

Who sets up the bridge? Tracking scientific collaborations between China and the European Union

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Who sets up the bridge? Tracking scientific collaborations between China and the European Union

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Abstract

In the past decade, collaborations between China and the European Union (EU) have been rapidly expanding. Hitherto, however, little research has been carried out to assess the implementation and impacts of such collaborations. This article presents an in-depth analysis of the scientific collaborations between China and the EU28, focusing on the major research priorities and benefits of these collaborations. To shed light on the initiatives of collaborations, corresponding authors are detected and classified into three categories: Chinese local, Chinese abroad, and non-Chinese. Evidence shows that academic collaborations between China and the EU28 have been mainly set up by Chinese researchers. In the fast-growing China–EU collaborative fields, the revealed comparative advantage scores in China have improved substantially. In the EU28, however, there is no such obvious improvement.

Key words: scientific collaborations; China; the EU28; comparative advantage; corresponding authors.

1. Introduction

Along with its fast growth, China has acknowledged the importance of international collaboration for the fulfilment of research and innovation objectives. A number of bilateral and multilateral cooperation agreements and programmes with different countries have been established to stimulate knowledge transfer across national borders (Andreosso-O'Callaghan and Qian 1999; Suttmeier 2014). This has served to strengthen formal collaborations and to enhance the scope for deepened institutional cooperation. The 12th Five Year Plan for Science and Technology Development stated that the internationalization of scientific research activities will be further enhanced and that China will actively participate in international science and technology organizations and large international science programmes. While building its local innovation capacity, China has been actively attracting and profiting from global knowledge and networks (Bound et al. 2013).

Towards building a collaborative relationship with Europe, by 2015, China has provided 20,000 scholarships to support Chinese students and scholars to study in European countries, and 10,000 to support European Union (EU) students and scholars to study in China. Meanwhile, 2,000 Chinese students benefitted from Erasmus

Mundus scholarships in 2012.¹ In Europe, the strategic document 'A Long-Term Policy for China-Europe Relations', issued in 1995, demonstrated Europe's intention to cooperate with China (European Commission 1995).

As a result of cooperation support from both sides, China and Europe have kept a good track record of collaboration on research and innovation. In the 7th Framework Programme, Chinese researchers were the third most allocated to recipients of funding amongst non-European researchers (European Commission, 2016). An increasing number of Chinese scholars participated in the EU framework programme after the EU–China Science and Technology agreement of 1998. A number of initiatives between the EU and China also took place outside of the Framework Programmes. Consequently, the number of collaborative publications between China and the EU28 in 2014 was more than seven times as high as that in 2000, from 2,535 to 19,241.

Apart from the general number of collaborative publications between China and the EU28, however, little is known about the collaboration patterns and strengths and weaknesses of both parties. As pointed out by Wang (2016), China's development in science is characterized by its divergent capacity across disciplines.

Cooperation in the fields where China has the strongest comparative advantage is undoubtedly beneficial to its EU partners. Likewise, China is also attempting to set up collaborations in fields where Chinese researchers can learn and benefit most from its western partners.

International collaboration in science is a self-organizing system, which reflects the interests of academic individual researchers. Nevertheless, the feedback received from the aggregated individual collaborations can influence the organization of science at macro level, i.e. national or regional level (Wagner and Leydesdorff 2005). To foster more profitable collaboration for both parties and to formulate options for international policy on research and innovation cooperation between the EU and China, this article presents an in-depth analysis of the scientific collaboration between China and the EU28, focusing on the major research priorities and benefits of the collaborations.

2. Data collection and methodology

The data set was collected from Thomson Scientific's Science Citation Index Expanded and Social Sciences Citation Index. Given that the matching information of authors' names and institutes' names was provided by Thomson Web of Science only after 2006, we focus on the joint articles between China and the EU published between 2008 and 2014. Using our query, we obtained 89,569 papers jointly published between China and the EU28 in the studied 7 years. Data from the year 2008, 2010, 2012, and 2014 (51,722 papers in total) were downloaded and imported into SQL Server to process detailed information of corresponding authors.

It has been well acknowledged that in a publication with multiple authors, the first author is usually the one who contributes most to the research work. Corresponding authors, however, are those responsible for both scientific and non-scientific assembly (Pichini, Pulido and García-Algar 2005). The corresponding author is often the one who is responsible for coordinating the completion and submission of the work, responding to comments about the publication, and communicating with co-authors (Strange 2008; Osborne and Holland 2009; Smith and Williams-Jones 2012). Namely, besides the normal authorship intellectual contribution, a corresponding author guides the 'the entire research process in the role of guarantor for the integrity of the entire study' and defends 'the paper as a whole in scientific and non-scientific assembly' (Pichini, Pulido and García-Algar 2005: 174). As the number of co-authors and collaborating countries increases (Gazni, Sugimoto and Didegah 2012; Uddin et al. 2012), the coordination responsibility of the corresponding author becomes even more important. In a fund-supported publication, the corresponding author is often affiliated with the institute of the funding resource (Smith and Williams-Jones 2012). The author who obtained funding for the research, known as the principal investigator of the team, is responsible for 'beginning the discussion' and for creating an ideal communication environment for all the co-authors (Osborne and Holland 2009). In sum, the leader of the research team often plays the role of corresponding author (Hu 2009). Therefore, corresponding authorship is used in our study to track the ones who took the initiatives in the project and who set up the collaborations. To this end, we, in particular, extracted all the information (including names, institutes, and countries) for the corresponding authors.

In processing the data, we first distinguish Chinese researchers from non-Chinese ones. Due to the uniqueness of Chinese names, as explained by Wang et al. (2013), Chinese researchers can be well identified by their names typed in the standard Pinyin system. Even for the Chinese diaspora overseas, though some have added English first names in a few cases, their Chinese surnames have usually been kept unchanged. This makes it possible to track the Chinese researchers from the publication author list. Furthermore, by combining the author names with their institution names and locations, we classify Chinese researchers into two categories, namely, located in China and located in the EU. Hence, corresponding authors in this study are classified into three categories: Chinese local, Chinese abroad, and non-Chinese. To avoid confusion, we exclude the set of papers published by researchers who have both Chinese and European affiliations, which consists of 5,376 records and accounts for about 10% of the total 51,722 papers.

In evaluating collaboration performance, collaboration diversity is of great importance. This study applies the Herfindahl index (also known as Herfindahl-Hirschman Index) to measure the diversity level of academic collaborations between China and the EU. The concentration degree of collaborative fields is defined as follows:

$$H_i = \sum_{i=1}^{149} S_i^2 \tag{1}$$

Where H_i is the Herfindahl index (for a certain region or country), and S_i is the share of collaborated output in field i . A higher Herfindahl value indicates that collaborations are highly concentrated in certain fields, while a lower Herfindahl value shows that collaborations are widely distributed across different fields.

Considering the heterogeneity of nations (e.g. country size and capacity), evaluation of the strength (or weakness) of one particular country in one particular fields needs to be linked up with national capacity as well as worldwide academic performance. To examine the comparative advantages of China and the EU in certain academic fields, we rely on the concept of revealed comparative advantage (RCA), which was proposed by Balassa (1965 and 1977). Correspondingly, the RCAs for China and the EU can be calculated as follows:

$$RCA_{iCN} = \frac{\frac{PUB_{iCN}}{\sum_{i=1}^{149} PUB_{iCN}}}{\frac{PUB_{iw}}{\sum_{i=1}^{149} PUB_{iw}}} \quad i = 1 - 149 \tag{2}$$

and

$$RCA_{iEU} = \frac{\frac{PUB_{iEU}}{\sum_{i=1}^{149} PUB_{iEU}}}{\frac{PUB_{iw}}{\sum_{i=1}^{149} PUB_{iw}}} \quad i = 1 - 149 \tag{3}$$

Where RCA_{iCN} and RCA_{iEU} are the comparative advantage values for academic discipline i in China and the EU28. PUB_{iCN} and PUB_{iEU} are the publication numbers of field i in China and the EU28. PUB_{iw} is the publication number of this field in the rest of the world.² If the value of RCA (for a particular field) is higher than 1, this means that this region (either China or the EU) has a comparative advantage in terms of publication quantity in this particular academic area. Otherwise it signals a comparative disadvantage in this field.

To explore the most dynamic major collaboration fields, we first look at the top 30 most collaborative fields between China and the

EU28. This consists of 74,030 papers during the period 2008–14, accounting for 82.4% of the total joint publications. Among these 30 major collaborative fields, we further spot nine fast-growing fields (with growth rates higher than 20%). These fast-growing major collaborative fields are *Energy fuels*, *Telecommunications*, *Science and Technology and other topics*, *Instruments and Instrumentation*, *Environmental Sciences and Ecology*, *Oncology*, *Business economics*, *Engineering*, and *Computer science*.

3. Results

3.1 Collaboration concentration

With efforts from both sides, the jointly published academic research between China and the EU28 has increased substantially, not only in the total number but also in a wider scope. As shown in Fig. 1, the Herfindal index of collaborated publications between China and the EU28 has dropped steadily over the years, which means that collaborations between China and the EU28 are becoming more and more widely distributed across different fields.

In Europe, the collaborated output came mainly from three countries (UK, Germany, and France), which together account for more than half of the total collaborated papers (with China). Six countries (UK, Germany, France, Italy, the Netherlands, and Sweden) accounted for 72% of the total joint output between the EU28 and China. With those countries, the collaboration has reached a wide range of research fields with a relatively low Herfindahl value (Fig. 2). However, the collaborations between China and the majority of small European countries were relatively concentrated in certain fields.

3.2 Composition of corresponding authors

By looking at the names of authors and institutes, we distinguish three types of corresponding authors, i.e. Chinese researchers in China, Chinese researchers in the EU, and European researchers.

Chinese researchers affiliated with Chinese institutes form the major part of the corresponding authors in the jointly published academic research, accounting for more than 50% (Fig. 3). This proportion increased steadily after 2010 and reached about 59% in 2014. European researchers accounted for about 20% of the total corresponding authors. This share presented a decreasing trend in

the later years, from 22% in 2010 to 19% in 2014. Chinese researchers affiliated with European institutes comprised a percentage of around 8%. Compared to the percentage of non-Chinese researchers, the corresponding-author proportion of Chinese researchers in the EU was considerable. The fact that a substantial portion of the corresponding authors were Chinese researchers, either working in China or in the EU, demonstrates that Chinese researchers have been playing an important role in China–EU collaboration. This finding is in line with the results of Wang et al (2012, 2013), who find that Chinese immigrant scientists play an important role in China's international scientific collaborations. Focusing on the case of China–EU collaboration in science, our study shows that the academic cooperation bridge between China and Europe has been mainly set up by Chinese researchers.

3.3 Fast-growing fields and their RCAs

Despite the decreasing concentration in joint publication fields—which was reflected in the aforementioned Herfindahl index—some fields have appeared to be the preferential fields for EU–China joint research.

In the process of international scientific collaborations, great heterogeneity is often observed across scientific disciplines. *Chemistry*, *Physics*, and *Engineering* are the disciplines presenting the highest numbers of publications in both China and the EU. During the period 2008–14, these three fields accounted for 20.2, 13.4, and 12.8% of the national publications in China, respectively, and 8.5, 7.7, and 7.0% in the EU. However, these three disciplines vary greatly regarding China–EU collaborations. *Engineering* presents a high collaboration growth rate (i.e. 20.9% per year), as one of the fast-growing fields—among the 30 major collaboration fields—listed in our study, while collaborations in *Physics* grew slowly (i.e. at a rate 13% per year). Collaborations in *Chemistry* grew mildly in the middle, at a rate of 16.8% per year.

Among the top 30 most collaborative fields, nine presented a growth rate of over 20% per year in terms of the EU–China collaborated publications. Table 1 documents growth rates of these fields at four levels, i.e. worldwide, China, the EU, and China–EU collaboration. The growth rates of these fields worldwide are roughly in line with those in the EU28. However, these fields have been growing at a much higher speed in China. Interestingly, the publication output of collaborations between China and the EU28 increased even faster

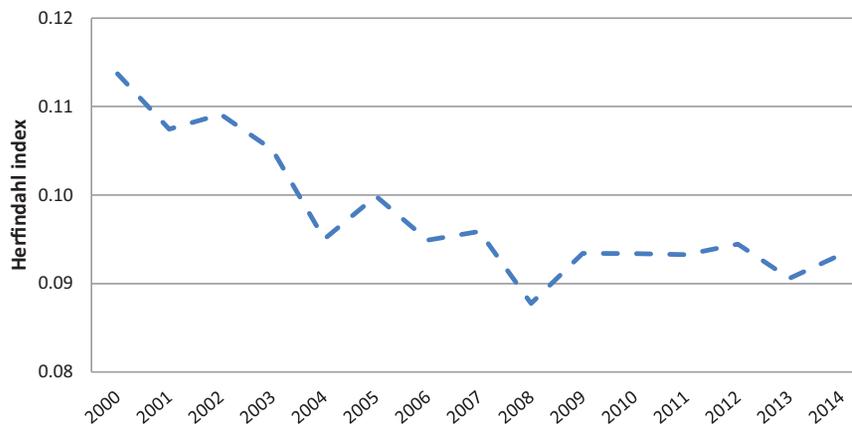


Figure 1. Herfindahl index of joint research collaborations between the EU28 and China.

Source: Thomson Reuters Web of Science.

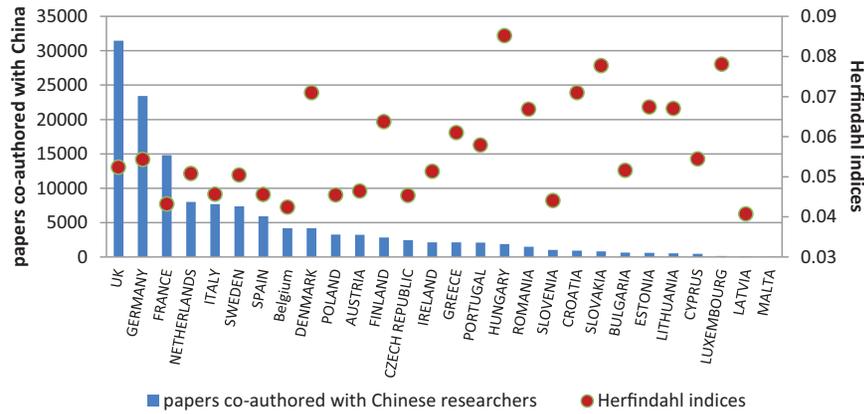


Figure 2. China–EU collaborations: number of joint publications and Herfindahl indices by country.

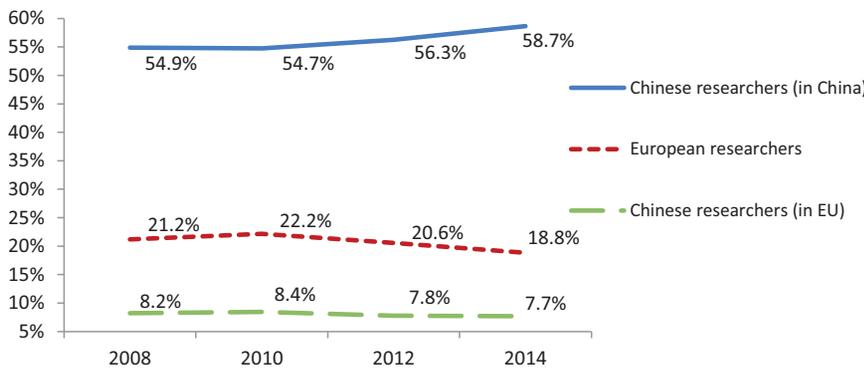


Figure 3. The share of corresponding authors.

than that in China (26.49% per year vs. 24.04% per year). Among the nine fast-growing fields, except *Oncology*, all other eight fields have presented a higher growth rate in the collaborative research between China and the EU28 than that of China (column (Col.) 4 vs. Col. 2 in Table 1). For comparison purposes, Table 1 also includes nine fields which have the slowest growth rates in the top 30 most collaborative fields. This will be further explained in Section 3.4.

If one looks at the absolute number of joint publications between European countries and China, the top rankings no doubt go to the large countries, such as the UK, Germany, and France. To exclude the country-size effect, we use the following normalized ratio (NR_k^i) to calculate the relative position of joint publications in country k and field i .

$$NR_k^i = \frac{JointPub_{k-CN}^i / JointPub_{EU-CN}^i}{JointPub_{k-CN} / JointPub_{EU-CN}} \quad (4)$$

Where $JointPub_{k-CN}^i$ represents the joint publications between country k and China in field i ; $JointPub_{EU-CN}^i$ is the total joint publications between all EU countries and China in field i ; $JointPub_{k-CN}$ indicates the joint publications between country k and China in all fields; and $JointPub_{EU-CN}$ is the total joint publications between all EU countries and China in all fields. Hence, the ‘promising’ collaborative partners, measured by the NR, are not necessarily always the most scientifically powerful countries. Table A1 lists the top European countries which exhibited collaboration preferences with China in the selected nine fields in the period of 2008 and 2014.

Figure 4 shows the correlation between the emerging collaborations (i.e. emerging joint publications in certain fields between European countries with China) and the comparative advantage values of the certain field in European countries (i.e. RCA_{EU}). Most observations (242 of 252) are located in the area where the RCA value is less than 2, where there is a positive correlation. The positive correlation indicates that more intensive collaboration is likely to happen in the field where the comparative advantage of this certain field in a particular European country is higher. The values of RCA and NR for the top European countries which collaborated most with China in the selected nine fields are presented in Table A1.

By analysing the specialization of collaborations between South Africa and Germany, Schubert and Sooryamoorthy (2010) find that scientists from South Africa—as an example of a peripheral region—actively look for strong and reputable partners in the disciplines where local specialization is low. For the case of China, our results indicate that the joint publications with European countries were more likely from the fields where the comparative advantage (in this particular European country) is relatively high.

3.4 Dynamic RCAs

From a dynamic perspective, this section explores the changes of RCA scores in both China and European countries. Among the top 30 most collaborative fields, a group of fast-growing fields and a group of fields with the slowest growth rates³ are reported in Table 1. In the fast-growing collaborative fields, except *Science and*

Table 1. Fast-growing collaborative fields between China and EU28

Fields—ranked by growth rate	Growth rate				Comparison* RCA_EU (Col. 5) (%)	RCA_EU		RCA_China		Changes (2014 to 2008)	
	Worldwide (Col. 1) (%)	China (Col. 2) (%)	EU28 (Col. 3) (%)	China and EU (Col. 4) (%)		2008 (Col. 6)	2014 (Col. 7)	2008 (Col. 8)	2010 (Col. 9)	EU (Col. 10)	China (Col. 11)
Fields with high growth rates											
Energy fuels	13.57	28.91	16.22	41.80	28.23	0.72	0.84	1.70	1.92	0.12	0.27
Telecommunications	6.34	26.43	8.47	34.30	27.96	0.72	0.83	1.27	1.68	0.11	0.68
Science and technology and other topics	16.21	28.55	16.96	29.60	13.39	0.82	0.89	1.57	1.42	0.06	-0.02
Instruments and Instrumentation	5.28	23.52	3.79	25.10	19.82	1.08	1.02	1.14	1.36	-0.07	0.46
Environmental Sciences and Ecology	5.73	18.83	6.14	22.50	16.77	1.10	1.16	0.95	1.09	0.06	0.08
Oncology	7.23	33.80	2.91	21.80	14.57	1.20	0.95	0.50	0.65	-0.24	0.52
Business economics	3.19	18.23	6.18	21.50	18.31	1.10	1.33	0.38	0.41	0.24	0.09
Engineering	4.86	18.99	4.57	20.90	16.04	0.85	0.86	1.42	1.54	0.02	0.22
Computer science	6.17	19.14	5.70	20.90	14.73	1.08	1.08	1.41	1.58	0.00	0.11
Average	7.62	24.04	7.88	26.49	18.87	0.96	1.00	1.15	1.29	0.03	0.27
Fields with low growth rates											
Astronomy and Astrophysics	-9.34	79.15	2.56	12.02	21.36	1.51	1.57	0.88	0.75	0.06	-0.12
Genetics and Heredity	-8.02	60.75	-0.19	11.96	19.98	1.23	1.10	0.72	1.09	-0.13	0.37
Biotechnology and Applied Microbiology	-2.37	49.33	5.51	10.78	13.15	0.93	0.99	1.61	1.26	0.06	-0.35
Polymer science	8.26	35.06	4.32	10.43	2.18	0.77	0.81	2.91	2.08	0.04	-0.83
Mathematics	2.96	46.53	2.22	10.23	7.27	1.17	1.09	1.95	1.75	-0.07	-0.19
Metallurgy and Metallurgical engineering	14.62	27.26	-0.53	9.72	-4.90	0.69	0.67	3.86	2.69	-0.02	-1.18
Plant sciences	-2.18	51.98	3.03	8.66	10.84	0.97	0.98	1.41	1.22	0.01	-0.19
Biochemistry and Molecular Biology	-4.37	57.21	0.39	8.39	12.76	0.99	1.00	1.01	1.11	0.01	0.10
Agriculture	-5.27	56.82	-0.13	7.75	13.03	0.93	0.92	0.80	1.02	-0.02	0.22
Average	-0.64	51.56	1.91	9.99	10.63	1.02	1.02	1.68	1.44	-0.01	-0.24

Note. *The comparison column (Col. 5) is calculated by deducting the growth rate of the specific field worldwide (Col. 1) from the growth rate of collaborated output between China and EU28 (Col. 4).

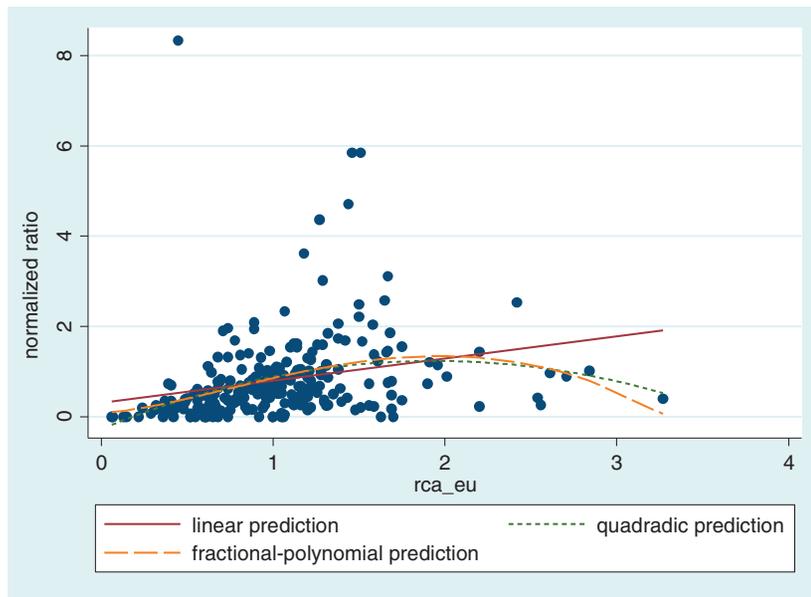


Figure 4. Relationship between normalized collaboration ratio (NR) and comparative advantage (RCA).

Note: There are in total 252 observations, from the nine fast-growing major collaborative fields.

Technology and other topics, all others have improved their RCA scores along with the increase of EU–China collaboration. In the second fast-growing field, *Telecommunications*, its RCA value increased by 0.68 (from 1.27 in 2008 to 1.95 in 2014). Similarly, high level of RCA improvement also took place in *Instruments and Instrumentations*, of which the RCA value increased by 0.46 (from 1.14 in 2008 to 1.60 in 2014). In the field of *Oncology*, its RCA level value has doubled (from only 0.50 in 2008 to 1.02 in 2014). In the EU, however, there was lack of such substantial improvement with regard to the values of RCAs in these fast-growing collaborative fields.

On average, the RCAs in the fast-growing fields have increased remarkably in China, by 0.27 from 2008 to 2014. In contrast, in the major collaborative fields with slowest growth rates, the RCAs in China have decreased tremendously, on average by -0.24 (see Col. 11 in Table 1). The changes for the European partners are marginal (see Col. 10 in Table 1).

The fact that in the fast-growing collaborative fields, China's RCA scores have increased relative to the EU28 indicates that China has benefited more from scientific collaboration with the EU. This links up with the fact, as shown earlier, that Chinese researchers are the dominant corresponding authors. Following the theory that corresponding authors are from the funding side and set up the collaboration bridge, it is interesting to observe that such bridges are created for joint work where China can benefit from gaining its RCAs. The European side, presumably due to not leading the joint projects, could not advance their RCAs in the fast-growing collaboration fields.

4. Discussions and conclusions

Aiming at 'revitalizing the nation through science and education strategy' (OECD 2008), China has been extending its collaborations with European countries. By extracting corresponding authors and distinguishing Chinese and non-Chinese researchers, this study provides insights into the mechanisms of joint publications between China and the EU28. First, our results show that the collaboration diversity is increasing, with more and more academic fields involved.

Secondly, evidence shows that academic collaborations between China and the EU28 have been mainly set up by Chinese researchers. This phenomenon can be potentially explained by the Chinese returning researchers. With a case study of plant molecular life scientists, Jonkers and Tijssen (2008) find that collaboration linkages can be set by Chinese overseas scientists returning home. In the present study, our data do not contain information on researchers' mobility. Hence it is hard to tell whether those Chinese corresponding authors have studied or worked in the EU. Nevertheless, our results confirm that the collaboration bridge between China and the EU has been mainly set up by Chinese researchers, and in particular by those who are affiliated with Chinese institute.

The third contribution of this study is, from a dynamic perspective, to evaluate the changes of the comparative advantages in the collaborative fields. In the fast-growing China–EU collaborative fields, the RCA scores in China have improved substantially. In the EU28, however, there is no such obvious improvement. This finding can be explained in two alternative ways. On the one hand, these could be the scientific fields which are strongly funded by the Chinese government, which in turn could lead to more international collaborations. On the other hand, the collaborations with the EU28

in these fields may have helped China to strengthen these particular research fields, improving their RCA scores. In either case, we see initial actions (or benefit) from the Chinese side, not the European side. International collaboration in science is a self-organizing process, where individual interest of researchers plays the most important role in carrying out collaborations (Wagner and Leydesdorff 2005). Macro-level policies (at national, regional, or institutional level), however, can facilitate mobility of researchers and provide opportunities for setting up new collaboration networks between countries (Wagner and Leydesdorff 2005; Ovalle-Perandones et al. 2013; Barth, Hausteine and Scheidt 2014). With more and more scholarships and funding programmes available, to best profit from scientific collaborations with China, the EU might need to give priority to supporting collaborations in the fields where China has higher RCA scores.

Conflict of interest statement. None declared.

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Notes

1. http://eeas.europa.eu/delegations/china/press_corner/all_news/news/2015/people_en.htm
2. This is calculated by the worldwide total minus China or the EU.
3. The fields with the slowest growth rates are also chosen from the top 30 most collaborative fields (see Section 2).

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Appendix

Table A.1. Fast-growing joint publications with China in selected fields

Country	Joint publications with China	% of the total EU	RCA	NR	Country	Joint publications with China	% of the total EU	RCA	NR	Country	Joint publications with China	% of the total EU	RCA	NR
Energy fuels					Telecommunications					Science and Technology and other topics				
Sweden	219	13.2	1.12	1.62	Luxembourg	8	0.5	1.67	3.11	Latvia	8	0.1	0.74	1.96
Denmark	123	7.4	1.26	1.60	Greece	91	6.0	2.42	2.53	Sweden	636	10.4	1.22	1.27
UK	649	39.3	0.62	1.12	UK	711	46.7	0.74	1.33	Denmark	348	5.7	1.08	1.22
Finland	48	2.9	1.06	0.92	Finland	59	3.9	1.61	1.23	Germany	1721	28.1	1.04	1.08
France	167	10.1	0.74	0.61	Ireland	42	2.8	1.31	1.16	Slovenia	58	0.9	0.98	0.83
Instruments and Instrumentation					Environmental sciences and Ecology					Oncology				
Bulgaria	48	4.1	1.51	5.84	The Netherlands	559	14.3	1.29	1.60	Malta	4	0.2	0.45	8.32
Cyprus	34	2.9	1.46	5.84	Denmark	251	6.4	1.59	1.38	Latvia	3	0.2	1.07	2.33
Lithuania	33	2.8	1.44	4.70	Ireland	112	2.9	1.08	1.21	Italy	335	17.4	1.58	2.04
Estonia	34	2.9	1.27	4.37	Finland	141	3.6	1.96	1.14	Spain	247	12.8	0.89	1.94
Croatia	43	3.7	1.18	3.61	Austria	146	3.7	1.15	1.04	Poland	133	6.9	0.71	1.90
Business economics					Engineering					Computer science				
UK	895	51.3	1.67	1.46	UK	5631	46.7%	0.68	1.33	Luxembourg	11	0.2%	2.20	1.44
The Netherlands	221	12.7	1.66	1.42	Luxembourg	21	0.2	0.97	1.03	UK	2088	46.3	0.93	1.32
Luxembourg	3	0.2	2.84	1.02	Denmark	441	3.7	0.67	0.78	Greece	129	2.9	1.91	1.21
Belgium	82	4.7	1.28	1.01	France	1516	12.6	0.90	0.76	Finland	131	2.9	1.28	0.92
Lithuania	10	0.6	2.61	0.96	Sweden	687	5.7	0.81	0.69	France	646	14.3	1.10	0.87

Note. See Equations (3) and (4) for the calculation of RCA and NR.