Shortages for Chinese researchers can be research capacity and infrastructure, and for German researchers, however, can most probably be young researchers. The shortage of China can be the advantage of Germany, vice versa. The large number of Chinese students pursuing PhD degrees abroad helps solve the shortage problem of young researchers in advanced countries including Germany. The collaboration results of China and Germany in the current study do reflect the compensation effect: Chinese researchers contribute to the growth of German publications although quality of such coauthored publications is not as high as those of German researchers; German researchers may help improve both quantity and quality of publications of China. In general, both China and Germany get benefits from collaboration, which has been proved by the growing number of co-authored publications.

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