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Knowledge flow in China's humanities and social sciences

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Abstract Despite fruitful studies on knowledge flow and interdisciplinarity, there are few investigations on knowledge flow in humanities and social sciences (HSS) and how knowledge from science and technology diffuses to HSS sub-disciplines. Based on Chinese and English articles in HSS, this study explored knowledge flow in China's HSS with an analysis of Chinese and English publications from 1998 to 2014. Findings include: (1) the interdisciplinarity degree of knowledge absorption in social sciences is higher than that of humanities in both Chinese and English articles, meanwhile the degree of interdisciplinarity in all HSS sub-disciplines increased constantly; (2) Chinese scholars in HSS increasingly tended to learn knowledge in hard sciences and applied it to their domains, especially in English articles; (3) in Chinese articles, Economics was the most crucial knowledge base, while Management, Education and Law were absorption-oriented sub-disciplines; in English articles Management, Law, Literature and Philosophy were absorption-oriented sub-disciplines.

Keywords Knowledge flow · Knowledge absorption · Interdisciplinarity · Humanities and social sciences · Hard sciences

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1 Introduction

Exploring disciplinary knowledge flow in humanities and social sciences (HSS) contributes to deeper understanding of the process of knowledge diffusion and reproduction. Knowledge flow is rapidly becoming one of the paramount factors of value creation in business activities (Hagel et al. 2009) as well as in academia. In different contexts, there are different definitions for knowledge flow. In the domain of information science, knowledge flow refers to a phenomenon of knowledge in a specific subject field utilized by another (Tsay 2015) It has been demonstrated that scientists increasingly depend on knowledge flow to produce research outcomes (Zhuge 2006). The creation of knowledge is not purely determined by a single isolated entity, and knowledge is transferred, shared and circulated among a variety of entities (Yan 2014). Interdisciplinary knowledge flow leads to interdisciplinary research that has a higher possibility to generate innovative breakthroughs for social needs and economic growth than mono-disciplinary research (Rafols and Meyer 2007a). On the other hand, a successful integration involving disparate bodies of knowledge is believed to generate ideas with a high scientific impact (Li and Shi 2016; Schilling and Green 2011; Schilling et al. 2003; Sun et al. 2016). Due to its important role in creating knowledge and even innovation, previous literature has attached great importance to knowledge flow, especially knowledge flow which is interdisciplinary.

In this study, the disciplinary structure and its evolution in knowledge absorption of HSS draw special attention. According to knowledge absorption theories (Liefner et al. 2012), technologically less advanced firms (latecomers) absorb knowledge to update their knowledge base. Similarly, in the academic world, disciplines may extract knowledge from more mature disciplines to produce new advancement. Therefore, by drilling down into the knowledge absorption of sub-disciplines in HSS, we can obtain a greater understanding of knowledge stock of HSS, which is in turn crucial for knowledge creation. Examining the interdisciplinary knowledge flow in China's HSS can help capture the dynamic process of knowledge absorption, diffusion and reproduction in the field.

Studying the knowledge flow in HSS in China should take into account articles written in both Chinese and English. Currently, burgeoning literature on social sciences in China usually places emphasis on English articles indexed by the Web of Science (WoS) (Liu et al. 2015a, b, 2017). However, due to the national orientation of HSS (Zhou et al. 2008) and the fact that many HSS studies in China are still presented in Chinese journals, HSS articles published in domestic journals in China should be incorporated into the analysis. Therefore, in this study, we analyze Chinese articles published in domestic journals and English articles indexed by WoS separately to obtain a complete understanding of the knowledge flow within China's HSS.

Exploring knowledge flow in papers authored by Chinese scholars in HSS also sheds light on how to raise the international visibility of China's HSS. According to statistics from Nature Index, (http://www.natureindex.com/faq) in recent years China has been the second largest contributor to high-quality scientific research articles in the world. However, in the Social Science Citation Index (SSCI), the proportion of articles written by Chinese authors has lagged far behind, indicating China's HSS researchers obtained less international visibility than their peers in hard sciences (Flowerdew and Li 2009; Zhou et al. 2010). Although there are multiple reasons for the low share of HSS papers in international academia [for example, HSS fields are inherently nationally oriented with diverse publication channels in addition to journals (Nederhof 2006; Hammarfelt 2014)], there exist biases for non-English speaking countries in SSCI (Zhou et al. 2010). HSS in China still has a long way to go towards internationalization. Accordingly, analyzing disciplinary

knowledge flow in China's HSS based on a comparative investigation on Chinese articles and English articles is a beneficial attempt to reveal the differences in the knowledge base, knowledge flow and citing behaviors of authors between these two groups of publications.

This study also provides insight into the contribution of hard sciences to HSS in knowledge creation. In recent decades, unprecedented data availability drove researchers in HSS to conduct more quantitative research. Research including both HSS and HS knowledge is considered effective to solve emerging complex problems (Mills et al. 2011; Mooney et al. 2013). In these circumstances more and more HSS researchers borrow knowledge from hard sciences and their publications become more science-oriented. However, limited research has systematically examined this trend in China's HSS research.

Although there is a large body of literature on disciplinary knowledge flow, little attention has been given to quantifying disciplinary knowledge flow in Chinese authors' publications in HSS based on a complete database consisting of both Chinese and English publications. To our knowledge, this is the first systematic study on disciplinary knowledge flow in HSS publications covering both Chinese and English articles published by researchers in China.

Questions surrounding the degree of interdisciplinarity, its evolution over time, and the disciplinary distribution in knowledge absorption in these publications, are yet to be investigated. The knowledge flow across sub-disciplines within HSS publications and its dynamic change are also unclear. Furthermore, the differences in the above two questions between Chinese articles and English articles are not readily apparent. To obtain a better insight into the evolutionary structure of knowledge absorption, this study examines the direct knowledge flow among sub-disciplines within HSS, and the knowledge transfer from hard sciences to HSS. Based on the data of Chinese articles and English articles in HSS published by China from 1998 to 2014, we investigate the following major research questions:

RQ1. How does the degree of interdisciplinarity in HSS evolve?
RQ2. How does knowledge flow across sub-disciplines within HSS?
RQ3. What is the difference of interdisciplinary knowledge flow between Chinese articles and English articles?

Answers to these research questions can provide systematic insights into the process of knowledge absorption, diffusion and creation in China's HSS, disclose different knowledge bases and citation behaviors of authors between Chinese and English articles, and reveal how HSS scholars apply knowledge of hard sciences in their publications.

The remainder of this study is organized as follows. Section 2 briefly reviews the literature on knowledge flow and interdisciplinarity, Sect. 3 introduces the data and methodology applied in this study. Results are provided to answer the major research questions in Sect. 4. Finally, discussion and conclusions are presented in Sect. 5.

2 Literature review

In this section, we briefly review the previous literature on knowledge flow and interdisciplinarity, especially studies focusing on HSS.

2.1 Knowledge flow

As knowledge and the process of knowledge transfer are unobservable, citation figures are typically used as an effective proxy to represent and measure knowledge flow. Citations indicate knowledge flow from the cited entity to the citing one. Among a variety of formal and informal knowledge carriers, articles and patents are employed in citation analysis to capture knowledge flow, through journals (Leydesdorff and Rafols 2011), disciplines (Tsay 2015), institutions (Bornmann and Leydesdorff 2015), countries (Hassan and Haddawy 2013) or authors (Yang and Wang 2015).

As a bidirectional activity, knowledge flow is classified into knowledge diffusion and absorption, considering the direction of citations (Miguélez and Moreno 2015; Liu and Rousseau 2010). Burgeoning literature focuses on disciplinary knowledge flow to unveil patterns of knowledge diffusion across disciplinary boundaries (Yan 2014). In the process of interdisciplinary knowledge flow measured by citations, some disciplines where papers are often cited are regarded as "donors", whereas others with many citing papers are known as "receptors" (Le Pair 1980). This implies that researchers borrow ideas or knowledge from other disciplines to their articles through citations. Therefore, investigating knowledge flow between disciplines is of great importance to reveal the contribution of disciplines in knowledge creation.

Some efforts have been made to examine knowledge flow in HSS. Some early empirical evidence showed that the boundaries of HSS disciplines were not limited (Pierce 1999). Examining the knowledge flow between planning literature and social sciences, Stevens (1990) showed that economics literature is the major knowledge source of planning. Investigating the citation flow and the migration of researchers, Urata (1990) found that HSS disciplines in Japan are not reciprocal. Specifically, philosophy, history and linguistics are knowledge exporters that provide a large amount of knowledge to other disciplines, while education and sociology play the role of importers absorbing knowledge from other disciplines. Another study argued that some information science journals heavily rely on knowledge in communication science journals, as reflected by citations (Borgman and Rice 1992). More recently, knowledge flow into and out of the field of information science was compared, revealing that information science was the major knowledge base of itself, and science and technology also contributed knowledge to it (Tsay 2015). Management science was thought of as a crucial donor for psychology and its main information was in turn acquired from Economics, Psychology and Sociology (Lockett and McWilliams 2005).

2.2 Interdisciplinarity

Interdisciplinarity is closely linked to knowledge flow in most of the current literature as it occurs when knowledge diffuses among different disciplines. The lack of a generic definition of interdisciplinarity has been mentioned in previous studies (Karlovcec and Mladenic 2015). Research can be perceived as interdisciplinary if concepts, research approaches, methods and/or data from different fields of established research are integrated (Levitt et al. 2011; Porter et al. 2007). Researchers have found that interdisciplinarity occurs via various patterns, including borrowing, collaboration, and/or boundary crossing (Pierce 1999). The importance of interdisciplinary research has been increasingly recognized because interdisciplinarity can lead to innovation, creativity, scientific progress, and intellectual breakthroughs (Morillo et al. 2003). For example, in the twenty-first century,

with the emergence of increasingly complicated scientific, technological and social issues, many researchers have argued there is a need to integrate various disciplines (Lee 2013). On the other hand, many increasingly complex social issues require resolutions that embed knowledge from different disciplines (Morillo et al. 2003). Interdisciplinary research has been suggested to be a phenomenon influenced by external drivers, e.g. funding priorities and social needs (Wagner et al. 2011). In recent years, literature on performance measures, management and evaluation of interdisciplinary research have accompanied the growth in interdisciplinary research (Wagner et al. 2011).

The focus of the existing literature is the measurement of interdisciplinarity. Most of these studies utilized SCI and SSCI as the main data source (Wagner et al. 2011), with Scopus (Adams et al. 2007) and Medline (Boyack 2004) being complementary databases. Constant efforts have been made to explore interdisciplinarity using various attributes, e.g., research formulation, team processes, collaboration and research outcomes. For example, it is assumed that cooperation among researchers in different fields can lead to cognitive integration (Porter et al. 2008). However, work co-authored by researchers from different disciplines may sometimes not necessarily bring the knowledge integration essential for interdisciplinary research. In other words, knowledge integration is an epistemological category, where measuring interdisciplinarity should depend on the content of research outcomes, instead of collaboration and affiliation (Rafols and Meyer 2007b; Zhou et al. 2008). Based on research outcomes, citation analysis is the most frequently used bibliometric technique for capturing interdisciplinarity. It is suggested that the degree of authors' knowledge integration by citing references can be more accurately mirrored by citations in authors' articles (Porter et al. 2008). The most common indicator of interdisciplinary research is based on the proportion of citations outside of the discipline of the citing article (Rafols and Meyer 2007a). In other words, when citations to other disciplines occur, knowledge exchange or integration among disciplines may take place (Wagner et al. 2011). To capture the process of knowledge integration, diversity and coherence are two important elements for further investigation (Rafols and Meyer 2010). Several indicators have been proposed to measure interdisciplinarity in research, e.g., Pratt index (Pratt 1977), citation outside category (Porter and Chubin 1985), Brillouin's Index (Kennedy et al. 1986), Shannon entropy (Barjak 2006). In addition, some network indicators are used as a measurement of interdisciplinarity, e.g., betweenness centrality (Leydesdorff and Rafols 2011). To avoid the betweenness centrality being influenced by the journal degree centrality, vectors can be normalized, e.g., by using the cosine measure (Ahlgren et al. 2003).

A number of prior studies have tried to measure the degree of interdisciplinarity in HSS. Looking at the historical evolution of interdisciplinarity from 1900 to 2008 based on 25 million WoS articles, Gingras and Larivière (2010) observed that interdisciplinarity in HSS remained stable from 1980 to 2000 and witnessed a considerable increase after 2000. For social sciences, authors also found that interdisciplinarity declined between 1965 and 1992, with sharp growth after 1994. Similarly, Levitt et al. (2011) concluded that interdisciplinarity in social sciences dropped from 1980 to 1990 and skyrocketed between 1990 and 2000. Information science was proved to have the highest increase in interdisciplinarity among all social sciences disciplines (Levitt et al. 2011).

In summary: although a large body of literature has explored some aspects of interdisciplinarity and knowledge flow, interdisciplinary knowledge flow across HSS sub-disciplines and how HSS draw on hard sciences knowledge remains unclear. The degree of interdisciplinarity in terms of knowledge absorption in HSS, and its dynamic change both deserve a deeper investigation. Furthermore, the difference in knowledge transfer in HSS between Chinese articles and English articles written by Chinese authors is unclear. To

bridge this gap, using Chinese researchers' publication data between 1998 and 2014, this study conducts a complete and systematic study of Chinese articles and English articles in terms of knowledge flow in HSS.

3 Data and method

3.1 Data collection and preprocessing

Our original dataset is comprised of 69,746 English articles with 1,314,402 references and 1,132,115 Chinese articles with 1,941,4897 references in HSS. These articles were published by research institutions in mainland China from 1998 to 2014. English articles were retrieved from the Social Science Citation Index and the Arts & Humanities Citation Index in the Web of Science (WoS), where the addresses include 'People's Republic of China'. Chinese articles were retrieved from the Chinese Social Sciences Citation Index (CSSCI),[1] which is the principal part of China's HSS output. It indexes journal articles published within mainland China, which are rarely written in English.

In this paper, the disciplinary delineation of papers is based on journals, consistent with the strategy in previous studies (Gingras and Larivière 2010). The discipline of the journal determined by ISI subject categories can be assigned to the article that is published in that journal (Porter et al. 2008). As for English articles, we adopted the disciplinary classification systems of journals indexed in SCI, SSCI from Journal Citation Reports (JCR), as well as Library of Congress classifications. On the other hand, the disciplinary classification systems of journals indexed in CSSCI and "A Guide to the Core Chinese Periodicals" (CNKI 2014) laid a foundation of disciplinary delineation regarding Chinese articles.

One journal could be categorized into more than one discipline in WoS. In order to simplify the measurement of interdisciplinarity, the discipline where a journal received the largest number of citations is the discipline to which it belongs. Then, based on citations, we categorized each English journal within our dataset into one of the 227 disciplines provided by the JCR. In CSSCI, each journal is already categorized into one discipline.

The difference of subject categories in SSCI, Arts & Humanities Citation Index (A&HCI) and CSSCI needs to be unified before we could conduct the interdisciplinary analysis. We mapped these three discipline classification systems to the official disciplinary categories system released by the Ministry of Education (MoE) of the People's Republic of China, which is composed of eight HSS sub-disciplines, i.e., Arts, Literature, History, Philosophy, Economics, Law, Management and Education. Among them, Economics, Law, Management and Education are regarded as sub-disciplines in social science, whereas Arts, Literature, History and Philosophy are in humanities. In addition, the MoE category contains four hard sciences disciplines, i.e., Science, Technology, Agriculture and Medicine.

We focused on journal articles so that other types of documents (e.g., books) were eliminated from the dataset. We also excluded references in English articles which were not indexed in WoS, and references in Chinese articles which were neither indexed by CSSCI nor the Guide to the Core Chinese Periodical which indexed a large number of hard sciences journals. After the preprocessing, the dataset contained 900,449 Chinese articles with 2,262,613 references and 37,002 English articles with 1,941,4897 references.

[1] Accessible at: http://cssci.nju.edu.cn/.

3.2 Method

To answer the first research question, this study adopts Brillouin's Index (Kennedy et al. 1986; Allen and Leung 2014) and interdisciplinary citation rates (CR) to capture interdisciplinarity of knowledge absorption in HSS, as shown in Eqs. 1 and 2.

$$Brillouin's\ Index = \frac{\log N! - \sum(\log n_i!)}{N} \tag{1}$$

$$CR_{ij} = \frac{n_{ij}}{N_i}. \tag{2}$$

In Eq. 1, N represents the total number of references and n_i represents the number of references in discipline i. The higher the value of Brillouin's Index, the stronger the interdisciplinary degree and the disciplinary diversity. In terms of Eq. 2, n_{ij} indicates the number of references in discipline i are from discipline j, whereas N_i indicates the total number of references in discipline i. This indicator expresses the comparative citation strength between the citing discipline i and the cited discipline j, implying the knowledge contribution made by cited disciplines to the citing disciplines.

Scientific activities can generate self-organized networks, such as networks of authors, institutions, documents and lexical content. Among these types, citation flow networks are considered in this study, which is also interpretable as knowledge flow or scientific influence. We focus on dynamic networks of citation linkages among sub-disciplines that are considered as the knowledge user (citing disciplines) and the knowledge base (cited disciplines) to investigate the status quo and dynamic evolution of knowledge absorption and diffusion during the sampling years (Zitt 2005). In these networks, weights of edges signify the strength of citation linkage between disciplines and nodes represent disciplines that are involved in the citing or cited activities.

To detect the key sub-disciplines in knowledge absorption and diffusion, we calculated an input–output index to measure the knowledge import and export in each sub-discipline. We defined the input–output index as (outdegree − indegree)/(outdegree + indegree). Disciplines were sorted into two distinct categories. If the value of the input–output index is between 0 and −1, which means outdegree is lower than indegree, the discipline is then regarded as an absorption-oriented discipline which tends to acquire knowledge in humanities and social sciences rather than to spread. Similarly, if the value is between 0 and 1, which means outdegree is larger than indegree, the discipline is thus classified as a diffusion-oriented discipline where spreading knowledge activities play a dominant role. A value of 0 indicates that knowledge absorption (indegree) and diffusion (outdegree) in a discipline are balanced.

4 Results

First, we noted the disciplinary structure in knowledge absorption by analyzing the degree of interdisciplinarity (measured by Brillouin's Index) and disciplinary citation rates. Second, to disclose how knowledge is transferred across sub-disciplines in HSS, knowledge flow networks are provided in different periods of time. Specifically, we detect the key sub-disciplines in knowledge absorption and diffusion, depict the knowledge linkage between sub-disciplines and calculate an input–output index to measure the knowledge import and export in each sub-discipline. In addition, the comparison between Chinese

articles and English articles are displayed throughout this section, with a focus on the role hard sciences play in knowledge absorption in HSS. Self-citation is considered in all the following results. However, we also conduct a similar analysis with self-citations removed, and the general findings remain the same.

4.1 Knowledge absorption in China's HSS

4.1.1 The degree of interdisciplinarity

The interdisciplinarity degree of knowledge absorption in social sciences is higher than that of humanities both in Chinese articles and English articles. This is because during the sampling years, the total average Brillouin's indices of social sciences in Chinese and English articles are 5.187 and 4.992 respectively, higher than those of humanities in Chinese articles (4.600) and in English articles (4.017). A similar trend can be observed in the annual average Brillouin's indices across the years. As shown in Fig. 1, the values of Brillouin's index of social sciences in both Chinese articles and English articles range from 2.3 to 2.7, higher than those in humanities ranging between 0.5 and 2.0, indicating a consistently higher interdisciplinarity degree of social sciences than humanities over the years 1998–2014.

The interdisciplinary degree of knowledge absorption of social sciences in Chinese articles is almost the same as that in English articles while Chinese articles represent a higher degree of interdisciplinarity in humanities than English articles with an approaching trend. As shown in Fig. 1, two trend lines of Brillouin's Index of Chinese articles and English articles in social sciences nearly overlap completely, implying that the interdisciplinarity of knowledge flow in social sciences in Chinese articles resembled that of English articles with a slightly increasing tendency.

In contrast, there were differences between the interdisciplinarity of Chinese articles in humanities and that of English articles. On the whole, the interdisciplinarity of Chinese articles in humanities was higher than that of English articles with a more significant

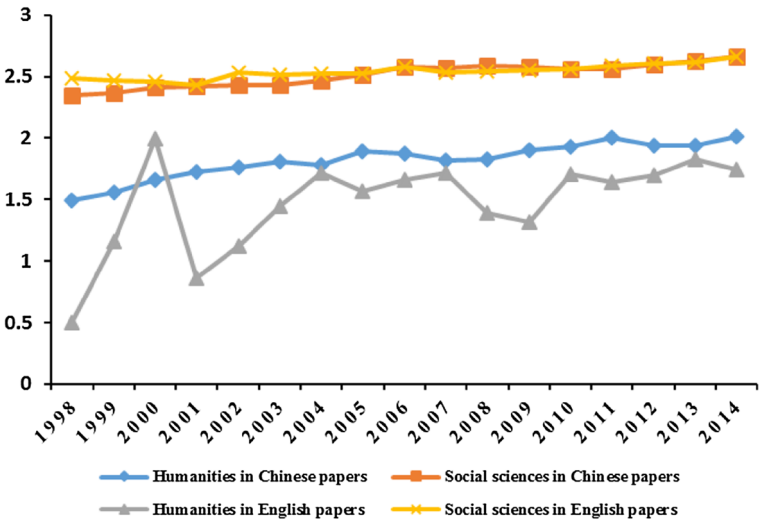

Fig. 1 Brillouin's Index of Chinese articles and English articles in China's HSS from 1998 to 2014

fluctuation. Additionally, the gap between the two narrowed, showing the two Brillouin's Index lines of Chinese articles and English articles in humanities gradually approach each other.

To uncover the interdisciplinary level of sub-disciplines in humanities and social sciences, this study utilised the Brillouin's index of eight sub-disciplines in HSS as shown in Fig. 2. The interdisciplinary diversity of knowledge absorption in all sub-disciplines generally shows a rising trend over the years. In addition, except for Philosophy, other sub-disciplines in humanities are lower in Brillouin's index compared to their counterparts in social sciences. This finding is true in both Chinese articles and English articles. Differences exist not only between social sciences and humanities, but also between sub-disciplines within humanities and those within social sciences. Specifically, in humanities, the interdisciplinary level of knowledge absorption in Philosophy is the strongest, followed by History, Arts, and Language and Literature in Chinese articles. However, in English articles, the Brillouin's index of Language and Literature is higher than those of History and Arts even though Philosophy is still ranked the first. In social sciences, Law holds the highest interdisciplinary diversity while Economics is the lowest in both Chinese articles and English articles.

4.1.2 Knowledge absorption within HSS and from hard sciences

Figure 3 shows the citation rates of humanities/social sciences over the years with the other disciplines and those from hard sciences as cited disciplines. It can be seen that the intradisciplinary citation rate of humanities and social sciences in Chinese articles ranges from 0.836 to 0.901 and from 0.836 to 0.851 respectively, which is higher than those in English articles (from 0.843 to 0.507 for humanities, and from 0.842 to 0.790 for social sciences). This indicates that researchers who publish English articles in HSS tend to acquire knowledge from other disciplines, compared with researchers who publish Chinese articles. On the other hand, in both Chinese and English articles, humanities and social sciences witnessed an increasingly high interdisciplinary citation rate. Agriculture,

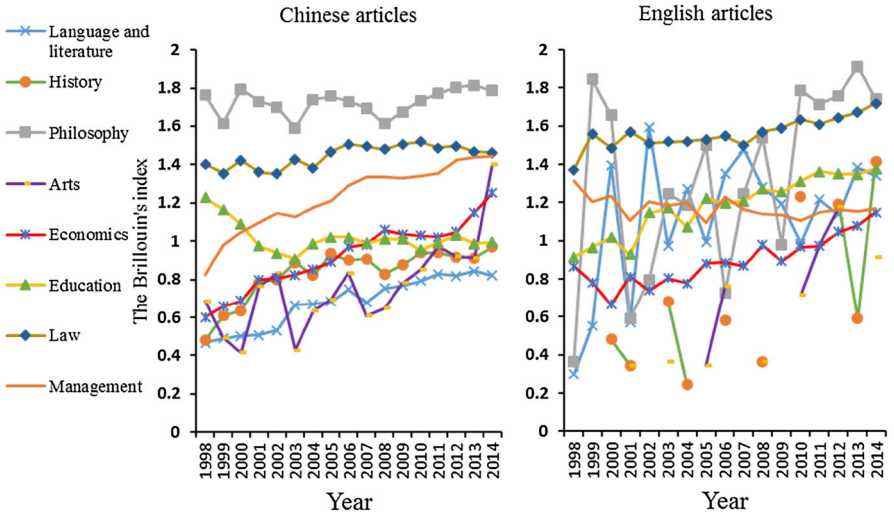

Fig. 2 The Brillouin's index of sub-disciplines in Chinese articles and English articles

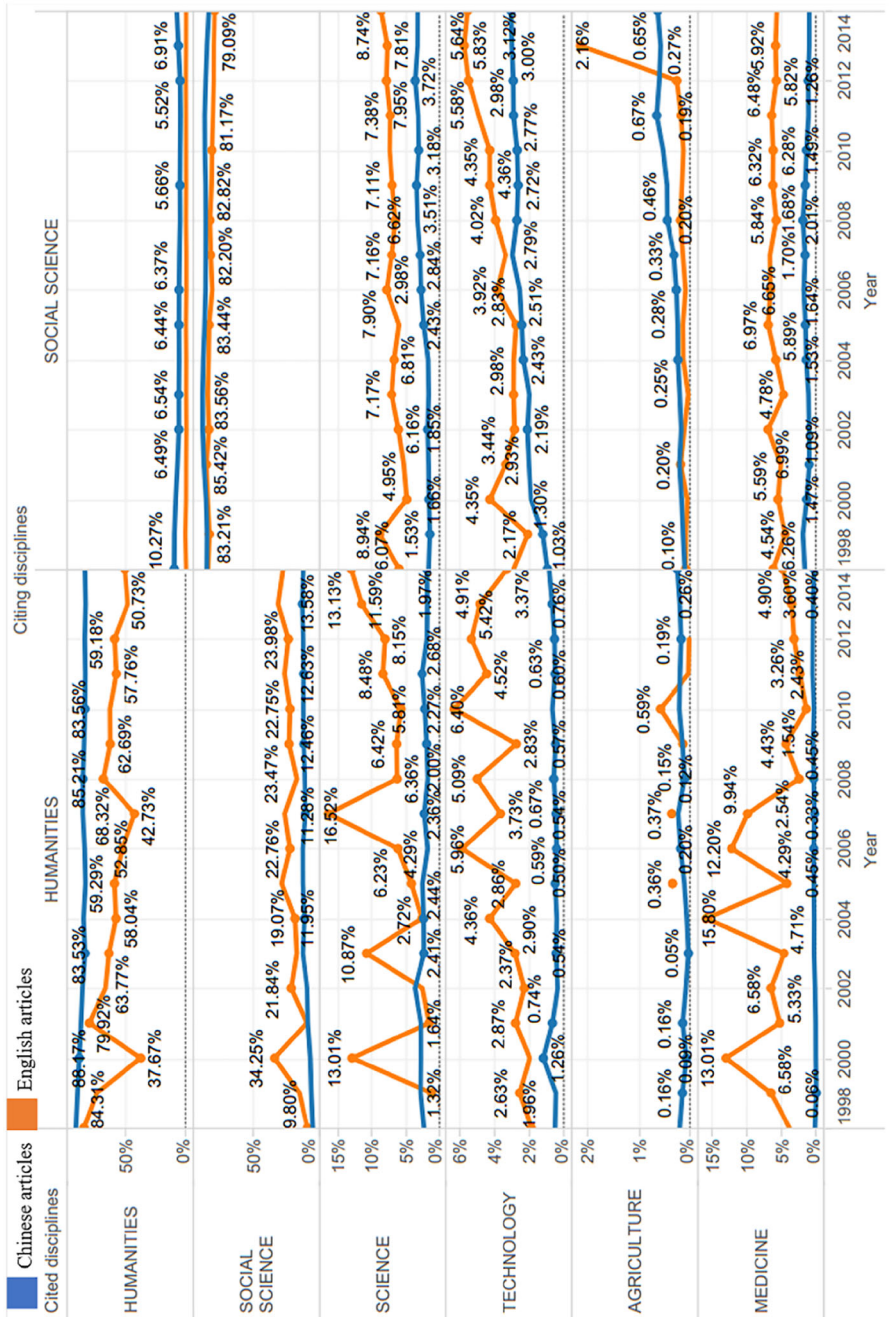

Fig. 3 The citation rates of disciplines in Chinese and English articles

Medicine, Science and Technology play a significantly crucial part in knowledge absorption of HSS, which is reflected by the citation rate of these four disciplines, as reported in Fig. 3.

4.2 Knowledge flow among sub-disciplines in HSS

4.2.1 Density and key disciplines

Our analysis shows that the knowledge flow networks including humanities, social sciences and hard sciences became more intensive, in that the network densities of both Chinese and English articles increased across the years. Specifically, in Chinese articles, the network density was 0.644 in 1998, and rose to 0.705, 0.712, 0.720, 0.727 in the later four periods with a 4-year time interval (i.e., 1999–2002, 2003–2006, 2007–2010, 2011–2014), signifying that knowledge flow was more and more frequent among the disciplines. Although the density of networks in English articles is far lower, it increased from 0.272 in 1998 to 0.462, 0.53, 0.614 and 0.629 in the aforementioned four periods.

In addition, it was also found that knowledge flow is more active in social sciences than in humanities. The disciplines are ranked in Fig. 4, based on their indegree (knowledge absorption, i.e. the number of citations) and outdegree (knowledge diffusion, i.e. the number of references) during the sampling years. It shows that, as a whole, disciplines in social sciences were on the top of lists in Chinese and English articles. In Chinese articles, it is noticeable that in the early years Management ranked first in absorbing and diffusing knowledge but was then surpassed by Economics. This indicates that, as a former paramount participant in knowledge absorption, Management has been substituted by Economics in recent years. Furthermore, History plummeted in its rankings throughout the whole period, dropping from second to sixth place in both knowledge absorption and diffusion, signifying a recession of History research.

In terms of knowledge flow in English articles, Education and Management are on the top of the list, with the former declining markedly and the latter growing and maintaining its position as first place. In English articles, humanities was at a disadvantage in knowledge flow as not only its knowledge absorption was inferior to social sciences but also its knowledge diffusion fell behind Technology and Science. Interestingly, this phenomenon is not apparent in Chinese articles.

4.2.2 Knowledge linkage between disciplines

In Chinese articles, the interaction between Economics, Management and Law is the strongest in knowledge flow. As reported in Fig. 5, the link between Management and Economics, and that between Economics and Law were red and bold in networks. Observing the arrow size, Economics was the most crucial interdisciplinary knowledge base to Management and Law. By comparison, Law and Management did not make an equal contribution to the development of Economics during these 17 years even though knowledge spreading between Economics and Management became gradually balanced. In terms of disciplines in hard sciences, Technology and Science constituted the main interdisciplinary knowledge source of Management and Economics as Medicine did to Education. Furthermore, we found that in every network, compared with the other lines launched by Technology and Science, the lines between Technology or Science and Economics or Management are bolder. Likewise, the linkages launched by Medicine and

A
1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
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F 6 6 6 5 4 4 4 4 3 3 3 3 3 4 4 4 4
G 4 4 3 3 3 3 3 3 4 4 4 4 4 3 3 3 3
H 1 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
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J 10 10 9 9 9 9 7 8 8 8 8 8 8 8 8 8 8
K 12 12 12 12 12 12 12 12 12 12 12 12 12 12 12 12 12
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F 6 6 5 4 4 3 4 3 3 2 2 1 1 1 1 1 1
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F 1 1 1 2 2 1 3 4 4 2 3 3 4 4 3 3 3
G 4 5 6 5 5 5 4 5 5 5 5 6 5 5 5 6 7
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K 9 10 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
L 5 6 3 3 3 4 3 2 3 2 4 4 3 3 4 4 4
D
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C 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
D 6 6 6 6 6 6 6 6 7 6 6 6 6 6 6 6 6
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G 3 3 3 3 3 3 3 2 2 3 3 3 2 2 2 2 2
H 1 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1

◀**Fig. 4** The outdegree (*green*) and indegree rank (*red*) of sub-disciplines in Chinese (**a**, **b**) and English (**c**, **d**) articles. *Note* The number on the *left side* of matrices denotes the sub-discipline number. The number in the matrices indicates the rank of sub-disciplines based on citation numbers (*green*) and references numbers (*red*). Sub-discipline code: *A* Arts; *B* History; *C* Language and literature; *D* Philosophy; *E* Economics; *F* Education; *G* Law; *H* Management; *I* Science; *J* Technology; *K* Agriculture; *L* Medicine. As this figure focuses on knowledge absorption in HSS, the indegree ranks of Agriculture, Medicine, Science and technology are excluded. (Color figure online)

those pointing to Education are thicker. Besides, the agricultural knowledge distributed in humanities and social sciences were balanced.

In English articles, there was a stronger knowledge interaction between disciplines and the knowledge source of disciplines became increasingly diverse. As shown in Fig. 6, the number of strong linkages between disciplines that are red and bold was more than that in Chinese articles and declined from the first period (i.e., 1998) to the last period (i.e., from 2011 to 2014). Before 2007, the knowledge flow from Education to Management, from Education to Law, from Economics to Management was included in strong network linkages, which implies that knowledge of Education was the most important knowledge source to Management and Law in addition to Education itself, and that Economics was another critical knowledge base benefiting Management. After 2007, these linkages, except that from Economics to Management, were not as strong as they were before, signifying that the distribution of knowledge source disciplines became increasingly balanced. Surprisingly, knowledge flow from Medicine to Law was the strongest in every period compared with other knowledge bases of Law, indicating that Medicine contributed to Law considerably. In addition, Management tended to absorb knowledge from Technology and Science as knowledge linkages between Management and these two disciplines were also intensive.

4.2.3 Absorption-oriented and diffusion-oriented disciplines

In Chinese articles, Management, Education and Law were classified to absorption-oriented disciplines while the others were diffusion-oriented disciplines. Calculating input–output index, it is found that the value of Management, Education and Law were below 0 in most of the sample years, which means that these disciplines inclined to absorb knowledge from disciplines in humanities and social sciences and that citations of articles in these disciplines were lower than the number of references in articles in these three fields. Moreover, differences in the indices trend among these three disciplines were significant. The input–output indices of Management dropped from −0.090 to −0.122 with a diminishing trend. This indicates that Management as a sub-discipline gradually became more of a knowledge consumer rather than a provider over the sampling years. Distinct from Management, Education and Law experienced a continuously rising trend in the input–output index that increased from −0.155 to −0.062 and from −0.191 to −0.106 respectively. Both Education and Law have been absorbing knowledge from other sub-disciplines, but in recent periods, knowledge diffusion and absorption of these two sub-disciplines tended to be more balanced. In English articles, Management and Law played a role as absorption-oriented sub-disciplines, as well as Language and Literature, and Philosophy.

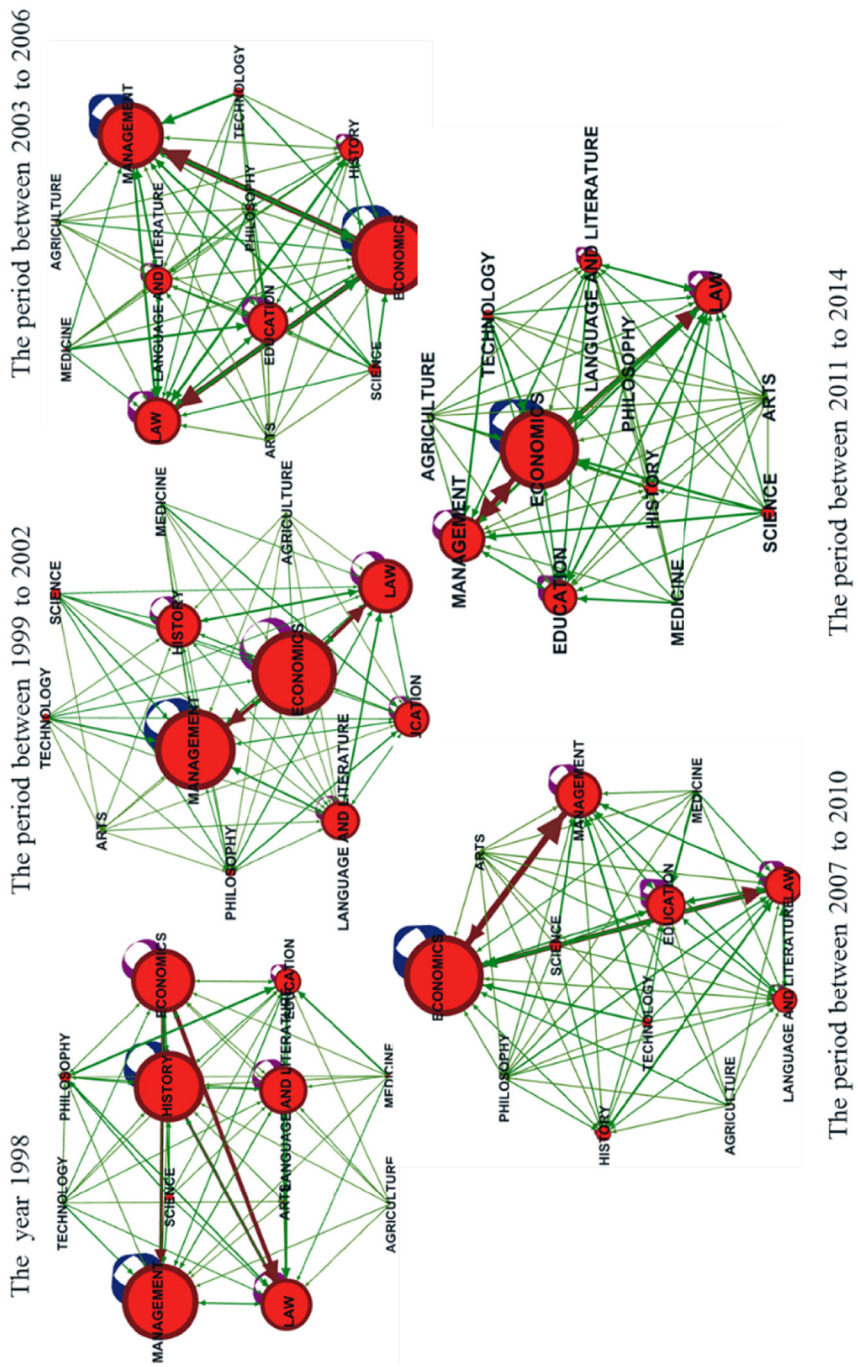


Fig. 5 Knowledge flows networks in five periods in Chinese articles

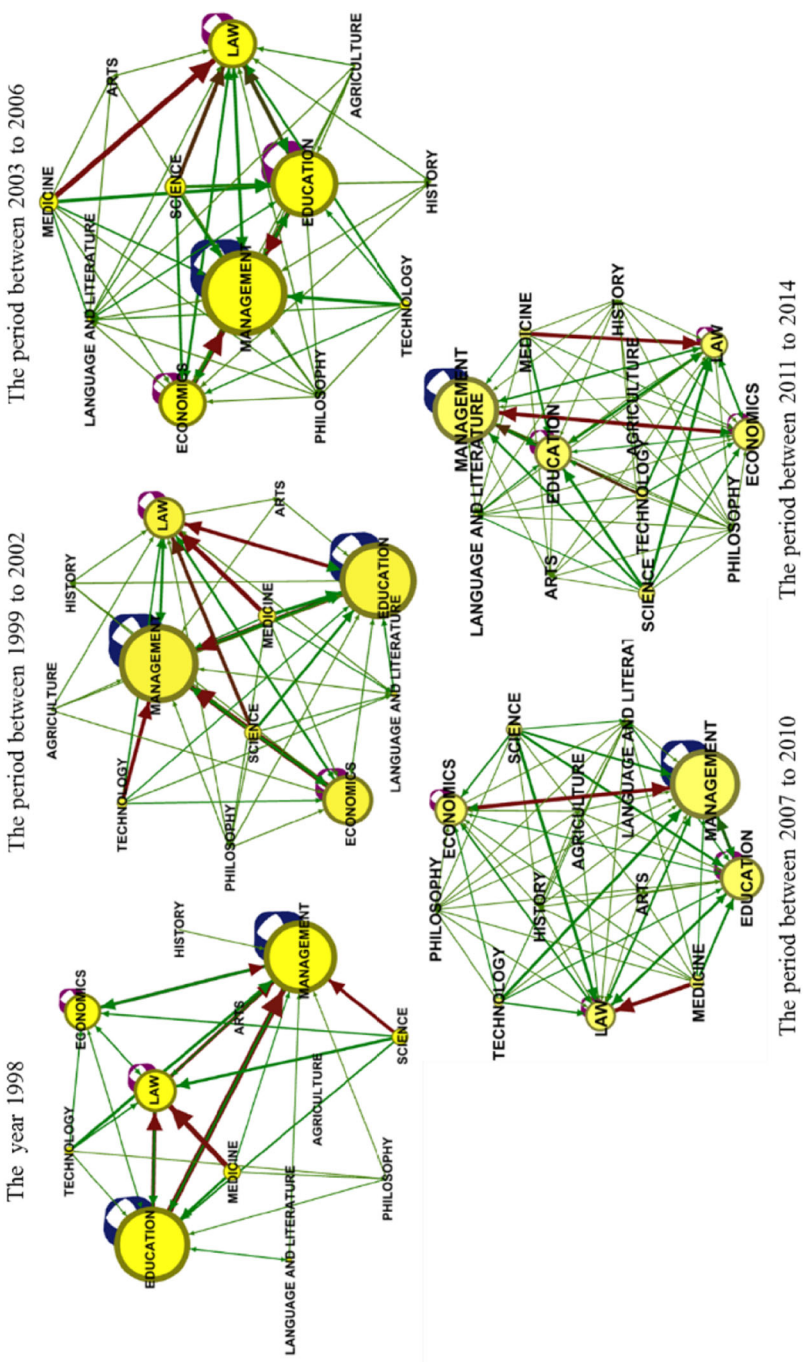
5 Discussion and conclusion

Based on the data of Chinese and English articles published by researchers in China from 1998 to 2014, this paper explored the knowledge flow in HSS. Given the differences we found in knowledge flow within HSS of Chinese articles and English articles, our data indicate that including these two types of publications in this study is a desirable strategy to avoid a limited and biased understanding. Major conclusions are summarized as follows.

Firstly, the interdisciplinarity of knowledge absorption in social sciences is higher than that of humanities both in Chinese articles and English articles. Meanwhile, the degree of interdisciplinarity in eight HSS sub-disciplines constantly increased. This finding is in accordance with the emergence of government and funding agency policy-related incentives to encourage interdisciplinarity (Levitt et al. 2011). In response to this change, researchers, regardless of which disciplines they work in, may attempt to conduct more interdisciplinary research. Based on results of this study, growth in the degree of interdisciplinarity is a trend in both humanities and social sciences papers published in Chinese journals and English journals. However, the change in interdisciplinarity varied between sub-disciplines. In general, sub-disciplines in social sciences were found to be more interdisciplinary than those in humanities. This finding is understandable as studies on social sciences are more closely related to emerging sophisticated social issues whose resolutions require knowledge from different disciplines.

Secondly, previous studies found that researchers in most humanities sub-disciplines tended to work independently. For example, in Spain, 43% of publications in social sciences are co-authored, and this figure is far smaller in Linguistics and Language, reaching only 3% from 1986 to 1988 (Rubio 1992). Kyvik (2003) confirmed that 43% of publications in social sciences and only 14% of publications in humanities have one author. These figures may illustrate that humanities are less "team-oriented" than social sciences. This may impede the interdisciplinary collaboration, and thus we see only a moderate degree of interdisciplinarity in humanities.

Thirdly, it was observed that HSS scientists in China increasingly tended to apply knowledge in hard sciences to their domains, especially in English articles. Even though some researchers have found that interdisciplinarity is more likely to take place between disciplines which are relatively close to each other (Anon 2008; Holm et al. 2013), borrowing knowledge from hard sciences has been increasingly frequent in HSS. In previous studies, it has been claimed that interaction between HSS and hard sciences can effectively solve complex problems (Mooney et al. 2013; Mills et al. 2011). Furthermore, integrating knowledge from different disciplines may bring high citations which are strongly related to academic success (So et al. 2015; Schilling and Green 2011). These may be the reasons for the growing number of references belonging to hard sciences and cited by HSS researchers. Furthermore, in English papers, the proportion of hard sciences references is higher than that in Chinese papers. This may imply a difference in citation behaviors between researchers who publish Chinese articles and those who publish English ones. It seems that English articles are more science-oriented as English articles cited more from hard sciences. Researchers perceive publishing high-quality international papers as the key to career development and to participation in a global academic community. However, as previously mentioned, the international visibility of China's HSS is low. Given our finding that hard sciences is cited more frequently by HSS in English papers, applying more hard sciences knowledge is likely to be a helpful strategy for authors in China who are


The year 1998
The period between 1999 to 2002
The period between 2003 to 2006
The period between 2007 to 2010
The period between 2011 to 2014
LAW
EDUCATION
MANAGEMENT
ECONOMICS
MEDICINE
SCIENCE
ARTS
HISTORY
AGRICULTURE
TECHNOLOGY
PHILOSOPHY
LANGUAGE AND LITERATURE

◀**Fig. 6** Knowledge flows networks in five periods in English articles. *Note:* the five periods represent the year 1998, the period from 1999 to 2002, 2003 to 2006, 2007 to 2010 and 2011 to 2014, respectively. The *arrow* from sub-discipline *i* to *j* stands for the number of references in *i* which are cited by *j*. The size of *solid circle* labeled by sub-discipline *i* indicates the total number of citation it received. The thickness of the linkage and size of the *arrow* are proportional to the number of citations between the sub-disciplines

accustomed to publishing Chinese articles to publish more English articles in international journals.

Fourthly, the knowledge flow across HSS sub-disciplines is not balanced. We found that in Chinese articles, Economics was the most crucial interdisciplinary knowledge base and played a role of the knowledge provider to other HSS sub-disciplines; In contrast, Management, Education and Law were absorption-oriented disciplines as knowledge consumers. In English articles, Management, Law, Literature and Philosophy were absorption-oriented disciplines. These results imply that the knowledge exchange among HSS sub-disciplines is imbalanced. This is well understood as existing literature has stated that knowledge flow across disciplines is not reciprocal (Urata 1990). More specifically, we found that authors in the field of Management tended to borrow knowledge from Education and Economics in their English articles, while authors in Law significantly used Education knowledge in their English publications. Authors can benefit from these findings when conducting interdisciplinary research, as interdisciplinary knowledge in specific sub-disciplines may be more useful.

From the findings we obtained, it appears to be some differences in knowledge flow between Chinese articles and that between English articles written by Chinese authors. In addition to the disciplinary knowledge flow, the knowledge diffusion between the national and the international academic communities should be paid special attention to in the future. As Park and Leydesdorff (2008) pointed out, some journals in the domestic publishing market function as a bridge that makes the international literature more accessible to domestic scholars in Korea. It is worth further investigations in the context of China. Furthermore, whether factors such as publication language (Bozeman and Corley 2004), collaboration mode (Yoon and Park 2017) and geographical distance (Wang et al. 2017) can play a role in international collaboration should also be examined. Besides, given that online communication through social media platforms among researchers has been rapidly growing in recent years (Lee et al. 2017), online scholarly communication can also be used to detect knowledge flow, and the differences between knowledge flow in online and traditional scholarly communication channels remains interesting questions in future studies.

There are some limitations in this study. First, in HSS, monographs and reports are also important knowledge sources, which were not included in this study. Second, we did not consider the cognitive distance of sub-disciplines in HSS when exploring the interdisciplinary knowledge flow. Third, apart from citations, there are some other channels of knowledge flow (Fadul 2014), e.g., personal contact, regular interaction, online communications, which were not included in this study. Last but not least, this study identified patterns, but did not provide the reasons behind the patterns. Future studies can explore these directions to further the understanding of knowledge flow in HSS.

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