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Global pattern of science funding in economics

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Abstract Based on the original data of 100,275 SSCI indexed papers in the field of economics in 2009–2014, this work applied scientometrics and network analysis methods to study the funding pattern of funding ratio, impacts, indices' relationship and collaboration structure in major countries/territories. Results show that, unlike the notable standing of economics, the global funding ratio of economics in 2009–2014 is just 8.3 %, much lower than the average level of social sciences. Although USA seems to be far ahead in the innovation of economics, the coverage of its science funding has been not widespread. By contrast, the funding ratio of China ranks highest, but the effect of funding needs to be strengthened. We observe an approximate power–law relationship among three basic measures of funded economics papers, including citations, total numbers and h-indexes. The cooperation researches in economics present a key structure of three main components: USA as the central part, a core group of Asia Pacific and another core group of Europe. The collaboration pattern of continents is largely based on the connection between Europe and USA.

Keywords Research funding · Economics · Bibliometrics · Citation analysis · Scientific collaboration networks · Information networks

Introduction

Science funding, considered as the key public resource in current academic community, has an irreplaceable function in research development, scientist training and cultural construction (Vardakas et al. 2015; Ebadi and Schiffauerova 2016). Science funding

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agencies of major countries/territories have allocated a large amount of competitive fundings for many academic fields. Therefore the academics and policy makers have natural demands of watching on the situation and patterns of these investments and related outputs. But the quantitative analysis needs large scale data, repeatable data sources and appropriate quantitative approaches. Since the Web of Science (WoS) database has fully labeled the funding information of research papers from mid-2008, it is possible to analyze the funded literatures based on bibliometric methods at the large scale level. Consequently, the large scale scientometric analysis of funding and funded papers becomes a hotspot in recent years. For examples, the funding analysis in Nano research (Shapira and Wang 2010; Wang and Shapira 2011), the general study of natural science (Wang et al. 2012) as well as social science (Xu et al. 2015), and the interesting and in-depth observation in the specific field, mathematics (Zhou and Tian 2014).

Similar to the fundamental standing of mathematics in natural sciences, economics also plays a significant role both in research paradigm and application practice in social sciences. Thus in current social science, economics has been one of the key fields in the investment of academic resources. In this paper, we focus on the funded papers in economics, an interesting and important field. Based on the dataset of 100,275 SSCI indexed papers of economics in WoS during 2009–2014, we try to explore four fundamental aspects of funding pattern in economics, including the funding ratio, impacts, indices' relationship and collaboration structure.

The paper is organized as follows: after giving a brief review of bibliometrics in economics and the emerging trend of funding analysis, we describe in section "Datasets and methods". Then, we present and analyze the detailed results in 'Results and discussion' section, followed by a conclusion section including the major findings, limitations and possible future research directions.

Literature review

Bibliometric studies in economics

Since the beginning of economics development, the economics theories, scopes, methods have blended into each other, from micro economics theory to macroeconomics theory, input–output analysis to advanced econometric model, integrated economics to financial economics, industrial economics and so on. It makes economics become a leading subject in social science.

Economics has also been one of the subjects with most abundant outputs of papers in social sciences. Therefore bibliometric methods have been used in economics. For instance, by bibliometric analysis, Hodgson and Rothman (1999) found that, as the first economic power, USA also dominated the economics research. 79.9 % authors of the 15 top journals in 1995 came from USA. Sutter et al. (2002) statistically analyzed the institutions and educational backgrounds and the contributions of European authors in top 10 journals of economics. Some works were related to the cooperative Innovation. Schymura and Löschel (2014) made a survey on the collaboration ratio and degree among the authors in Journal of Environmental Economics and Management (JEEM). Bidault and Hildebrand (2014) analyzed the influence of collaboration on authors' output quality. In the aspect of theory, Sutter and Kocher (2001) showed an interesting phenomenon: in economics,

personal research outputs of authors satisfy Lotka's law, while research outputs of institutions meet Zipf's law.

In addition to the analysis of authors, bibliometrics is also applied to the measurements of research outputs and impact of journals, institutions and countries/territories in economics. Based on citation analysis, Azar (2007) ranked the journals of behavioral economics and social economics. Hoepner et al. (2012) evaluated the most influential articles, journals, authors and institutions of environmental ecological economics in twenty-first century. At countries/territories level, Guimarães (2002) found that although the economics research output in Portugal increased, the productivity decreased; By sorting out Chinese economic researches, Du and Teixeira (2012) argued that their scope of influence was mainly limited to China and USA. Moreover, the measurement method applied to the evaluation of development and impact on various subdisciplines of economics. Costanzaa et al. (2004) observed the publications in ecological economics for the internal influence and the impact on other subjects by citation analysis. Wagstaffa and Culyerb (2012) showed the development and changes of health economics in 40 years by bibliometrics.

These studies prove that bibliometrics could be used to explore the history, current situation and development of economics. As an important element of academic system, science funding can also become an interesting topic for bibliometric analysis.

Scientometric analysis for funding

For supporting the basic research, science funding is one of the most important ways used in major countries/territories widely. Governments of most countries attached more importance to the funding system and allocated enormous amount of money to support the academic research. Thus the academia has a strong demand for the clarification of the related output and performance. Bibliometrics and scientometrics provide the best quantitative tools to meet this demand. In recent years, the scientometric analysis of science funding can be divided into the three categories.

1. Empirical study at macro level. Wang et al. (2012) analyzed the science funding status of the countries whose numbers of SCI papers ranked top 10 in 2011. This work divided the institutional models of countries/territories into single-institution oriented, double-institutions oriented and multi-institutions oriented based on the data in WoS and CNKI (China National Knowledge Infrastructure). Zhou and Tian (2014) explored the status of mathematics funding in all districts of China. They found that the distribution of funding was very uneven, and Beijing, Shanghai and Jiangsu ranked ahead. Another macro aggregation level in scientometrics, subject, also could be a valuable perspective. Xu et al. (2015) reported that the funding ratio in social sciences is just around 1/3 as much as that in natural sciences.
2. Researches on the role of funding in scientist training, research innovation and collaboration. Jain et al. (1998) denoted that SERC (Science and Engineering Research Council) funding provided many positions for chemistry doctorates and university curriculums. Meanwhile, it established friendships and collaborations among project participants, and provided a great deal of help to scientist training and international collaboration. Ubfal and Maffioli (2011) empirically explained funding had a positive and significant impact on the collaboration and outputs of researchers. Tan et al. (2012a, b) drew a funding collaboration network of 40 countries/territories and showed that China collaborated much more with USA than other countries. These works show

that scientometrics analysis also can help researchers to investigate the detailed feature of funding and the related scientific activity.

3. Specific measures for funding. In general, many underlying indicators or new measures in bibliometrics could work in scientometrics analysis of funding. And some specific measures for funding analysis also will be interesting. For example, after putting forward the h-index of funding (Zhao et al. 2009), Zhao and Ye (2011) introduced input–output measure, denoted as h-Efficiency index, which combined the h-index of funded papers supporting by a certain kind of funding and the expenditure investment of this funding.

Previous studies predicted that, based on the repeatable data source and standard tools coming from scientometrics, the large scale quantitative study of funding can be one of the best ways to understand the pattern and performance of current funding. This method provides basic facts and reference data for domain experts and scholars, and thus could help administrators to review the field in long-term perspective. For the funding system, scientometric analysis leads to a new supplemental method for peer review in many disciplines. Here we will try to use it to explore the funding pattern in a significant social subject, economics.

Datasets and methods

Based on the data of SSCI indexed journals in citation database of WoS, we collected the 100,275 research papers published from 2009 to 2014 in the subject category of 'ECONOMICS'. The original data were divided into two categories: 'All papers' and 'Funded Papers'. 'All papers' refers to all the funded and none-funded papers, while 'Funded papers' refers to the papers supported by at least one science funding in 'All papers'. The core retrieval strategy of 'Funded papers' in this article is as follows:

$$\begin{aligned} FO = (&a^* \ or \ b^* \ or \ c^* \ or \ d^* \ or \ e^* \ or \ f^* \ or \ g^* \ or \ h^* \ or \ i^* \ or \ j^* \ or \ k^* \\ &or \ l^* \ or \ m^* \ or \ n^* \ or \ o^* \ or \ p^* \ or \ q^* \ or \ r^* \ or \ s^* \\ &or \ t^* \ or \ u^* \ or \ v^* \ or \ w^* \ or \ x^* \ or \ y^* \ or \ z^* \ or \ 1^* \ or \ 2^* \ or \ 3^* or \ 4^* \ or \ 5^* \ or \\ &6^* \ or \ 7^* \ or \ 8^* \ or \ 9^* \ or \ 0^*) \end{aligned}$$

In the retrieval strategy, we used 'FO' to search all the types of fundings. The retrieval formula covers 26 English letters and 10 Arabia digital characters, together with truncation symbol *, to match the names of fundings to ensure all funded papers can be determined. We further defined the countries/territories and publication time in the original data and computed the following groups of underlying indicators (or results):

(a) The numbers of highly cited papers and uncited papers among all the 100,275 papers and 8342 funded papers;
(b) The papers, funded papers and h index of the countries/territories whose number of SSCI economic papers in 2009–2014 ranked in top 30;
(c) The funding ratios of the countries/territories;
(d) The list and data of major funding agencies for economics in 2009–2014.

In addition, Table 1 describes the basic indicators used in the empirical study.

Table 1 Major measures in this study

Indicators	Description/definition
Highly cited papers	It refers to the papers ranked in the forefront of the discipline by citations in a statistical period, which represents a significant progress or high impact work in the discipline to a certain extent. Here we use the concrete definition given by Essential Science Indicators (ESI), a basic analysis and evaluation tool to measure scientific performance and track scientific development trend launched by ISI in 2001. The highly cited papers are the papers ranked 1 % in the related discipline by citations in the past decade
Uncited papers	Uncited papers refers to the papers which have not been cited since published. Although time seem a major factor for uncitedness, uncited papers are obviously not a positive indicator for any author
h-Index	H index means there are h papers been cited at least h times (Hirsch 2005). It can combine the impact with the quantity of important papers at the same time. It is the most famous new index for academic evaluation in the past 10 years
Funding ratio, F_r	The ratio of funded papers to all papers. This indicator is used to measure the scope of funding support for the countries/territories and other scientific entities (see Eq. 1) $F_r = \frac{N_F}{N} \times 100\,\%$ (1) N is the total number of papers, and N_F represents the total number of funded papers
ESI highly cited papers ratio, ESIR	It refers to the ratio of ESI highly cited papers to all papers, which is used to measure the impact of papers for the countries/territories and other scientific entities (see Eq. 2) $ESIR = \frac{N_E}{N} \times 100\,\%$ (2) N denotes the total number of papers, and N_E is the ESI highly cited papers
Uncited papers ratio, UPR	The ratio of uncited papers to all papers. It is a contrarian indicator to measure the impact of a set of papers. It can be calculated by Eq. 3 $UPR = \frac{N_U}{N} \times 100\,\%$ (3) N is the total number of papers, and N_U represents the number of uncited papers
Funding ratio of ESI highly cited papers, EFR	The ratio of funded papers to total ESI highly cited papers, which is calculated by Eq. 4 $EFR = \frac{N_{FE}}{N_E} \times 100\,\%$ (4) N_{FE} represents the number of highly cited funded papers, and N_E denotes the number of ESI highly cited papers
Ratio of funded papers to uncited papers, UFR	The ratio of funded papers to total uncited papers, which is calculated by Eq. 5 $UFR = \frac{N_{FU}}{N_U} \times 100\,\%$ (5) N_{FU} is the number of uncited funded papers, and N_U denotes the number of uncited papers in all papers

Results and discussion

Overall profiles of science funding in global economics

Funding ratios of global economics in 2009–2014

Although economics has been considered as a very important subject in social sciences, the funding ratio of economics in 2009–2014 is only 8.3 %. Compared with the funding ratio

of natural sciences in 2009–2010 (56.5 %), this funding ratio is even substantially lower, and it is also much lower than the average funding ratio of social sciences in 2009–2013 (22.4 %) (Xu et al. 2015). Even it is only half of the funding ratio in another important social subject, management.[1] However, as shown in Table 2, the funding ratio of international economics research has been improved in 2009–2014. The sole good news is the funding ratio in 2014 has increased by 38.4 % than that in 2009.

Table 2 presents the highly cited papers and uncited papers of economics in 2009–2014. During the 6 years, there are 850 ESI highly cited economics papers, including 123 funded papers. In economics, the funding ratio of highly cited paper (14.47 %) is largely higher than that of all papers. It indicates that, the fundings for economics, actually, support more high impact researches. On the other hand, there are 5.56 % funded papers which had not been cited. This uncited ratio is much lower than that of all economics papers. On the significance of citation analysis, citation is related to academic impact of papers. Our data shows that, though the funding ratio of economics seems not high, science funding effectively plays a role of promoting high-impact researches and decreasing uncited papers in this field.

Distribution of economics funded papers in the countries/territories

Currently, most science fundings mainly support researchers in their own countries/territories. Thus, it's meaningful to discuss and compare the output of fundings in various countries/territories. Table 3 presents the funded papers of the major countries/territories whose number of all SSCI indexed papers ranks in top 20.

For economic powers, their funded papers and ratios are unevenly distributed. In 2009–2014, both the number of papers and funded papers of economics in USA ranked first, which was 3 times as much as second one, England. However, the economics funding ratio of USA was only 8.98 % (ranked 13th), lower than that of the world average. China had published 4983 SSCI indexed papers of economics in the same period, ranking 6th, and the number of funded papers was 3rd. Meanwhile, China's funding ratio was about 17.18 %, ranking first. This result is consistent with the conclusion drawn by natural science and social science (Tan et al. 2012a, b; Xu et al. 2015) that funding ratio of China ranked first in the major countries/territories. In addition, Canada and Denmark also had higher funding ratio in economics, while that of Turkey and Ukraine was less than 4 %.

To some extent, funding ratio can describe the scope and coverage breadth of funding in a certain country/territory. Thus, we calculated the number of all papers, funded papers and funding ratio of the top 20 countries/territories mentioned above in 2009–2014 yearly, as shown in Table 4. It is shown that most countries/territories had expanded the scope of funding in economics. The funding ratio of China in 2014 was about 20 %, ranking ahead and approaching the average level (22 %) of social sciences (Xu et al. 2015) in the world.

To conclude, according to their changes in funding ratio, we found the 20 countries/territories can be divided into four types, as following.

1. *Overall drop* It includes Switzerland, Taiwan and Turkey, whose funding ratio in 2014 was lower than that in 2009 (see Fig. 1a). Their changes of funding ratio contrast with the world trend.

[1] By the retrieval and calculation and in WoS database, we found the funding ratio of SSCI indexed papers in management ('MANAGEMENT' category) in 2009–2014 is 16.9 %.

Table 2 Profile of SSCI indexed papers and funded papers in global economics in 2009–2014

Period	Papers (N)	Funded papers (N_F)	Funding ratio (F_r)	ESI highly cited papers (N_E)			Uncited papers (N_U)		
				N	N_F	F_r (%)	N	N_F	F_r (%)
2009	14,697	1023	6.96	125	20	16.00	2418	64	2.65
2010	15,716	1246	7.93	126	16	12.70	3064	87	2.84
2011	16,381	1413	8.63	145	21	14.48	3753	138	3.68
2012	17,691	1439	8.13	163	16	9.82	5430	218	4.01
2013	17,916	1499	8.37	150	24	16.00	7381	396	5.37
2014	17,874	1722	9.63	141	26	18.44	12,205	1000	8.19
2009–2014	100,275	8342	8.32	850	123	14.47	34,251	1904	5.56

Table 3 SSCI indexed papers and funded papers of top 20 countries/territories in economics from 2009 to 2014

Countries/territories	Papers	Rank_1	Funded papers	Rank_2	Funding ratio (%)	Rank_3
USA	35,974	1	3230	1	8.98	13
England	11,449	2	1044	2	9.12	12
Germany	8839	3	630	5	7.13	16
France	5364	4	436	9	8.13	14
Australia	5233	5	541	6	10.34	9
People's Republic of China	4983	6	856	3	17.18	1
Italy	4881	7	332	10	6.80	17
Spain	4870	8	534	7	10.97	6
Canada	4795	9	753	4	15.70	2
Netherlands	4457	10	482	8	10.81	7
Japan	2901	11	195	14	6.72	18
Switzerland	2289	12	224	12	9.79	10
Taiwan	2285	13	174	17	7.61	15
Sweden	2034	14	215	13	10.57	8
Belgium	2001	15	253	11	12.64	4
South Korea	1877	16	182	16	9.70	11
Turkey	1532	17	49	19	3.20	19
Denmark	1406	18	193	15	13.73	3
Norway	1362	19	158	18	11.60	5
Ukraine	1215	20	3	20	0.25	20

2. *Overall stability* Some developed countries/territories, such as USA, England, Germany, France, Italy, and Japan, belong to this type. Their changes of funding ratio in 2009–2014 were stable in the range of 5 % (see Fig. 1b). Most of these countries/territories are also economic powers. And their academic outputs as well as funding systems remained in a stable state.

Table 4 The changes of funded papers of top 20 countries/territories in economics from 2009 to 2014

Countries/territories	2009			2010			2011			2012			2013			2014		
	N	N_F	F_r (%)	N	N_F	F_r (%)	N	N_F	F_r (%)	N	N_F	F_r (%)	N	N_F	F_r (%)	N	N_F	F_r (%)
USA	5559	422	7.59	5807	493	8.49	5975	573	9.59	6079	570	9.38	6248	542	8.67	6306	630	9.99
England	1633	135	8.27	1679	166	9.89	1839	175	9.52	2033	182	8.95	2103	198	9.42	2162	188	8.70
Germany	1147	85	7.41	1231	73	5.93	1369	110	8.04	1522	92	6.04	1752	123	7.02	1818	147	8.09
France	685	41	5.99	788	62	7.87	875	82	9.37	931	78	8.38	1068	84	7.87	1017	89	8.75
Australia	660	60	9.09	825	71	8.61	761	82	10.78	942	92	9.77	1033	119	11.52	1012	117	11.56
People's Republic of China	538	90	16.73	571	106	18.56	711	101	14.21	865	151	17.46	1075	163	15.16	1223	245	20.03
Italy	624	34	5.45	697	44	6.31	762	55	7.22	869	50	5.75	939	73	7.77	990	76	7.68
Spain	647	61	9.43	737	96	13.03	812	95	11.70	836	89	10.65	900	91	10.11	938	102	10.87
Canada	714	86	12.04	804	128	15.92	770	136	17.66	809	128	15.82	840	129	15.36	858	146	17.02
Netherlands	640	51	7.97	659	74	11.23	721	80	11.10	769	81	10.53	839	94	11.20	829	102	12.30
Japan	443	23	5.19	453	25	5.52	457	39	8.53	507	29	5.72	521	31	5.95	520	48	9.23
Switzerland	284	29	10.21	339	36	10.62	369	37	10.03	403	39	9.68	473	52	10.99	421	31	7.36
Taiwan	249	28	11.24	325	23	7.08	370	27	7.30	475	25	5.26	441	31	7.03	425	40	9.41
Sweden	283	24	8.48	278	28	10.07	348	33	9.48	344	43	12.50	341	37	10.85	440	50	11.36
Belgium	250	17	6.80	299	40	13.38	330	49	14.85	351	42	11.97	393	47	11.96	378	58	15.34
South Korea	230	17	7.39	282	16	5.67	310	27	8.71	317	36	11.36	343	35	10.20	395	51	12.91
Turkey	202	10	4.95	241	7	2.90	235	6	2.55	288	9	3.13	281	4	1.42	285	13	4.56
Denmark	178	17	9.55	189	31	16.40	217	28	12.90	260	41	15.77	258	37	14.34	304	39	12.83
Norway	180	15	8.33	212	17	8.02	227	25	11.01	208	26	12.50	232	33	14.22	303	42	13.86
Ukraine	177	0	0.00	228	1	0.44	375	1	0.27	412	0	0.00	10	1	10.00	13	0	0.00

N indicates the number of papers; N_F represents the number of funded papers of the year; F_r is funding ratio

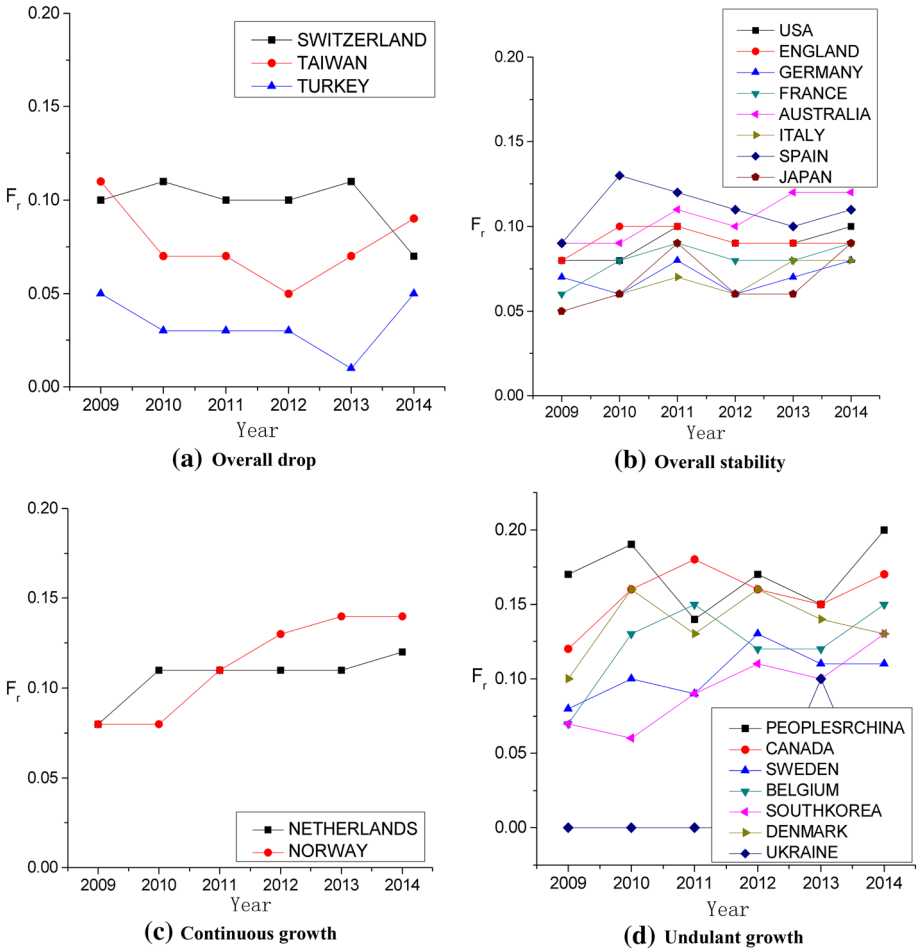

Fig. 1 Four categories of changes in funding ratios

3. *Continuous growth* This specific type involves two innovative and developed countries, Norway and Netherland. They had continued growth of the funding ratio during 2009–2014 (see Fig. 1c).
4. *Undulant growth* This one includes some up and coming countries/territories, like China, Canada and South Korea, whose funding ratios had improved in general with fluctuation. The difference between maximum and minimum values of every year exceeded 5 % (see Fig. 1d). Yet, in general, these countries/territories had improved the scope of funding support during 2009–2014.

Distribution of high impact funded papers in the countries/territories

As the set of research papers actually attracted more attention by academic community, highly cited papers are related to the hotspots and developments of their own or related subject. Table 5 demonstrates the ESI highly cited papers of 20 countries/territories,

including the funded papers. It reveals that USA far exceeds other countries by 578 highly cited papers, and it had an unshakable leading position in economics research. Despite keeping the high impact and quantity of papers at the same time is very difficult, USA's ratio of highly cited papers ranked second, just lower than Netherlands, another well-known innovative country. England also did well in highly cited papers with the number of 20 $\sim$ 30 annually. China had published 34 ESI highly cited papers in the 6 years, including 5 funded papers. But the number of highly cited papers, the ratio of highly cited papers and the ratio of funded highly cited papers of this country just ranked 15th, 17th, and 12th respectively. For China, both the impact of research and effectiveness of funding need to be improved.

Uncited papers of countries/territories supported by funding

Different from the positive perspective of highly cited papers, the number of uncited papers, at least for now, can be considered as a negative indicator to evaluate the impact of papers. Table 6 gives the statistics of uncited papers in the countries/territories whose number of economics papers ranked top 20 in 2009–2014. Although USA produced a large

Table 5 The funding ratio and related measures of highly cited papers for 20 countries/territories

Countries/territories	Total papers				Funded papers				EFR (%)	Rank
	N	N_E	ESIR (%)	Rank	N	N_E	ESIR (%)	Rank		
USA	35,974	578	1.61	2	3230	76	2.35	5	13.15	14
England	11,449	163	1.42	4	1044	31	2.97	3	19.02	8
Germany	8839	81	0.92	10	630	14	2.22	7	17.28	9
France	5364	40	0.75	13	436	10	2.29	6	25.00	5
Australia	5233	45	0.86	11	541	12	2.22	8	26.67	3
People's Republic of China	4983	34	0.68	15	856	5	0.58	17	14.71	12
Italy	4881	37	0.76	12	332	6	1.81	10	16.22	11
Spain	4870	35	0.72	14	534	8	1.50	12	22.86	6
Canada	4795	63	1.31	7	753	9	1.20	15	14.29	13
Netherlands	4457	116	2.60	1	482	15	3.11	2	12.93	15
Japan	2901	12	0.41	16	195	5	2.56	4	41.67	2
Switzerland	2289	30	1.31	8	224	3	1.34	14	10.00	17
Taiwan	2285	6	0.26	19	174	1	0.57	18	16.67	10
Sweden	2034	30	1.47	3	215	3	1.40	13	10.00	16
Belgium	2001	24	1.20	9	253	2	0.79	16	8.33	18
South Korea	1877	7	0.37	17	182	3	1.65	11	42.86	1
Turkey	1532	5	0.33	18	49	0	0.00	19	0.00	19
Denmark	1406	19	1.35	6	193	4	2.07	9	21.05	7
Norway	1362	19	1.40	5	158	5	3.16	1	26.32	4
Ukraine	1215	0	0.00	20	3	0	0.00	20	0.00	20

N denotes the number of all papers; N_E represents the number of ESI highly cited papers; ESIR represents the ratio of highly cited papers; EFR represents the ratio of funded highly cited papers

number of uncited papers, the ratio was not high. Generally, language has a strong influence on the appearance of uncited papers (Zhao 2015). All the non-native English countries/territories, such as China, France, Spain, and Japan, could have a relatively high ratio of uncited papers. But, our results reveal that, for funded papers, the uncited ratio of China ranked first and was almost twice that of other major non-native English countries/territories, like Japan. In conclusion, compared with other powers, the funding support of China produces less high impact papers and more uncited papers. The government and scientific community of China need to improve this situation.

In order to explore the changes of uncited papers over time for each country/territory, we counted uncited papers and uncited funded papers of each country/territory in 2009–2014 annually. It is well-known that time has a significant influence on the accumulation of citations. Thus the uncited ratio of all samples in this study increased year by year without exception. We also observed the ratios of uncited funded papers were lower than that of uncited papers in most of the top 20 countries/territories except Turkey, whose ratio of uncited funded papers was higher than that of total uncited papers in 2010, 2011, and 2013. Our data also shows that some countries with high funding ratio, such as China, Canada and Norway, may not have low ratio of uncited papers in each year. Norway's ratio

Table 6 The uncited papers of 20 countries/territories

Countries/territories	Total papers				Funded papers				UFR (%)	R_U
	N	N_U	UPR (%)	R	N	N_U	UPR (%)	R		
USA	35,974	9313	25.89	17	3230	606	18.76	13	6.51	9
England	11,449	2942	25.70	18	1044	154	14.75	19	5.23	14
Germany	8839	2635	29.81	11	630	147	23.33	6	5.58	12
France	5364	1834	34.19	8	436	94	21.56	8	5.13	15
Australia	5233	1691	32.31	10	541	89	16.45	18	5.26	13
People's Republic of China	4983	1749	35.10	7	856	209	24.42	5	11.95	1
Italy	4881	1578	32.33	9	332	68	20.48	10	4.31	18
Spain	4870	1762	36.18	6	534	117	21.91	7	6.64	8
Canada	4795	1427	29.76	12	753	145	19.26	12	10.16	3
Netherlands	4457	1069	23.98	20	482	89	18.46	15	8.33	5
Japan	2901	1190	41.02	5	195	60	30.77	2	5.04	16
Switzerland	2289	621	27.13	15	224	40	17.86	16	6.44	10
Taiwan	2285	985	43.11	4	174	48	27.59	3	4.87	17
Sweden	2034	559	27.48	14	215	46	21.40	9	8.23	6
Belgium	2001	553	27.64	13	253	45	17.79	17	8.14	7
South Korea	1877	855	45.55	3	182	50	27.47	4	5.85	11
Turkey	1532	702	45.82	2	49	25	51.02	1	3.56	19
Denmark	1406	342	24.32	19	193	36	18.65	14	10.53	2
Norway	1362	353	25.92	16	158	32	20.25	11	9.07	4
Ukraine	1215	1110	91.36	1	3	0	0.00	20	0.00	20

N denotes the number of all papers; N_U represents the number of uncited papers; UPR represents the ratio of uncited papers; UFR represents the ratio of funded uncited papers; R is the rank of UPR

of uncited funded papers in 2009 was even as high as 22.2 %. It indicates that, when the funding breadth expands, the funding agencies may provide more projects to the risky program, and these projects may not produce influential results. On the other side, academic community should also consider that, for the subjects whose research cost is relatively lower than natural sciences, such as economics, adopting a more extensive form of financial supporting and encouraging high risk innovation could also be a considerable choice for funding agencies.

Major "sponsors" of economics in the world

Science funding agencies are the key departments providing financial support to academic researches. Thus they become very important organizations for academic development in most major countries/territories. By downloading and analyzing the institutional information of all funded papers of economics in 2009–2014, we got the top 10 science fundings (funding agencies) ranked by funded papers in economics, as shown in Table 7. This result shows an interesting phenomenon. Two kinds of fundings mainly focusing on natural science, the NSF of USA and the NSFC of China, are listed as top 2 in the table. It implies that fundings in natural science also could cover some topics of economics and play an important role in the development of current economics.

Empirical relations between basic measures of funded papers

After giving the profiles of science funding in global economics, here we try to explore the theoretical results of funded papers in economics. Similar to the power law relations in informetrics (Egghe 2005; Zhao and Ye 2013), we find that three underlying measures of funded papers in this subject, including the total citation of funded papers (C), the number of funded papers (P), and the h-index of funded papers (h), present power law type models at countries/territories level. As shown in Fig. 2, the power–law relationship model with a high goodness is fitted between P, C and h. This result reflects: although funded paper is just a specific subset of all papers, the mechanism of them still accords with traditional quantitative law of informetrics and scientometrics. Therefore, exploring the mechanism of funding by informretirc and scientometrics models may be an interesting idea in future researches of science funding. Notably, in Fig. 2, the power exponent of fitting model

Table 7 Top "sponsor" of economics in the world

Fundings/funding agencies	Papers	Rank
National science foundation (NSF)	709	1
National natural science foundation of china (NSFC)	406	2
Economic and social research council	202	3
European commission	196	4
German research foundation	174	5
Natural sciences and engineering research council of Canada	168	6
Social sciences and humanities research council of Canada	143	7
Australian research council	136	8
Spanish ministry of science and innovation	120	9
European Union	100	10

between C and p is close to 1, which indicates there is an approximate linear relationship between them. Namely, for funded paper sets of countries/territories, the citations will be about four times as more as the number of papers.

Global pattern and structure of funded collaboration network in economics

As very important resources to promote the development of science, in addition to promoting the mutual collaboration between domestic scholars, science funding also has the function of strengthening the communication and collaboration (Ebadia and Schiffauerovaa 2015) among international scholars. Therefore, international collaborated papers not only reflect the role of funding agencies to promote global collaborations, but also reveal the relationships of collaborative innovation among the countries/territories.

Based on the datasets of current papers, we tried to explore the collaboration pattern and innovation structure of economics research among countries/territories and the continents by the method of network analysis. After extracting main collaboration links between major countries/territories, we constructed the funded collaboration network of countries/territories in economics during 2009–2014. Figure 3 shows the main structure of this network. In the figure, nodes represent countries/territories, links between nodes denote transnational or interregional collaborations between countries/territories, and thickness of the links reflects the collaboration strength, i.e. the number of collaboration times. In order to display clearly, the figure only contains the countries/territories which have at least 30 collaborations, together with their links. According to the method of h-subnet (Zhao et al. 2014), we abstracted core links of the networks. The h-strength of whole network is 35. And the links, whose strength thresholds are at least 35 (represented by red line in Fig. 3), form the core collaboration structure in overall network.

It is shown that the collaboration between China and USA has the highest strength in the network, reaching 259 times, and the collaboration between England and USA follows it, with 246 times. In Fig. 3, USA has relatively close collaborations with most nodes and stands in the center of whole network. Two subgroups, 'Asia Pacific' and 'Europe', appear

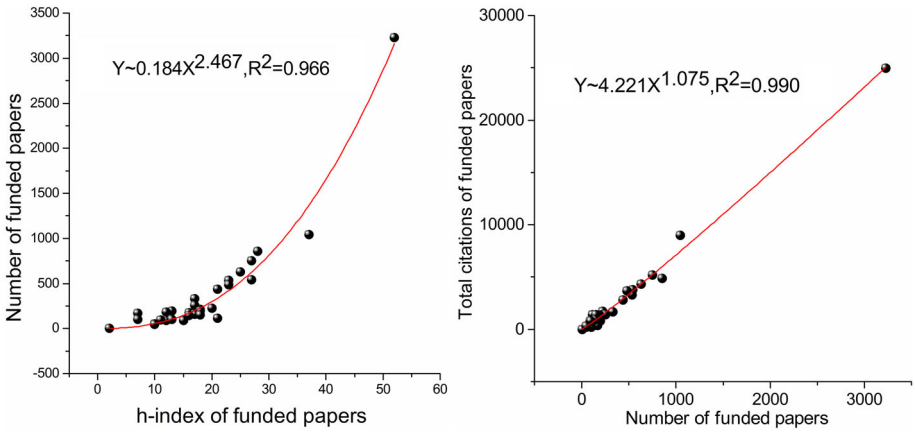

Fig. 2 Power law relationship among the three underlying scientometric measures of funded papers for countries/territories

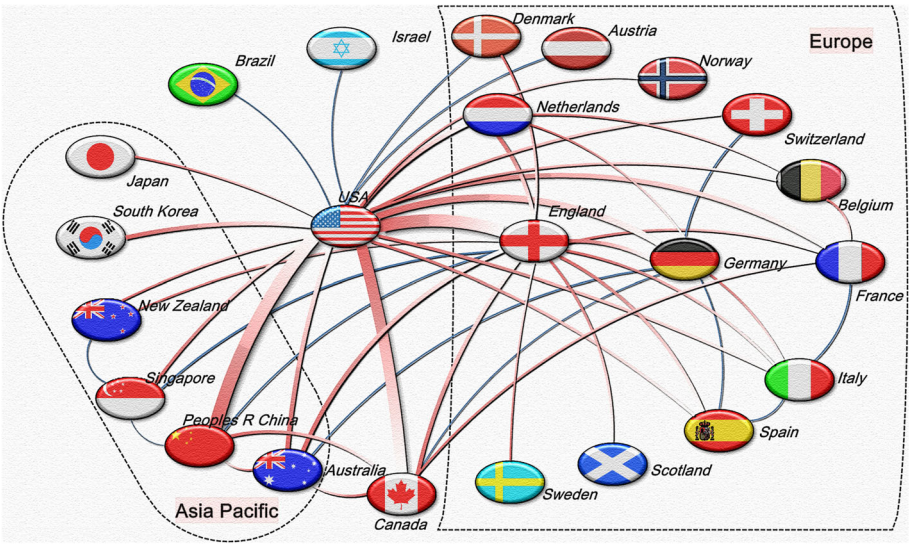

Fig. 3 Main structure of the funded collaboration network of countries/territories in economics in 2009–2014

in the overall network. It is generally similar to the collaboration topology drawn by funded papers of natural science (Tan et al. 2012a, b).

However, there are also important differences. First, in economics, European countries account for half of the main collaboration countries, and England is in the collaboration center of European countries. Its position is significantly higher than Germany, contrarily in natural sciences (Tan et al. 2012a, b). The outstanding performance of England in economics relates closely to the prominent status of its top universities in economics researches. Secondly, different from natural science, Asia–Pacific countries link with each other more frequently and closely in economics. The increasing economic collaborations among APEC member countries may have a significant impact on the research collaboration. Last, due to the controversial issues in politics and economics between China and

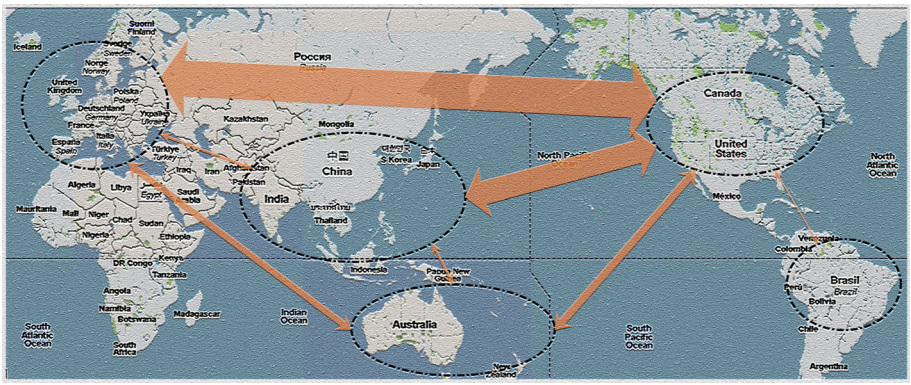

Fig. 4 Intercontinental funded collaboration network of economics during 2009–2014

Japan in recent years, these two neighboring countries don't have high strength collaboration in economics research.

Expanding the analysis perspectives to the continents, we construct intercontinental collaboration networks of funded economics papers. As demonstrated in Fig. 4, the links in the figure represent intercontinental research collaborations between the main countries of continents, while the thickness of the links represents collaboration strength. The intercontinental collaborations mainly present three triangular collaborations:

1. Europe, Asia, and North America compose the main triangular relation. The collaboration between Europe and USA is the core intercontinental collaboration, leading the collaborative research structure of the world in economics, followed by North America and Asia, whose economics research collaboration is also frequent.
2. The second triangular is made by Asia, North USA and Oceania, and the relation between Asia and Oceania is obviously weaker than that between North America and Oceania.
3. The third triangular is made by Europe, Asia and Oceania. The collaboration scale between Europe and Asia is not obvious, even lower than the collaboration between Europe and Oceania, which is 2.3 times the former collaboration strength. From a global perspective, the most developed region, North America, keeps close research collaborations in economics with other continents, and Asia has weak collaboration with other continents except North USA. In addition, the collaboration link between North America and South America is also relatively weak.

Conclusion and outlook

In conclusion, the funding analysis of economics during 2009–2014 shows that, though the funding ratio of global economics researches rises year by year, it is still obviously lower than the overall level of natural sciences and other social sciences. In spite of this, funding plays an important role in promoting high-impact researches and decreasing uncited papers in economics. Based on the funded papers and citations of the countries/territories, we found that the numbers of papers, funded papers, highly cited papers of USA and England were far ahead of other major countries/territories. However, their funding ratios were below the world average. By contrast, the funding ratio of China ranked 1st, but its efficiency of funding system and academic impact of funded papers need to be improved. According to the changes of funding ratio in recent years, we found major countries/territories can be categorized into four types with specific features: 'overall drop', 'overall stability', 'continuous growth' and 'undulant growth'.

On the theoretical aspect, we further explored the relations between basic measures of funded papers and found that there is an approximate power–law relationship among the numbers of funded papers, citations of funded papers and h-index of funded papers. The network analysis shows that, the collaboration of economics researches presents a core network structure containing three main components: the central part (USA) and two core groups (Asia Pacific and Europe). USA and Europe made a have a close connection in economics, which leads the collaboration and innovation of economics researches in the world.

Based on the emerging approach of scientometric funding analysis, we analyzed the global pattern of science funding in economics during 2009–2014. It may provide

reference for future policy making in economics as well as the related social sciences. However, there are still some limitations in the work: The scope of data just contains SSCI indexed papers; the period of data is limited to 2009–2014; and the method of academic impact is still confined to citation analysis. In future study, we will try to use various databases, which could cover different languages and wider range of research papers, to compare the differences of funded outputs between Economics, Management, Psychology, Sociology, and other mainstream social sciences. In addition, the further investigation may also consider combining the academic outputs with the financial investment of funding, and lead to concise and creative input–output models of science funding.

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References

Azar, O. H. (2007). Behavioral economics and socio-economics journals: A citation-based ranking. *The Journal of Socio-Economics, 36*(3), 451–462.

Bidault, F., & Hildebrand, T. (2014). The distribution of partnership returns: Evidence from co-authorships in economics journals. *Research Policy, 43*(6), 1002–1013.

Costanzaa, R., Sternb, D., Fisher, B., He, L. N., & Ma, C. B. (2004). Influential publications in ecological economics: A citation analysis. *Ecological Economics, 50*, 261–292.

Du, Y., & Teixeira, A. A. C. (2012). A bibliometric account of chinese economics research through the lens of the china economic review. *China Economic Review, 23*(4), 743–762.

Ebadi, A., & Schiffauerova, A. (2016). How to boost scientific production? A statistical analysis of research funding and other influencing factors. *Scientometrics,*. doi:10.1007/s11192-015-1825-x).

Ebadia, A., & Schiffauerovaa, A. (2015). How to become an important player in scientific collaboration networks? *Journal of Informetrics, 9*(4), 809–825.

Egghe, L. (2005). *Power laws in the information production process: Lotkaian informetrics*. Oxford: Elsevier.

Guimarães, P. (2002). The state of Portuguese research in economics: An analysis based on publications in international journals. *Portuguese Economic Journal, 1*(1), 3–25.

Hirsch, J. E. (2005). An index to quantify an individual's scientific out-put. *Proceedings of the National Academy of Sciences of the United States of America, 102*(46), 16569–16572.

Hodgson, M. G., & Rothman, H. (1999). The editors and authors of economics journals: A case of institutional oligopoly? *The Economic Journal, 109*(453), 165–186.

Hoepner, A. G. F., Kant, B., & Scholtens, B. (2012). Environmental and ecological economics in the 21st century: An age adjusted citation analysis of the influential articles, journals, authors and institutions. *Ecological Economics, 77*, 193–206.

Jain, A., Garg, K. C., Sharma, P., & Kumar, S. (1998). Impact of SERC's funding on research in chemical science. *Scientometrics, 41*(3), 357–370.

Schymura, M., & Löschel, A. (2014). Incidence and extent of co-authorship in environmental and resource economics: Evidence from the journal of environmental economics and management. *Scientometrics, 99*(3), 631–661.

Shapira, P., & Wang, J. (2010). Follow the money. *Nature, 468*(7324), 627–628.

Sutter, M., & Kocher, M. G. (2001). Power laws of research output. Evidence for journals of economics. *Scientometrics, 51*(2), 405–414.

Sutter, M., Kocher, M., & Masic, R. (2002). Representation and educational background of European economists in top journals of economics. *Empirica, 29*(4), 275–288.

Tan, A. M., Zhao, S. X., & Ye, F. Y. (2012a). Characterizing the funded scientific collaboration network. *Current Science, 103*(11), 1261–1262.

Tan, A. M., Zhao, S. X., & Ye, F. Y. (2012b). Funds promote scientific output. *Current Science, 102*(4), 542–543.

Ubfal, D., & Maffioli, A. (2011). The impact of funding on research collaboration: Evidence from a developing country. *Research Policy, 40*(9), 1269–1279.

Vardakas, K. Z., Tsopanakis, G., Poulopoulou, A., & Falagas, M. E. (2015). An analysis of factors contributing to PubMed's growth. *Journal of Informetrics, 9*(3), 592–617.

Wagstaffa, A., & Culyerb, A. J. (2012). Four decades of health economics through a bibliometric lens. *Journal of health Economics, 31*(2), 406–439.

Wang, X., Liu, D., Ding, K., & Wang, X. (2012). Science funding and research output: A study on 10 countries. *Scientometrics, 91*(2), 591–599.

Wang, J., & Shapira, P. (2011). Funding acknowledgement analysis: An enhanced tool to investigate research sponsorship impacts: the case of nanotechnology. *Scientometrics, 87*(3), 563–586.

Xu, X., Tan, A. M., & Zhao, S. X. (2015). Funding ratios in social science: The perspective of countries/territories level and comparison with natural sciences. *Scientometrics, 104*(3), 673–684.

Zhao, S. X. (2015). Uncitedness of reviews. *Current Science, 109*(8), 1377–1378.

Zhao, X., Gao, X., & He, P. (2009). The h-index of science funding: Comprehensive characterization of the quantity and impact of funded papers. *Bulletin of National Natural Science Foundation of China, 23*(1), 15–18. **(in Chinese)**.

Zhao, S. X., & Ye, F. Y. (2011). h-Efficiency: Measuring input–output performance of research funds. *Current Science, 101*(1), 21–22.

Zhao, S. X., & Ye, F. Y. (2013). Power–law link strength distribution in paper cocitation networks. *Journal of the American Society for Information Science and Technology, 64*(7), 1480–1489.

Zhao, S. X., Zhang, P. L., Li, J., Tan, A. M., & Ye, F. Y. (2014). Abstracting the core subnet of weighted networks based on link strengths. *Journal of the Association for Information Science and Technology, 65*(5), 984–994.

Zhou, P., & Tian, H. (2014). Funded collaboration research in mathematics in China. *Scientometrics, 99*(3), 695–715.