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The effect of competitive public funding on scientific output: A comparison between China and the EU

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Abstract

Public funding is believed to play an important role in the development of science and technology. However, whether public funding and, in particular, competitive funding from public agencies actually helps to increase scientific output (i.e. publications) remains a matter of debate. By analysing a dataset of co-publications between China and the EU and a dataset of joint project collaborations in European Framework Programs for Research and Innovation [FP7 and Horizon 2020 (H2020)], we investigate whether different public funding agencies' competitive assets have different impact on the volume of publication output. Our results support the hypotheses that competitively funded research output varies by funding sources, so that a high level of funding does not necessarily lead to high scientific output. Our results show that FP7/H2020 funded projects do not have a positive contribution to the output of joint publications between China and the EU. Interestingly, cooperation in the form of jointly writing proposals to these EU programmes, especially when they are not granted by the European Commission, can contribute significantly to joint scientific publications in a later stage. This applies in particular to cases where funding from China is involved. Our findings highlight the key role that funding agencies play in influencing research behaviour. Our results indicate that Chinese funding triggers a high number of publications, whereas research funded by the EU does so to a much lower extent, arguably due to the EU's strong focus on social impact and its funding schemes as tools to promote European integration.

Key words: competitive public funding; research evaluation; scientific output; international collaboration; China; EU member states

1. Introduction

Scientific knowledge can be generated in two ways: it can either be driven by academic interests within one discipline (also called 'curiosity-oriented' research) or it can be driven by needs from society, created in a transdisciplinary social and economic context which is led by industry or government (also called 'strategic' research) (see more discussions in Gibbons et al. 1994; Salter and Martin 2001). As scientific research requires access to substantial resources that are costly (Stephan 1996, 2010), public funding is needed in both types of research. In the former case, scientists can conduct research freely, but in the latter case there is more intervention by governments or funding agencies. The latter is seen as the prevailing model in modern society, and academic research has been moving from discipline-based to social problems (Gibbons et al. 1994; Benner and Sandstrom 2000).

Compared with general public funding (which is also called an internal block funding model), competitive project funding gives more direct monetary incentives to researchers to undertake certain types of research (Stephan 2010). For social, economic, or political aims, funding agencies can influence the scientific research carried out by research institutes via financial stimulation (Benner and Sandstrom 2000; Alberts et al. 2014; Ma, Mondragón and Latora 2015). Although the competitive project funding model has become more prevalent over the years (Guena 2001; Wang, Lee and Walsh 2018), questions have been raised about the efficiency of competitive project funding (Stephan 1996; Geuna 1999; Sandström and Van den Besselaar 2018; Wang, Jacob and Li 2019; Confraria and Wang 2020). In order to avoid an inefficient use of public resources, it is important to understand whether public funds are spent effectively and whether the peer review system can help to advance knowledge rapidly. This is not only important for evaluating the resource allocation but also for providing instructions for productive investment in the future (Jacob and Lefgren 2011).

Although it is often believed that general public funding increases scientific output, i.e. the number of publications (Payne and Siow 2003; Beaudry and Allaoui 2012), the effect of *competitive* project funding on scientific output has been subject of ongoing debate. Competitive funding does not necessarily lead to high scientific output, cf. Sandström and Van den Besselaar's (2018) study where competitive project funding was related to less efficient publication output (both volume and quality) compared to research carried out with a high degree of institutional funding. There are, however, also noticeable differences between sources of external competitive funding, and they may stimulate funding outcomes in very different ways. For example, Azoulay, Graff Zivin and Manso's (2011) study shows how differences in terms of freedom/control and acceptance of failure among funding organizations (FOs) may lead to huge differences in, e.g. the extent of highly cited papers. Fedderke and Goldschmidt (2015) find that public funding can improve research performance, but this is conditional on the capability of the researchers. Highly ranked researchers present a higher rate of return on funding than those with low ranking peers. Wang, Lee and Walsh (2018) also find differences in research novelty in different funded groups. Auranen and Nieminen (2010) show that countries with a relatively less competitive funding environment can be more efficient in generating scientific output than those with a more competitive funding environment.

Acknowledging that funded research to some extent may represent a complex set of strategies, priorities, and rules, i.e. intentions of policy-makers to support basic research, we aim to explore how policy-makers are using the funding as an instrument to steer academic research. Literature has shown that there are large differences in efficiency between national science systems (Sandström and Van den Besselaar 2018). In order to rule out the differences caused by different cultures or traditions, we examine the effects of competitive funding by looking at a set of joint publications and joint proposals. The sample we use involves joint publications between China and the EU member states and joint project collaborations/proposals in The European Union's Seventh Framework Program for Research and Innovation (FP7) and Horizon 2020 (H2020). We explore whether there is a difference in output of the FOs, thus reflecting different strategies under which the competitive funds are distributed.

Our results show how funding from China and the EU stimulate different research behaviour, illustrated by differences in the propensity to increase the publication output. According to our findings, the Chinese government seems to provide funding with the aim of increasing the recognizable and measurable scientific output, while EU funding is often associated with knowledge exchange and social impact, which may not directly be transferable to scientific output. Interestingly, joint FP7/H2020 proposals that failed to receive funding, can significantly contribute to joint publications if they are later funded by Chinese funding agencies. This emphasizes the crucial role that funding agencies play in influencing research behaviour.

The rest of the article is organized as follows. Section 2 provides the background of our empirical analysis. Section 3 documents data collection and methodology. Results are provided in Section 4, and Section 5 concludes.

2. Background

2.1 Funding and scientific research

It has been acknowledged that scientific research plays a crucial role in industrial innovations (Nelson 1986; Jaffe 1989; Mansfield 1991, 1998; Wang and Li 2018, 2020), and brings positive economic benefits in the long-run (Pavitt 2000; Salter and Martin 2001; Prettner and Werner 2016). In order to stimulate the production of scientific knowledge, science policies have been more and more committed to 'planning and management' of science (Dasgupta and David 1994). Funding is often used by policy-makers to steer scientific research. The funded research to some extent represents the intention of policy-makers to support basic research, while in some cases it represents their intention to promote certain types of society-oriented research (Braun 2003; Lepori 2006). As pointed out by Geuna (1999), the goal of funding agencies is not to buy research services but to succeed in reaching 'the policy goals through the tool of the research contract' (Geuna 1999: 118).

Although most societies encourage scientists to publish their scientific findings, the real value of science is its role as 'an instrument' and as 'an input into economic productivity', not the 'value in itself' (Johnson 1972: 16). Due to the fact that there is no standard to judge the value or promise of science, the public attitude towards science varies greatly across countries (Johnson 1972; Auranen and Nieminen 2010). Similarly, Dasgupta and David (1994) hold that scientific research is usually governed by 'institutions and social norms' and that the form of knowledge produced depends on the distinct rules of the research and incentive system. Nevertheless, the performance of scientific research is judged largely by 'scientific standards' (Johnson 1972; Stephan 1996; Auranen and Nieminen 2010).

Academic research output has been widely used as one criterion to evaluate public funding. General public funding has been believed to have a positive effect on scientific productivity. For instance, Payne and Siow (2003) find that an increase of 1 million US dollars in federal research funding to a university can lead to 10 more scientific publications. Also in relation to Canada, it is found that public research funding can help increase the number of scientific publications (Godin 2003; Beaudry and Allaoui 2012); the positive effect is especially strong if the funding is higher than a certain threshold (Godin 2003). Furthermore, Fedderke and Goldschmidt (2015) stress the importance of funding amount, by suggesting that substantial funding is associated with raised researcher performance.

In addition to the relation between public funding and the quantity of scientific output, studies have also shown that funded research has a higher social impact compared to research without funding support (Costas and van Leeuwen 2012; Gök, Rigby and Shapira 2016). Neufeld (2016) confirmed this for the biology field, by finding a positive impact of funding on the publication counts, the total citations, and the journal impact factor per paper.

However, opinions differ concerning the effects of competitive public funding. Due to the extra resources provided by funding, and the fact that research consortia are selected on the basis of competitive tendering procedures, the quality of funded research is often expected to be high (Auranen and Nieminen 2010). That is, superior performance in the past increases the probability of being granted. Hence, it is not the funding but the past performance that influences future performance (Arora, David and Gambardella 1998).

2.2 Funding and scientific collaboration

Public funding not only spurs local basic research but also facilitates research collaborations (Bozeman and Corley 2004). Funded projects are 'collaborative in nature' (Ma, Mondragón and Latora 2015), hence financial support makes it possible for researchers to participate in conferences or visit research institutes abroad, which in turn helps to set up collaborations between researchers from different countries. Through research funding, the intensity of collaboration between partners can be greatly enhanced (Zhao et al. 2018). Facilitated by the external funding, individuals are able to work together and integrate all kinds of knowledge resources to achieve the common goal of producing new scientific knowledge. Laudel (2002: 5) defines research collaboration as a 'system of research activities by several actors related in a functional way and coordinated to attain a research goal corresponding with these actors' research goals or interest'.

Funding from foreign countries, an indication of increased internationally collaborated research, has become more and more important for universities, and international research groups successful in receiving external funding exhibit a higher probability of producing publishable research (Geuna 1999). It is generally expected that researchers (teams) with larger grants would collaborate more and to have more publications (Lee and Bozeman 2005). Competitive research funding is by some seen as highly stimulating to research productivity due to its creation of co-authorships (Ayoubi, Pezzoni and Visentin 2018),

Toward understanding the relationship between funded collaborations and research productivity, most studies have put efforts mainly on the structure of the collaborations without giving much attention to the different types of output stimulated by the funding agencies. By focusing on the EU-funded research network, Defazio, Lockett and Wright (2009) find that collaborations did not lead to an increase in research production in the funding period, but a positive effect was found after the funding period. We would like to challenge their conclusion that 'it requires time to develop structures of collaboration that are effective in enhancing researcher productivity'. In our opinion, research output is not (or not only) influenced by the time it takes to set up effective collaboration structures but also by the strategies of the funding agencies influencing the research output. For example, some funding agencies may prioritize publications only, while others may be interested also in communication with stakeholders. In the study by Defazio et al.(2009), it might have been the case that, after the EU-funded projects had finished, researchers became more productive because they got involved in other funded (or unfunded) projects. We contend that collaborations subsidized by different funding agencies would vary in the productivity as well as the type of research output.

In this study, we aim to fill the above-mentioned gap in the literature. Namely, by focusing on the collaborative research pairs supported by different types of funding resources, we investigate whether different public funding agencies impact the research output of their funded research differently, i.e. leads to different forms of scientific output?

2.3 Empirical background—collaborations between China and the EU28

China-EU collaboration has been strengthened by both China and the European Union. In 1998, both parties signed the EU-China Agreement on Cooperation in Science and Technology, which was renewed in 2004 and 2009. The document 'A Long-Term Policy for China-Europe Relations', issued in 1995, stressed the necessity for European Union to develop a long-term relationship with China and introduced an action-oriented strategy to strengthen that relationship (European Commission 1995). The Ministry of Science and Technology of China (MOST) and DG Research and Innovation signed the Agreement on Implementing the Science & Technology Partnership Scheme (CESTYS) in May 2009. The National Natural Sciences Foundation of China and DG Research and Innovation signed an Administrative Arrangement in March 2010.

Efforts have been made to promote student exchange between China and European Union. In 2012, 35,000 students from EU member states studied in China; and according to Du Yubo, Vice Minister of Education, 30,000 scholarships would be granted to Chinese students to study in Europe in the period 2014–9 (Tuo 2013). There were nearly 1,000 Chinese participations in the Marie Skłodowska-Curie programme between 2007 and 2013 (European Union 2015).

With the mobility of researchers, there are on the one hand more and more academic papers published jointly (Wang and Wang 2017), while on the other hand more and more researchers have been involved in writing new project proposals to seek for potential funding opportunities. According to reports from the European Commission (2015, 2016a), in FP7, Chinese researchers were the third most allocated to recipients of funding among non-European researchers. In H2020, there were 187 eligible proposals with Chinese organizations involved by 2015 (European Union 2015).

The National Natural Science Foundation of China (NSFC) is the biggest basic research foundation in China, accounting for nearly half of the total public funding in China.[1] Besides NSFC, there are also other major core FOs such as the MOST and the National Social Science Fund of China. In Europe, the Framework Programmes (FPs) have been the main financial instruments via which the European Union supports research and Innovation. Recent FPs like FP7 (2007–13, €62.9 billion[2]) and H2020 (2014–2020, €80 billion[3]) are the biggest funding programmes covering all disciplines to foster research in the European Research Areas. Besides the FPs, there are also discipline-specific funding types. For instance, CERN[4] (known as the European Council for Nuclear Research) aims at establishing a world-class fundamental physics research organization in Europe, EMBO (European Molecular Biology Organization) funds research in life science.[5] In addition to FP7/H2020 and discipline-specific funding, the European Research

Council and the Marie-Curie programme are also well-known research funding sources in Europe.

The primary goals of the major research foundations in China and in the EU seem to be similar to each other, i.e. to support research and innovation, to improve scientific knowledge, and to promote excellent science. Taking one of the largest science foundations in China (NFSC) as an example, the tasks of NFSC include to fund creative and timely ideas to achieve excellence in science; to focus on the frontiers of science in unique ways to lead the cutting edges; to support application-driven basic research to enable breakthroughs; and to encourage transdisciplinary leading-edge research to promote convergence. The ultimate goal of NFSC is to build a science funding system that makes a 'fundamental contribution to strengthening original innovation capacity to become world's leading science and technology power' (National Natural Science Foundation of China 2018: 2). In Europe, the primary priority of H2020 is also Excellent Science, aiming to 'reinforce and extend the excellence of the Union's science base and to consolidate the European Research Area in order to make the Union's research and innovation system more competitive on a global scale' (European Commission 2016b: 4). 'The overall goal is to ensure that Europe produces world-class science and technology that drives economic growth'. (European Commission 2016b: 5). Interestingly, although the primary goals seem to be the same, the means to reach these goals (i.e. funding evaluation system) can be different. We will examine this topic further in the following sections.

3. Data and methodology

Publication count is often used as a proxy to evaluate scientific performance (Stephan 1996). Publications resulting from funding must include an acknowledgment of grant support, including the funding agency and followed by the grant number(s). Funding acknowledgement statements are usually included in the manuscript in the form of a sentence under a separate heading entitled 'Acknowledgement' or 'Funding', if applicable. In early 2009, Web of Science released new searching functions about funding information with three new searching field tags, including FO (Funding Organization), FG (Grant Number), and FT (Funding Text), which collect and extract the funding acknowledgement statement from publications. These new funding-related search field tags make it possible to analyse the funding supported research output.

Publication data used in this study are collected from Clarivate Analytics' Science Citation Index Expanded (SCI-E) and Social Sciences Citation Index (SSCI). In our analysis, we focus on the international collaborations at national level. Affiliation address is used to identify the location of researchers. This study analyses in total 115,816 joint publications between China and EU member states in the period 2003–14. In this publication dataset, we further have two sub-datasets: (1) publications without FO information (2003–8) and (2) publications with the above-mentioned FO information (2009–14). In the latter dataset, there are in total 81,996 joint publications between China and EU member states, and about 77% of these papers (62,928) acknowledged financial support from funding agencies. FOs were first cleaned by VantagePoint software and then names were checked manually. We have checked all the organization names which have funded no less than 10 publications in the studied period. Some names that cannot be identified with the countries and that funded few publications (<10) were not included.

There are two sets of funding data employed in this research. The first set was collected from SCI-E and SSCI. Using VantagePoint software, we extracted the field of FO from all the co-publications between China and the EU28. Based on the location of FOs, we classify funding resources into three types: (1) China, (2) European Commission (such as FP7, H2020, etc.), and (3) individual European countries (such as national strategic programmes and bilateral programmes with China).

The second set of funding data was provided by the European Commission's datawarehouse ECORDA. This dataset includes funding proposals and projects granted in the European FPs. Our study is based on data for the seventh Framework Programme (FP7) and the early phase of H2020, covering the years 2007 until 2015. There were in total 1,618 proposals jointly written by China and EU states, of which 253 projects were granted with research funding from the European Commission (either as FP7 or H2020 projects). To examine the interaction between each pair among these 29 countries (28 EU members and China), partnership data have been transformed into the format of a 29×29 matrix, for both *funded projects* and *unfunded proposals*. The matrix of funded projects at year t is constructed as follows:

$$\begin{bmatrix} F_{1,1,t} & F_{1,2,t} & \ldots & \ldots & F_{29,29,t} \\ F_{2,1,t} & \ldots & \ldots & \ldots & \ldots \\ \ldots & \ldots & F_{i,j,t} & \ldots & \ldots \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ F_{29,1,t} & \ldots & \ldots & \ldots & F_{29,29,t} \end{bmatrix}. \quad (1)$$

Where $F_{i,j,t}$ is the number of joint funded projects of country i and country j at year t. Similarly, we also create the matrices for unfunded proposals by year. Thus, we have 16 matrices[6] for both funding proposals and granted projects in the period 2007–15. The same method is also applied to construct the matrices of joint publications for different countries in different years.

Our aim is to assess the publications and FP7/H2020 cooperation between 29 countries in the social network datasets, thus we use multiple regression quadratic assignment procedure (MRQAP) to implement the regressions. All variables in the MRQAP regressions are in the 29×29 matrix format. For handling dyadic data where pairs are linked, the quadratic assignment procedure has been tested to be superior to ordinary least squares in both simple and multiple regression models (Krackhardt 1988). In conducting the MRQAP tests, we use the double semi-patriating permutation method suggested by Dekker, Krackhardt and Snijders (see more details in Dekker, Krackhardt and Snijders 2007).

In measuring the intensity of international scientific collaborations, we adopt the Jaccard index (see also in Luukkonen et al. 1993).

$$CI = \frac{CO_{ij}}{P_i + P_j - CO_{ij}}. \quad (2)$$

Where CO_{ij} is the number of co-authored papers between country i and country j; P_i is the total publication number by country i; and P_j is the total publication number by country j.

For the published joint research, funding resources are decomposed into three types: funded by China, funded by the EU, and funded by individual EU member states.[7] The shares of different funding resources in country i at year t are calculated as follows:

$$\text{CN funded}_{\text{share}}\text{it} = \frac{\text{CN funded publications}_{\text{it}}}{\text{all funded publications}_{\text{it}}}, \quad (3)$$

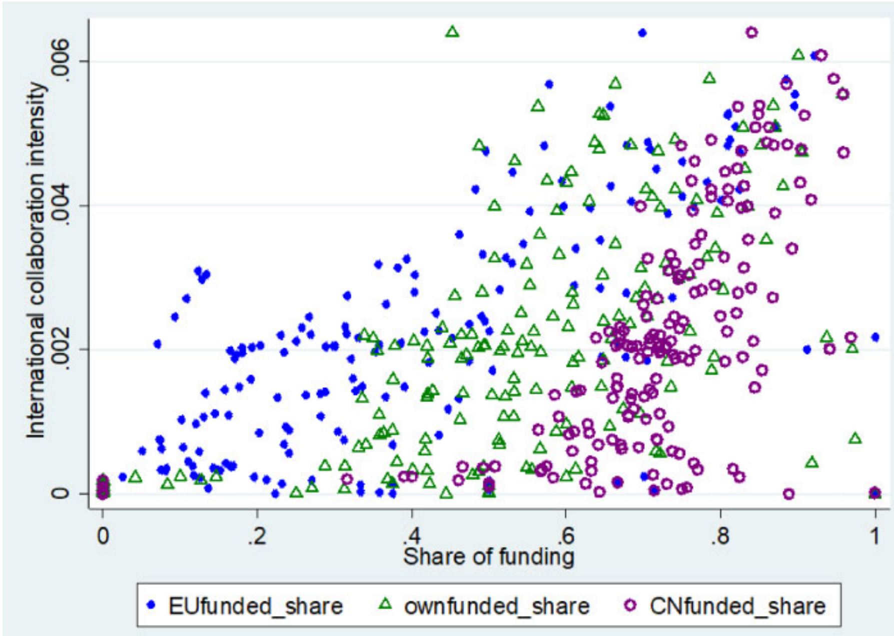

Figure 1. Scatter plot of correlation between joint publication intensity and funding share (2009–14). *Note:* (1) The calculations for the funding shares are provided in Section 3 Equations (3–5). (2) Each point represents a country at one certain year.

$$\text{EU funded}_{\text{share}}\text{it} = \frac{\text{EU funded publications}_{\text{it}}}{\text{all funded publications}_{\text{it}}}, \quad (4)$$

$$\text{Own funded}_{\text{share}}\text{it} = \frac{\text{Own funded publications}_{\text{it}}}{\text{all funded publications}_{\text{it}}}. \quad (5)$$

3.1 Control variables on the EU member state groups and languages

Based on the year of joining the European Union, EU member states are classified into three groups: before 2000, between 2001 and 2007, and after 2007 (see Table A.1). This information for each country is further transformed into a relation matrix captured by the variable of EU membership time group. Countries from the same year group will be assigned the value 1, other countries will receive the value 0.

Language barriers are often assumed to be an important factor influencing collaboration communications. As EU member states are greatly heterogeneous and there are 24 official languages in the EU, our study takes into consideration the official languages that are shared between countries. There are in total 14 official languages that are shared by at least two countries (see Table A.2).[8] Countries sharing the same official languages are assumed to collaborate more easily. The information of shared official languages is also transformed into a relation matrix (29 × 29).

4. Results

4.1 Collaboration intensity and funding structure

China and the EU28 have jointly published in total 81,996 papers in the period between 2009 and 2014, and 76.7% of these publications acknowledged funding support. In the sub-set of publications that acknowledged funding agencies from either China or European Union, there are 57,000+ records. By decomposing FOs into three types (funded by China, funded by the EC, and funded by individual EU member states), we find that the scientific research jointly published between China and the EU28 has been mainly funded by Chinese organizations. Around 80% of joint publications acknowledged funding support from Chinese organizations. Following that, funding from national level in EU member states also contributed to 48% of the joint publications, and about 13% of these joint publications received funding from the European Commission. It is worth noting that one scientific publication can be supported by multiple FOs, e.g. from both China and European Union.

Figure 1 plots the correlation between funding resources and international collaboration intensity. This shows that the international collaboration intensity (measured by the Jaccard index) is positively correlated with all these three types of funding (funded by China, funded by the EC, and funded by individual EU member states). Located on the right side of Figure 1, funding from China has the highest share. National funding programmes from EU member states contributed the second most. Funding from the European Commission is located on the left with a relatively lower share. For all of these three types of funding sources, there is a general positive correlation between share of funding and international collaboration intensity.

4.2 Research capacity and funding resources

To deepen our understanding of funding schemes, we connect funding resources with research capacity of each country. Figure 2 shows that, in the process of collaborating with China, EU member states with high research capacity (proxied by the number of total publications at national level) received a relatively small share of funding from the European Commission. For instance, in the UK during the period of 2009–14, on average 13% of the publications with funding acknowledgements were funded by the European Commission. The share of EU funding[9] was also low in Germany and Sweden; 15% and 18%, respectively.

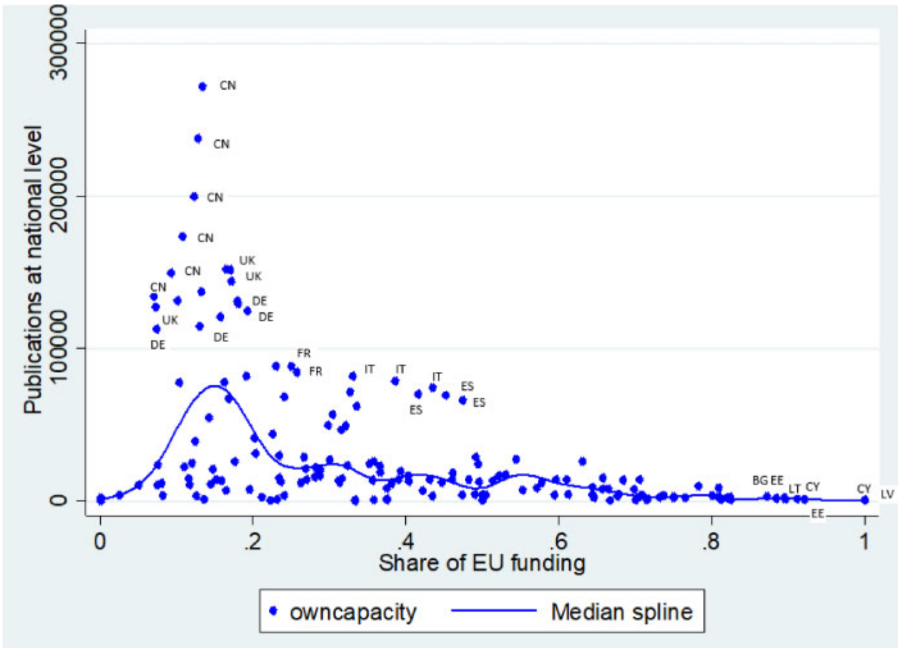

Figure 2. Scatter plot of correlation between own research capacity (i.e. total publications) and share of EU funding (2009–14).

There is a long tail on the right side of the figure, mainly consisting of small European countries with low research capacity. In those countries, due to the lack of national government funding, the share of EU funding is relatively high. Bulgaria (BG), Cyprus (CY), Estonia, Lithuania (LT), and Latvia (LV) are the countries which had the highest shares of EU funding. In some cases, funded publications all acknowledged the funding from European Commission, e.g. CY in 2010, and LV in 2010 and 2011.

On the contrary, funding from China exhibits a different pattern (see Figure 3), with the long tail on the left side of the figure. In the extreme cases—such as CY in 2009, LV in 2010 and Malta in 2010, 2011, and 2012—there were no publications sponsored by the Chinese government. In other countries with low scientific capacity, such as BG, Romania (RO), Greece, Hungary, and LT, the share of publications funded by China was low in particular in the earliest year, i.e. 2009.

However, in the countries with high research capacity (i.e. the top players in the collaboration), such as the UK and Germany (DE), on average 75% of the joint publications co-authored with Chinese researchers were funded by Chinese organizations. This is in line with earlier findings that research funding goes to 'rich clubs' (Ma, Mondragón and Latora 2015; Szell and Sinatra 2015). This also shows that there is a 'Matthew effect' in the funding system in China, i.e. research groups with a higher profile (in terms of publication records) have a higher probability of receiving more funding.

In China, the core FO, the NSFC, is essential in providing financial support to basic scientific research. The NSFC is responsible for almost 50% of the China-EU joint publications with funding acknowledgement.[10] Special programmes from the Chinese government, such as Fundamental Research Funds for the Central Universities and the 973 Program, also played an important role in sponsoring joint publications between China and EU member states. Funding from the China Scholarship Council, which aims to support Chinese students to study abroad and foreign students to study in China, has turned out to be another important resource in promoting joint scientific publications.

In the EU, European Council for Nuclear Research, the European Regional Development Fund, and the Marie Skłodowska-Curie Programme appear to be most important (specific) programmes in funding joint publications between China and the EU28. These programmes have turned out to be crucial in involving also the small EU member states in the joint research.

4.3 Effect of funding and co-publications

In this section, we examine the relationships between joint funding experiences and scientific co-publications. We use multiple regression quadratic procedure (MRQAP) to assess the impact of funding projects (or proposals) upon research output, and vice versa.

Table 1 documents the regression results of the effect of FP7/H2020 funded projects (or unfunded proposals) on the output of scientific collaborations between China and the EU member states. There are in total seven different dependent variables, i.e. (1) total joint publications[11] 2011–4; (2) funded joint publications 2011–4; (3) joint publications funded by China, EU, or individual EU countries; (4) joint publications funded by China; (5) joint publications funded by the EC; (6) joint publications; and (7) joint publications without any financial support from any funding agencies.

Model 1a examines the contributions of FP7 and H2020 proposals and projects in the earlier years (2007–10) to the joint publications in the later years (2011–4). Interestingly, funded FP7/H2020 projects have a significantly negative effect on the number of joint publications, which indicates that partnerships working in the same funded FP7 or H2020 projects do not lead to joint publications. One possible explanation may be that, in FP7/H2020 funded projects, much time and resources need to be spent on submitting deliverables which are not academic publications, e.g. deliverables relating to policy reports and stakeholder involvement.[12] Another explanation may be that some projects are related more to

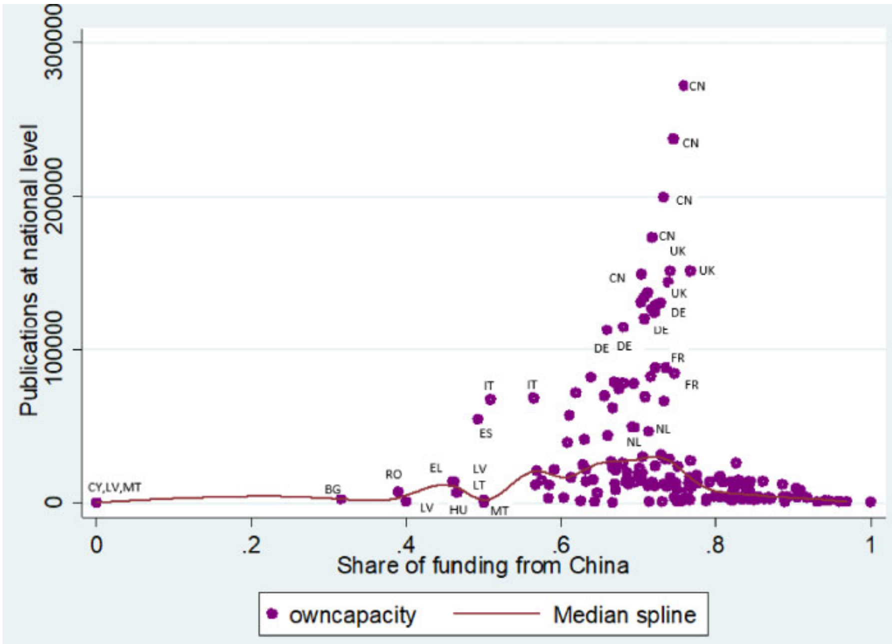

Figure 3. Scatter plot of correlation between own research capacity (i.e. total publications) and share of funding from China (2009–14).

innovation and to an R&D intensive, yet non-publishing industry sector, and therefore less to academic research.

However, unfunded proposals significantly and positively contribute to the joint research output. This reveals that rejected applications can still lead to successful output elsewhere. One example comes from Norway, where in a survey among Norwegian researchers that had applied the Research Council of Norway for funding, a majority of the respondents agreed that even though their applications were rejected, working on the applications was seemed as useful because it was used in future applications, generated new project ideas or established new collaborations with external partners (Ramberg 2016). Another example relates to Switzerland. Ayoubi, Pezzoni and Visentin (2018) found that taking part in a Swiss research grant competition already boosted scientists' number of publications, while it also extended their knowledge base and collaboration network, regardless of whether the funding was granted. These findings are in line with the patterns observed in our study, i.e. even failed applications may be beneficial to future collaborations.

Model 1b examines such contributions in the group of joint publications with funding acknowledgement, namely funded joint publications. The results of Model 1b are similar to those of Model 1a. That is, funded FP7/H2020 projects had negative effect on the output of joint publications, while unfunded proposals can lead to significant positive contribution to the scientific output. To further explore this issue, we test the contribution of unfunded FP7/H2020 proposals to publications funded by different resources (Models 1c–f).

Models 1d–f show that failed FP7 (or H2020) proposal cooperation has a significant and positive effect on producing joint publications which were funded by China, the EU, and individual EU member states. Among these three cases, the coefficient in the China-funded model (Model 1d) has the highest value (1.214). This means that the experience of writing joint FP7 (or H2020) proposals, though failed in getting EU funding, can contribute greatly in obtaining funding from China in the later years. In Model 1g, we test the effect of funded and unfunded FP7/H2020 projects on later joint publications without any funding acknowledgement (so called unfunded publications). The coefficients stay similar to those in the earlier models.

If publications were sponsored by organizations from China and/or the EU together with third parties, such publications are included in 'joint publications funded by China, EU, or individual EU countries' (column 1c). However, if articles were sponsored purely by third parties (without European or Chinese organizations involved), they are included in the sample in column 1h in Table 1. Similar to the results in other groups, the regression for Group 1h shows that failed FP7 or H2020 proposal cooperation can still lead to joint publications funded by the third parties.

Explanations on the results regarding EU member state groups, languages, and distances are provided in the next section on control variables.

The relationship between co-publications and joint project collaborations can be tested in both directions. Following the above analysis, which focused on the contribution of joint projects to joint publications, here we also examine the contribution of co-publications to later cooperation in writing project proposals.

Hoekman et al. (2013) find that scientific collaboration between different regions in the European Union has a minor effect on acquiring FP funding, and research funding significantly stimulates co-publication activities between regional pairs 'that did not intensively co-publish before participation'. Our results in Table 2, however, suggest that in the process of collaborating with China, the scientific collaborations in *earlier* years—rather than in later years—have a stronger positive effect on joint funding proposals. Despite this difference, this study and Hoekman et al. (2013) both demonstrate the co-publication activities between EU member states in later years, which will be further explained in the next section with regard to control variables.

Table 1. Results of quadratic assignment procedure regressions

Dependent variable	Model 1a Joint publications (2011–4)	Model 1b Joint publications _funded (2011–4)	Model 1c Joint publications_ funded by China, EU, or individual EU countries (2011–4)	Model 1d Joint publications_ funded by China (2011–4)	Model 1e Joint publications_ funded by the EU (2011–4)	Model 1f Joint publications _funded by individual EU countries (2011–4)	Model 1g Joint publications_ unfunded (2011–4)	Model 1h Joint publications_ funded by third parties (2011–4)
Intercept	0	0	0	0	0	0	0	0
	(15.346)	(70.035)	(87.323)	(190.758)	(250.230)	(198.528)	(−50.790)	(−17.481)
FP7 and H2020 funded	−0.304**	−0.300**	−0.300**	−0.414***	0.080	−0.092	−0.338**	−0.292**
projects (2007–10)	(−27.567)	(−21.454)	(−19.681)	(−21.373)	(1.626)	(−3.593)	(−6.543)	(−1.752)
FP7 and H2020 unfunded	1.138***	1.135***	1.134***	1.214***	0.813***	0.994***	1.138***	1.114***
proposals (2007–10)	(38.026)	(29.940)	(27.471)	(23.099)	(6.088)	(14.362)	(8.125)	(2.466)
EU membership time group	−0.086**	−0.084***	−0.085***	−0.080***	−0.077*	−0.086***	−0.072**	−0.073**
	(−276.557)	(−215.293)	(−200.284)	(147.020)	(−55.866)	(−120.161)	(49.464)	(−15.593)
Geographical distance	0.009	−0.007	0.004	−0.008	0.089	−0.024	0.026	0.030
	(0.009)	(−0.005)	(0.003)	(−0.004)	(−0.019)	(−0.010)	(0.005)	(0.002)
Language	−0.006	−0.009	−0.010	−0.027	−0.009	−0.012	−0.002	−0.001
	(−22.849)	(−27.388)	(−27.412)	(−57.384)	(−8.010)	(−20.314)	(−1.748)	(0.335)
R^2	0.739	0.738	0.735	0.688	0.715	0.797	0.702	0.735
N	812	812	812	812	812	812	812	812

Note: (1) joint publications (a) = joint publications_funded (b) + joint publications_unfunded (g); joint publications_funded by China, EU, or individual EU countries (c) = joint publications_funded by China (d) + joint publications_funded by the EU (e) + joint publications_funded by individual EU countries (f); joint publications_funded (b) = joint publications_funded by China, EU, or individual EU countries (c) + joint publications_funded by third parties (h). (2) Standardized coefficient in parentheses.

*P < 0.05; **P < 0.01; ***P < 0.001.

Table 2. Results of quadratic assignment procedure regressions

Dependent variable	Model 2a Joint FP7 and H2020 proposals (2007–15)	Model 2b Joint FP7 and H2020 funded projects (2007–15)	Model 2c Joint FP7 and H2020 unfunded proposals (2007–15)
Intercept	0	0	0
	(2.337)	(1.964)	(0.373)
Jointpub (2003–06)	1.443**	1.443**	1.429**
	(0.357)	(0.089)	(0.268)
Jointpub (2007–10)	−0.740	−0.793	−0.716
	(−0.107)	(−0.028)	(−0.078)
EU membership time group	0.227***	0.285***	0.206***
	(54.778)	(17.107)	(37.671)
Geographical distance	0.185*	0.138	0.199*
	(0.013)	(0.002)	(0.011)
Language	0.038	0.039	0.037
	(10.677)	(2.712)	(7.965)
R^2	0.661	0.572	0.682
N	812	812	812

Note: Standardized coefficient in parentheses.
*P < 0.05; **P < 0.01; ***P < 0.001.

By dividing the joint proposals into two groups, i.e. funded and unfunded, Table 2 also serves to test the funding selection bias. We examine whether compared to other funding programmes FP7/H2020 granted financial support to more non-academic partners, so that consequently collaborations in FP7/H2020 do not lead to joint publications. To test the funding selection bias (Arora, David and Gambardella 1998),[13] in Table 2, we investigate the contributions of joint publications to the joint FP7/H2020 proposals. Joint publications are classified into two groups: the earlier years (during 2003–6) and the later years (during 2007–10). Joint FP7/H2020 proposals (Model 2a) is further decomposed into funded group (Model 2b) and unfunded group (Model 2c). The results show that the scientific collaborations in *earlier* years (during 2003–6)—rather than in later years (during 2007–10)—have a stronger positive effect on writing joint funding proposals (Model 2a). Most importantly, the results are consistent for both funded projects (Model 2b) and unfunded proposals (Model 2c). This indicates that joint academic cooperation in the past contributed equally to the FP7/H2020 funded projects as well as unfunded proposals. In other words, there is no evidence showing that FP7/H2020 funded projects are more connected with collaborative partners with less joint publication experience. This confirms that a different performance in publications in Table 1 is not caused by funding selection bias. (The explanations on results related to control variables are provided in the next section.)

4.4 Results about control variables

In Table 1, the significant negative coefficient of the EU membership (time group) variable indicates that the 'new' EU member states have been actively collaborating (in term of joint publications) with the 'old' EU member states. This result, in line with Hoekman et al. (2013), can also explain the intensive collaboration network in the EU in recent years (Wang, Wang and Philipsen 2017). This signals the integration process of European countries while conducting academic collaborations, in particular among countries that joined the EU in different time groups.

The EU membership variable in Table 2 shows a positive effect on joint FP7 or H2020 proposals. This suggests that, different from conducting joint scientific publications, EU member states are still fond of working on joint FP7 or H2020 projects with partners that joined the EU at a similar time (mostly this concerns cooperation between 'old' members).

The EU membership group has also a significantly positive effect on writing joint proposals in FP7 and H2020. This means that, in writing joint proposals, more collaborations are observed between EU member states that joined the EU at a similar time.

In relation to China-EU28 collaboration, language barriers and geographical distance do not seem to be important in impeding scientific collaborations. The evidence of such barriers to research collaborations have been investigated with much inconsistent findings. Some studies have concluded that language spoken by partners or their geographical proximity are not significant for research collaboration (Nokkala et al. 2008), while others, such as Guellec and Van Pottelsberghe de la Potterie (2001) argue that two countries are more likely to collaborate if they are geographically close to each other, if they have the similar technological specialization and if they share a common language. In the case of Chinese-European collaboration in the period of 2007–15, both the geographical distance and language differences do not seem to matter.

In general, we find that EU member states have been greatly integrated in the process of collaborating with China, in particular in terms of joint publications between 'new' EU member states and 'old' ones. One should bear in mind that the collaborations studied here do not include cooperation only between EU partners, but collaborations between the EU and China. Namely, each joint publication or funding proposal examined in this study involves China.

5. Discussion and conclusions

Using co-publication and funding data between China and the EU28, this study explores whether different public funding agencies stimulate different research forms and outputs. Our results show that scientific research funding from China greatly supports scientific research of top performers (partner countries with high research capacity) while funding from the EU plays a crucial role in supporting European countries with a low national research capacity. This may reflect the different aims of different FOs. Chinese funding agencies likely focus on the top players in order to achieve immediate high publication output, while EC funding agencies often set regional integration (EU internal market goals) as their priority.

In China, although the total amount of money spent by the Chinese government is unknown, funding efforts have been greatly turned into academic publications. We believe that this is related to the funding evaluation system in China which stresses the importance of immediate academic values (i.e. publications) that can be measured directly, which is also apparently pursued in the priority setting of the NSFC.[14]

This is also the case in many European countries where part of the national funding of higher education institutions is typically dependent on a performance-based activity measure like the number of publications in Web of Science. It is often expected that partners with larger grants would collaborate more and have more publications (Lee and Bozeman 2005). Large parts of the FPs in the EU are, however, different. They stress the function of the projects as means to creating and sharing knowledge which is not necessarily aimed at scientific publishing, and thus difficult to measure in the short term. EU funding programmes often emphasize the priority of regional integration and social networks in the European Union rather than academic publications (Pavitt 2000). This may also explain the results of Defazio, Lockett and Wright (2009) that funded collaborations have no contribution to scientific output during the EU funding period, but do contribute positively after the projects are finished.

Another interesting finding was that non-funded proposals—i.e. collaborative FP7 or H2020 proposals that were rejected—contributed significantly to later publications. The experience of writing joint FP7 or H2020 proposals, when a research consortium failed in obtaining the funding it aimed for, can still lead to a successfully funded project by a different sponsor (for instance a governmental agency of an EU member state, other European research foundations, or the Chinese government) and hence may contribute significantly to the scientific output at a later stage. Interestingly, those unfunded FP7 and H2020 proposals—if later funded by Chinese funding agencies—will have the highest chance to produce joint publications. This confirms the hypothesis that competitive funding is one of the means for government to implement research policy. We believe our results may signal a Chinese strategy to enhance the overall research capacity of China (readily identifiable by, e.g. bibliometric indicators), while the EU has downplayed such indicators, turning its focus to more process-oriented indicators of the research process (e.g. user-involvement, Open Access, Responsible Research and Innovation, build-up of research capacity in new EU member states).

Although initially aiming at the EU programmes funding, such collaborations can significantly contribute to publications if they are later funded by Chinese funding agencies. This indicates that, for a certain research group with a potential amount of knowledge basis, the final product delivered can be steered by the funding contract. These findings highlight the key role that funding agencies play in influencing research performance.

We agree with the literature (Stephan 1996; Arora, David and Gambardella 1998) that funding agencies are likely to choose best performers to implement their tasks. However, we would like to add that the final form of research output is crucially dependent on the specific public agency involved in the competitive funding (in our example: Chinese or EU funding agencies).

There are several limitations to this study. One is that the publication dataset and FP7/H2020 proposal dataset are limited to China and EU collaborations. Although it sufficiently shows the difference between China and EU research policies, it does not cover the complete picture of the funding systems in China or the EU. Second, this study focuses on one type of scientific research output (WoS publications), and measures the quantity of scientific output, not the quality of such output. Third, there exists some limitation of searching via only FO (Funding agency) to extract funding information in WoS, which may miss a part of funded records (Tang, Hu and Liu 2017; Liu, Tang and Hu 2020). Further research covering these issues is encouraged.

Conflict of interest statement. None declared.

Notes

1. See more in Li (2018) and http://main.sgg.whu.edu.cn/uploads/soft/190321/2_1658006111.pdf.
2. https://ec.europa.eu/research/evaluations/pdf/archive/fp7_monitoring_reports/7th_fp7_monitoring_report.pdf.
3. https://ec.europa.eu/programmes/horizon2020/en/what-horizon-2020.
4. CERN is an abbreviation of 'Conseil Européen pour la Recherche Nucléaire'. See also at https://home.cern/about.
5. http://embo.org/.
6. Eight matrices for funded projects and eight for unfunded proposals.
7. The share of publications funded by individual EU member states is called 'ownfunded_share'.
8. https://en.wikipedia.org/wiki/Languages_of_the_European_Union.
9. See Equation (4) for the calculation of the share of EU funding.
10. Joint publications without funding acknowledgement were not considered in this sample.
11. Joint publications refer to the publications jointly written by at least one researcher from China and one researcher from the EU member states.
12. Indirectly, some of these 'non-academic' deliverables may still generate future academic output by researchers who are not members of the consortium.
13. In the selection process, funding may more likely flow to certain types of researchers (or teams), depending on their past performance.
14. Publications and patents are the important criteria used in ex-post evaluations (see more in National Natural Science Foundation of China 2018: 87).

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Appendix

Table A.1. Time groups of joining the European Union

EU 28	Country_code	Before 2000	Between 2001 and 2006	Between 2007 and 2014
Austria	AT	1		
Belgium	BE	1		
Bulgaria	BG			1
Croatia	HR			1
Cyprus	CY		1	
Czech Republic	CZ		1	
Denmark	DK	1		
Estonia	EE		1	
Finland	FI	1		
France	FR	1		
Germany	DE	1		
Greece	EL	1		
Hungary	HU		1	
Ireland	IE	1		
Italy	IT	1		
Latvia	LV		1	
Lithuania	LT		1	
Luxembourg	LU	1		
Malta	MT		1	
Netherlands	NL	1		
Poland	PL		1	
Portugal	PT	1		
Romania	RO			1
Slovakia	SK		1	
Slovenia	SI		1	
Spain	ES	1		
Sweden	SE	1		
UK	UK	1		

Table A.2. Shared official languages in EU member states

	Croatian	Czech	Danish	Dutch	English	French	German	Greek	Hungarian	Irish	Italian	Slovak	Slovenian	Sweden
Austria	1						1		1				1	
Belgium				1		1	1							
Bulgaria														
Croatia	1										1			
Cyprus								1						
Czech Republic		1										1		
Denmark			1				1							
Estonia														
Finland														1
France						1								
Germany			1				1							
Greece								1						
Hungary									1			1	1	
Ireland					1					1				
Italy						1	1				1		1	
Latvia														
Lithuania														
Luxembourg						1	1							
Malta					1									
Netherlands				1										
Poland														
Portugal														
Romania									1					
Slovakia		1							1			1		
Slovenia									1		1		1	
Spain														
Sweden														1
UK					1					1				
Sum	2	2	2	2	3	4	6	2	5	2	3	3	4	2

Source: https://en.wikipedia.org/wiki/Languages_of_the_European_Union.