

Are Scientometrics, Informetrics, and Bibliometrics Different?

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Abstract

Bibliometrics, scientometrics, and informetrics (also called the three-metrics) are three related terms in metrology. With development of science and social science and continuation of metrology, convergence among these three terms has been developed a lot. Analyzing their current situation and relationships can promote comprehensively understanding of these three specific fields under metrology. For this study, we collect the data sets of the three terms through keywords search in Web of Science in the recent 10 years (2007-2016). We also compare them in terms of the distribution of publications and cooperation (recognition level), the main research topics (intellectual structure), and the reference situation (knowledge communication) and visualize results. These results show that three metrics differ in subject background and vary in the degrees of utilization and recognition, but are share in theories as well as many methods and technologies. They are similar in general structure and citation situation although some details content is different. We recommend the addition of bibliometrics in the title of the International Society for Scientometrics and Informetrics.

Keywords

Bibliometrics, Scientometrics, Informetrics, Knowledge Domain
Visualization, Cite Space

1. Introduction

Since 1960s, three similar terminoloies: Bibliometrics, Scientometrics and Informetrics, appeared in fields of library science, information science, philology and science of science. After decades of efforts on research and promotion, these fields all progressed at different degrees and became widely recognized by aca-

demia. Despite of different research objects and purposes, they have the same origin and share common principles, methods and tools. Therefore, academia refers to these subjects as three-metrics [1]. These terms are usually used to describe similar and overlapping objectives, such as bibliographies (books and libraries), science, information phenomena, and the World Wide Web [2]; however, their well-documented historical origins differ, and they are not necessarily synonymous [3] [4].

Research objects, goals, and methods of the three-metrics have changed a lot during researches process, however, still in crisis. New branches such as webmetrics and altmetrics [5], and new indexes and evaluation measures including Citescore and the H index, have also appeared [6]. Although these three terms differ in disciplinary background and contexts [1], they are used in accordance with their own cognition and position, and sometimes their usage is indistinguishable and interchangeable, thereby causing significant confusion [7].

The authorities of metrics journals indexed by SCIE and SSCI, “scientometrics” and “Journals of Informetrics”, haven’t included “bibliometrics” into their title. Titles of some other journals include “bibliometrics”, but those journals may be not so widely known: “International Journal of Bibliometrics in Business and Management”, “Cybermetrics: International Journal of Scientometrics, Informetrics and Bibliometrics”. The Conference of International Society for Scientometrics and Informetrics (ISSI) that is the most significant conference in the three metrics includes scientometrics and informetrics in its titles not bibliometrics. Given that confusion can harm the development and application of the three metrics [4], interrelationships of three-metrics and their development should be examined. This study explores the current situation and interrelationships of the three metrics from the following three aspects: the number of published papers and cooperation (recognition level), the main research topics (intellectual structure), and the reference situation (knowledge communication).

2. Background

2.1. Definitions of Bibliometrics

Bibliometrics originated in bibliography and statistical bibliography, and have its root in library science; Bibliometrics methods have been applied in various forms for more than a century [4]. The terminology “bibliometrics” was first introduced by Pritchard [8], who defined it as “the application of mathematical and statistical methods to books and other media of communication”. Reference [9] expanded the definition scope of bibliometrics by defining it as the quantitative treatment of the properties of recorded discourse and behavior appertaining to it. Then, Broadus [10] defined bibliometrics as the quantitative study of physically published units, or of bibliographic units, or of alternatives of either. Reference [11] extended bibliometrics to explore the science and scholarly communication.

2.2. Definitions of Scientometrics

Scientometrics stems from “the work of the historian of science Derek de Solla

Price in parallel to the development of the citation indexes by Eugene Garfield” [2]. Reference [12] coined the Russian equivalent of the term “scientometrics” in 1969, and defined it as the quantitative study of various kinds of intelligence process in the development of science. The term is concerned with the quantitative features and characteristics of science and scientific research, and has formed a stable field and obtained broad acceptance from the journal *Scientometrics*, which was built in 1978. Scientometrics is a discipline that uses mathematical methods to quantify the scientific research personnel and achievements to reveal the process of scientific development, and can provide scientific basis for scientific decision making and management [1]. Scientometrics uses citation analysis and other quantitative methods to evaluate scientific research activities and thus guide the policy of science [5].

2.3. Definitions of Informetrics

With the rapid development of information technology and the popularization of the Internet, information, material and energy have become the three pillars of human society. Informetrics has also drawn wide attention [13]. Otto Nacke first proposed the German term “informetrie”; Corresponding English term “Informetrics” soon appeared in subsequent literatures [1]. Nacke expanded concept of Informetrics on first Seminar on Informetrics in Frankfurt in 1980; Informetrics didn’t only spread rapidly in English-speaking countries but was also recognized by International Federation for Information and Documentation (FID), marking rise of new branch of discipline [2]. As early as 1980, FID established Informetric communications (FID/IM). By the early 1990s, the term “informetrics” obtained wide recognition. In 1997, webometrics was defined as “the application of informetrics methods to the World Wide Web” [14]; in 2007, *Journal of Informetrics* started publication.

Nacke believed that informetrics is a study applied in mathematical methods for information science objects [1]. This definition is slightly one sided because it limits the scope of informetrics in information science. Reference [15] extended informetrics to the quantitative study of any form of information; thus, informetrics is not simply a bibliographic record or any social group, or not limited to scientists. This definition enlarges the research scope and content of informetrics. Reference [5] defined it as an area “comprising all metrics studies related to information science” and more general than the bibliometrics and scientometrics. Reference [1] divided informetrics into two aspects of broad and narrow senses. The broad sense of informetrics research is very broad, whereas the narrow sense of informetrics mainly uses mathematical, statistical, and other quantitative methods to study the characteristics and laws of information quantitatively.

2.4. Relationships among the Three Metrics

The three metrics have evolved to share many of the objectives and have many methods and tools in common [1]. The three metrics refer to “component fields

related to the study of the dynamics of disciplines as reflected in the production of their literature” [4]. The three metrics often appear simultaneously, or used interchangeably by authors, such as the Second International Conference on Bibliometrics, Scientometrics, and Informetrics (now called “ISSI”). However, the terms differ in their discipline attribute; specifically, bibliometrics belongs to library and document science, scientometrics belongs to the science of science, and informetrics belongs to information science [1] [16] [17]. Scientometrics and informetrics have been proposed for nearly 50 and 40 years, respectively; however, they lack their own uniform concepts that can be widely accepted by the public; Different definitions of bibliometrics also exist [4].

The relationship among the three metrics has long been investigated and the lack of consensus. Reference [16] explored the origin and interrelationship of the three metrics; he suggest that informetrics subsumes bibliometrics and scientometrics, while scientometrics taken as leaning to policy studies and bibliometrics conceded more to library studies. Reference [18] emphasized that the authors’ use of “bibliometrics” synonymously for the three metrics has resulted in chaos; meanwhile, in terminology there seems to be little consent, and are actually drifting apart. Reference [4] analyzed the differences among the three metrics by investigating the history of the three terms through analyzing the number of papers and journals between 1968 and 2000. Reference [1] suggested that the three metrics belong to different superordinate disciplines; however, they have the same research objects, indicators, and methods. Some believed that the three metrics present a crossing and partial overlapping relationship, but others argued that the three metrics exhibit an inclusive relationship; for example, informetrics has greater scope and includes bibliometrics and scientometrics [1]. Besides, Milojević & Leydesdorff [2] investigated social and cognitive distinctness of iMetrics with respect to general information science using cosine similarity.

However, few studies have focused on systematically compared the content structure and knowledge communication of the three metrics in recent years. Although interrelationships among three-metrics under new environment are still in crisis, new terms such as altmetrics, webometrics, knowledgometrics have appeared one after another. Against this background, it is necessary to grasp and analyze the current status and interrelationships of the three-metrics.

3. Data and Method

A subject or discipline is analyzed using the literature statistics, which often accesses data samples in three ways: 1) choosing the top journals or core journals in the field as the data source [2]; 2) obtaining data source through the retrieval of representative keywords [4] and 3) through the discipline classification system in the literature database. The journals of three-metrics present great repeatability and overlapping, and documents of these three specific fields are widely distributed in many journals; No related category about the three-metrics exists in main literature databases. Thus, this study used “keyword search” to obtain data

for the comprehensive comparison of the similarities and differences among the three-metrics.

This study was carried out through analysing documents published on each of the three-metrics. We download data sets from SCI-E, SSCI, and A & HCI between 2007 and 2016. Following Hood and Wilson [4], we retrieve the literature of the three metrics using “TS = (bibliometric * or bibliometry or “statistical bibliography” or bibliometrie)”, “TS = (scientometric * or scientometry)” and “TS = (informetric * or informetry or informetrie)”. Then, we refined the research documents by selecting “articles”, “reviews”, and “proceedings papers”. We also combine the three search strategies to investigate the overlapping situation of the three-metrics.

The current situation and interrelationships of the three-metrics include various aspects, such as special core researcher, institutional, shared knowledge and vocabulary. In this study, we focused on three major areas: 1) the usage and distribution of the three metrics on the basis of the number of publications and cooperation; 2) the research contents and intellectual structure on the basis of field topics; and 3) the knowledge communication and flow on the basis of the citation and reference. For a specialty or field, these aspects not only reflect the distinct cognitive profile, but also reveal the social identity (that is, “its practitioners represent a community whose internal ties are much stronger than the ties with the outside community”) [2]. We use Excel and CiteSpace for data analyses and results presentation.

4. Result and Discussion

4.1. Overall Situation

From retrieval results, bibliometrics has the overwhelmingly dominant number of publications, which is approximately four times of that of scientometrics and 20 times of that of informetrics. We must note the large difference in the number of literature among the three fields in 2007-2016. Maybe main reason resulting in it is the difference in their history and degree of social recognition, since the choice of terminology is the result of scholars’ comprehensive cognition. Bibliometrics has been introduced earlier than the two other terminologies, and its basis theories and methods are widely recognized in various fields and thus familiar to people and commonly used by researchers. Furthermore, bibliometrics has a specific meaning and a clear object of study and scope, especially for library science; meanwhile, informetrics has many definitions, of which some including bibliometrics and scientometrics, but this term is too generalized to emphasized [1]. Finally, researches in the field of the three-metrics are based mainly on the literature information, such as keywords, authors, and organizations; thus, researchers are inclined to choose bibliometrics as it suitably describes their metric work and shared vocabulary [4].

As shown in **Figure 1**, the overlap ratio of bibliometrics with scientometrics is 10.18% ($468/(4089 + 468 + 71 - 30) * 100\%$), and that with informetrics is 1.54%

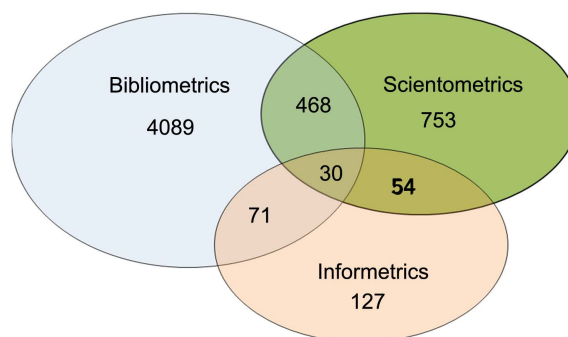


Figure 1. Search results of combining the three metrics.

$(71/(4089 + 468 + 71 - 30) * 100\%)$. The overlap ratio of scientometrics with bibliometrics is up to 37.60% $(468/(753 + 468 + 54 - 30) * 100\%)$, and that with informetrics is only 4.34% $(54/(753 + 468 + 54 - 30) * 100\%)$. The overlap ratio of informetrics with bibliometrics is 31.98% $(71/(127 + 71 + 54 - 30) * 100\%)$, and that with scientometrics is 24.32% $(54/(127 + 71 + 54 - 30) * 100\%)$. Such high overlap percentages result from the consequence of relatively small share of documents on informetrics. Besides, 30 papers include all of the three metrics, that is, three term sets co-occurred in the subject of these documents.

Many papers used bibliometrics and scientometrics simultaneously, due to their frequently occurring together. However, the overlap probability of the informetrics and scientometrics is high based on the relative value, which is consistent with the phenomenon that informetrics often mentions together with scientometrics in science communication (such as ISSI). Besides, 42.8% $(127/(127 + 71 + 54 - 30) * 100\%)$ documents of informetrics are included in documents of bibliometrics or scientometrics, in other words, only 57.2% documents of informetrics do not belong the two other fields, to some extent which indicates the lack of independence in the use of informetrics.

1) From **Figure 2**, we can tell the overall publishing trends. The number of articles on the three metrics continues to increase in 2007-2016. In the past 10 years, the annual volume of publications on bibliometrics is higher than that on scientometrics and informetrics. Bibliometrics continue to increase in recently and hasn't been outdated, although the subjects, methods and techniques of research have significant changes under new environment. Informetrics presents the smallest increase with stable number of publications from 2010 to 2012. One of the main reason is Informetrics covers a wide scope of research, thereby decreasing its degree of specificity and thus its degree of utilization. 2) The right side of **Figure 2** shows the number of documents with each of the different terms related to bibliometrics. The "bibliometric*" as the theme word accounted for the vast majority, it almost can represent the whole field and have continued to increase over 2007-2016; the use of "bibliometrie" is the least, no one had used it since 2012; the use of "statistical bibliography" and "bibliometrics" fluctuate uncertainly. It should be noted the total of the number of documents is more than 4598 since the different terms can appear together in a document. 3)

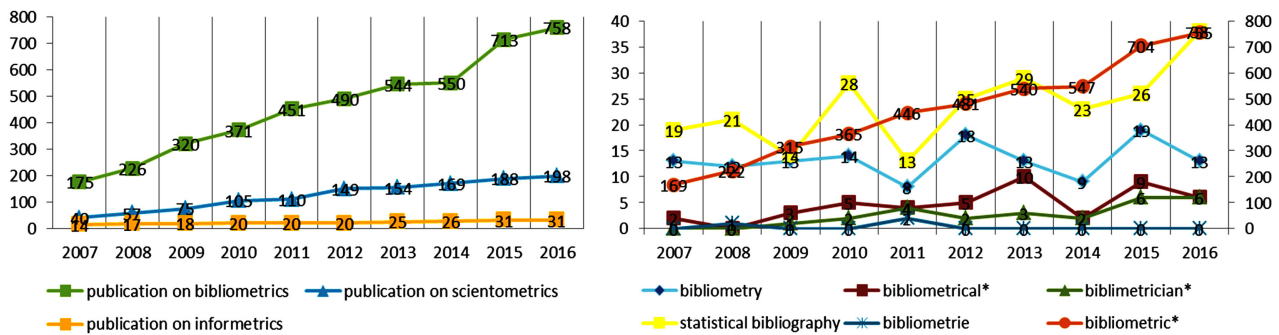


Figure 2. Number of documents in the three metrics and in each terms in bibliometrics (“bibliometric*” corresponds to the right Y axis, the rest of the terms to the left Y axis).

In general, bibliometrics is the most frequently usage, and shows the largest increase among the three metrics; On the contrary, informetrics is the least frequently used and presents the smallest increase; although some author maybe use the term “informetrics” or “scientometrics” due to some journal and conference with the same title.

4.2. Distribution of Publications and Cooperation

4.2.1. Number of Publications in Different Levels

The European countries dominate more than half of the top 10 national rankings of the three- metrics. As origins of the three-fields, Europe has a long history of research in these fields and popular research institutions and experts. With regard to American countries, the United States has the highest number of articles on bibliometrics and scientometrics. Brazil ranks out of the top 10 national of informetrics, and use few informetrics in studies. In Asia, China ranks in the top three in the three fields, and two other countries and regions ranked into the top 10 of scientometrics, which shows scientometrics has been widely explored and highly recognized and utilized. In Oceania areas, Australia enters only the top 10 of bibliometrics, indicating that degrees of utilization of bibliometrics in this country are much higher than those of scientometrics and informetrics. Regarding African, the number of articles in these three fields is few. Notably, South Africa ranks seventh in informetrics. Therefore, informetrics exhibits high degree of recognition and high productivity in South Africa, and which is inseparable from the economic level and political environment in the country.

At the institutional level, universities account for the majority of the top 10 institutional rankings of the three-metrics. A total of 6, 7, and 4 European institutions enter the top 10 of bibliometrics, scientometrics, and informetrics. This finding shows that European institutions play an important role, and is consistent with the results of the regional distribution. Of informetrics, Belgium’s Univ. Antwerp, Univ. Hasselt, and Katholieke Univ. Leuven are the top three institutions; the former two appear only in informetrics. In other words, the two institutions show strong research strength in informetrics. The main institutions of Asia are mostly from China, such as Peking Univ. on bibliometrics and scientometrics. Wuhan Univ. and Zhejiang Univ. are the only two high-yield institu-

tions of Asia in informetrics. Notably, Taiwan's Asia Univ. ranks first in scientometrics. With regard to American countries, Indiana Univ. enters the top 10 of the three metrics, which exhibits strong research strength. In African countries, only Univ. South Africa ranks fourth in informetrics. Besides, it is interesting to report the disciplinary or departmental affiliation (as opposed to institutional affiliation) of the authors of the three specific metrics fields. The distribution of departmental affiliation is extensive in the three-metrics by analysing the departmental affiliation of the first authors. In bibliometrics field, authors gathered in library, information, medicine, and S & T departments; for informetrics, most of authors came from information, library, and management departments. However, in scientometrics, many authors come from R & D, computer, medicine departments. This study showed that the researchers who associate more strongly with scientometrics are also affiliated with information science academic units (such as Sch Lib & Informat Sci, Ctr R & D Monitoring ECOOM, Dept Informat Studies, Dept Comp Sci, Dept Informat Sci, Sch Informat Studies).

At the journal level, many articles mainly on bibliometrics are published in *Scientometrics* (18.45%), *Journal of Informetrics* (4.96%) and *JASIST* (4.94%); and issued also in some multidisciplinary journals and LIS journals (such as PLoS One, Research Evaluation). A lot of articles on Scientometrics are concentrated in *Scientometrics* (28.04%), *Journal of Informetrics* (6.11%) and *JASIST* (4.70%), meanwhile, also distributed in other discipline journals (such as *Energy Education Science and Technology Part A-Energy Science and Research*), scientometrics is widely used in other disciplines and is closely applied and related to other disciplines, as it focuses on all scientific policies and the overall development of science. The papers on informetrics are published mainly in the *Journal of Informetrics* (23.85%), *Scientometrics* (20.08%), and *JASIST* (16.74%), which is consistent with the findings of Bar-Ilan [7]. *Journal of Informetrics* publishes articles mainly with quantitative analysis of informetrics, while it doesn't issue many papers each year [19]. Some articles on informetrics are published in those journals of computer and mathematics, suggesting that the development of informetrics is closely related to developments of computer technology and mathematical models. Many articles on the three-metrics are published in three core journals; most journals belong to the field of library and information science.

At the author level, some core researchers that predominantly focused on the three metrics can be identified. The top 3 high-yield authors in bibliometrics field include Bornmann, Abramo, and Ho; those in scientometrics include Groeneberg, Ho, and Leydesdorff; those in informetrics include Egghe, Rousseau, and Burrell. As the founder of the *Journal of Informetrics*, Egghe entered only the top 10 author rankings in informetrics field as well as Rousseau. They focus on mathematical models and are committed to the research and promotion of informetrics; they use informetrics frequently. Leydesdorff and Glanzel rank among the top 10 authors in all of the three areas. Leydesdorff is a doctor of so-

ciology, but his research involves various fields, especially scientometrics; he committed to solve problems of communication and innovation in the dynamics of S & T. Glanzel has high attainments in various areas, such as scientific knowledge mapping, scientific evaluation and index, and citation analysis. Bornmann is the author with the most published articles on bibliometrics; he works as a sociologist of science, and current research interests include research evaluation, peer review, bibliometrics, and altmetrics.

4.2.2. Cooperation Network

1) Co-Author network

Figure 3 shows that seven large groups are present in the co-author network of bibliometrics. The size of the nodes represents the number of publications of authors notably. D’Angelo, Abrano, Bornmann, and Ho, and other high-yield authors, have their own fixed partners and present close contact. As few articles published, some authors show many partnerships. For example, in Ho’s collaboration group, Waltman has a small number of articles but has six cooperative partners in the threshold. Similarly, Kostoff published few articles but collaborates with every member of the group. There are a lot of cooperative groups exist in bibliometrics. The cooperative interrelationship is so close that little collaboration between only two authors.

In **Figure 3**, scientometrics shows a large cooperation group and Groneberg is the center node of the group where Leydesdorff and Bornmann are also included; however, the two authors locate in the extension of the group. This group exhibits an intricate connection and a close relationship. A prominent cooperative group exists, in which Ho of four fixed partners is the center. Therefore, this group has a stable partnership. Many two-author and three-author groups exist. In general, the scale of the author collaboration network of scientometrics is sparse.

As shows in **Figure 3**, informetrics has a main cooperative group among others, in which Egghe and Rousseau are core nodes and Ye and Liu are included. Egghe and Rousseau published the largest number of articles on informetrics. They are contemporaries as well as prolific, and have more cooperative chance. The rest of the groups are dispersed. In addition to the largest group, more than

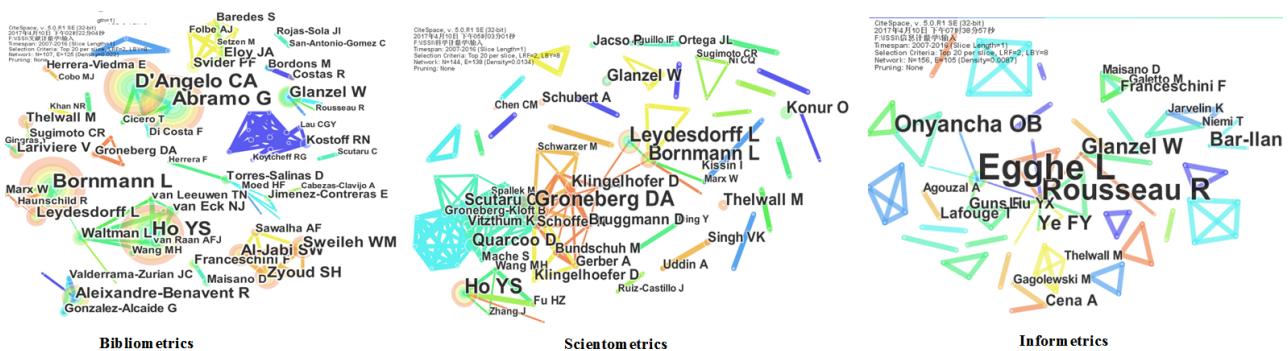


Figure 3. Co-author network of the three metrics.

10 three-author and two-author groups exist. The scale of the co-author network is small.

The size of co-author network depends on two main factors: the total number of articles and the habits of researchers. With regard to the first factor, authors with large numbers of articles have high numbers of co-author relationships, thereby leading to large-scale cooperation. For the second factor, some authors in special field prefer to cooperate with other authors, thereby forming large-scale and stable cooperation. Under the same thresholds, more large-scale cooperative groups (more than five authors) are there in bibliometrics than that in scientometrics and informetrics; however, many authors of the three metrics overlap. The cooperative group with Groneberg as its core node in scientometrics is the largest among the three fields. The cooperation among members are also frequent in the three-metrics. Although its size of cooperative groups is the smallest, informetrics possesses a major group with Egghe and Rousseau as its core nodes.

2) Institutional co-occurrence network

In the institutional co-occurrence network of bibliometrics, the connection is tight; cooperation between institutions is close. Many European institutions attach great importance to cooperation in bibliometrics. The Chinese Acad Sci presents high centrality and is an important mediator in the entire cooperative group to date. Leiden Univ., Univ. Granada, Asia Univ., and CSIC exhibit many cooperative relationships and published some articles on bibliometrics. Some institutions are very successful in cooperation even if they did not publish many articles, such as Univ. Amsterdam and Univ. Carlos III Madrid.

The institutional co-occurrence network of scientometrics shows three large groups (more than five institutions). In the first group, Asia Univ. and Univ. Amsterdam are the core nodes. This group includes the largest number of cooperative institutions, but shows sparse internal cooperation. In the second group, Goethe Univ. Frankfurt is the core node. In the third group, Univ. Granada and CSIC are the core nodes. In general, scientometrics presents a large number of cooperative groups but most in a small scale.

During the study period, informetrics possesses a significantly large cooperative group with Katholieke Univ. Leuven and Univ. Antwerp as the core. This group also includes Univ. Hasselt and KHBO Assoc KU Leuven. Notably, European institutions account for the majority of the group. Some Chinese institutions are also present in this group, such as Zhejiang Univ., Chinese Acad Sci, and Nanjing Univ. Chinese and European institutions exhibit frequent cooperation in informetrics. Indiana Univ. (American) and Dalian Univ. Technol (Chinese) assumed the role of intermediaries in their respective groups. Although they are excluded from the main cooperative group, their high degree of cooperation.

In general, universities are the main institutions with the institutional cooperation in the three fields. Bibliometrics has the highest degree of cooperation among the institutions and the cooperative relationship is close. Meanwhile, the

According to the statistics of keyword frequency, “science,” “citation,” “impact,” “Journal,” “citation analysis,” “H index,” and “impact factor” rank among the top 10 keywords in the three fields in 2007-2016. Therefore, the three fields are concerned on the scientific research output and impact, and citation analysis. Many researches use the citation analysis method and pay attention to the innovation and application of H indexes.

In summary, the subject results through the co-word analyses show the intellectual structure of each collection of publications on each metric. The topics of three metrics overlap a lot, and mainly include the evaluation of scientific output and impact, the innovation and application of indicators (such as the H index) and the cooperation mode etc. Bibliometrics focuses on exploring the development trend and research on the application of bibliometrics in scientific research management. Scientometrics focuses on exploring the application of its methods and techniques in other areas, the development of citation analysis and other methods, and the quality of scientific research output and development trends. Given that information is highly dependent on computer technology and mathematics, informetrics focuses on examining these indicators, application on information systems combining mathematical models and methods. The three metrics have both close linkages and differences among, and have more interconnections, cross connection, and overlapping than differences [1].

4.4. Citation Situation

4.4.1. Document Co-Citation Network

We cluster the scientific knowledge base using the document co-citation network. Bibliometrics includes five components (Figure 5). Scientometrics consists of six knowledge bases (Figure 6). Given that three of these bases have the same theme (but different direction), we merge the three identical parts into one, and four components are obtained. The knowledge base of informetrics consists of five parts (Figure 7). The connection between nodes represents the co-citation relationship between two documents. We analyze mainly the three metrics based on the high cited documents. In general, although the topics of the three metrics are similar, some contents in detail are different and the emphases of every metrics are also different and vary. It should be noted that the cluster is formed and named automatically by the CiteSpace, and there is a certain degree of randomness and inaccuracy.

According to Tables 1-3, Hirsch’s *An index to quantify an individual’s scientific research output* and Egghe’s *Theory and practice of the G index* are important documents in the three fields. The two articles have been used as the basis for the study on the H index in bibliometrics and scientometrics. Meanwhile, Hirsch’s article has also been used as the basis for the study on evaluation and ranking in informetrics, that is, the same literature is used in different angles. Reference [6] proposed the H index to evaluate the academic impact and the research performance of researchers; this document is the origin of the branch field. To overcome the shortage of the H index and measure the overall citation

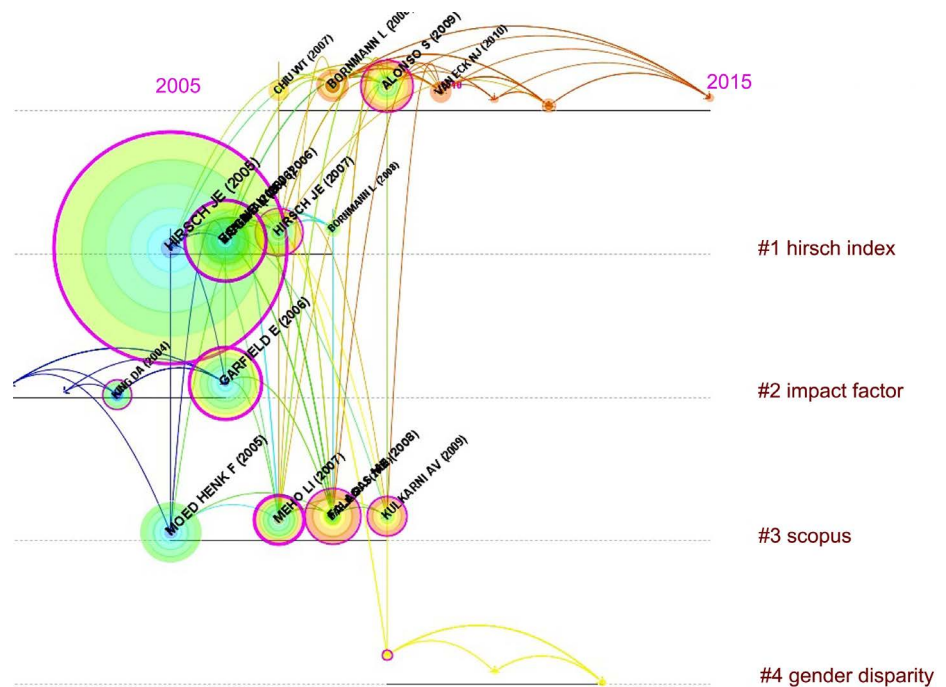


Figure 5. Document co-citation of bibliometrics.

Table 1. Important basic document of bibliometrics.

Cluster	Centrality	Author	Year	Title	Journal
#0 Research Trend	0.11	ALONSO S	2009	H-Index: A review focused in its variants, computation and standardization for different scientific fields	Journal of Informetrics
	0.03	BORNMANN L	2008	What do citation counts measure? A review of studies on citing behavior	Journal of Documentator
	0.07	VAN ECK NJ	2010	Software survey: VOSviewer, a computer program for bibliometric mapping	Scientometrics
#1 Hirsch Index	0.26	HIRSCH JE	2005	An index to quantify an individual' s scientific research output	PNAS
	0.32	EGGHE L	2006	Theory and practice of the g-index	Scientometrics
	0.12	HIRSCH JE	2007	Does the h index have predictive power?	PNAS
#2 Impact Factor	0.11	KING DA	2004	The scientific impact of nations	Nature
	0.38	GARFIELD E	2006	The History and Meaning of the Journal Impact Factor	JAMA
#3 SCOPUS	0.34	MEHO LI	2007	Impact of data sources on citation counts and rankings of LIS faculty: Web of science versus scopus and google scholar	JASIST
	0.11	FALAGAS ME	2008	Comparison of PubMed, Scopus, Web of Science, and Google Scholar: strengths and weaknesses	The FASEB Journal
	0.11	KULKARNI AV	2009	Comparisons of Citations in Web of Science, Scopus, and Google Scholar: for Articles Published in General Medical Journals	JAMA
#4 Gender Disparity	0.16	LEE J	2009	Use of the h index in neurosurgery Clinical article	Journal of Neurosurgery
	0	PAGEL PS	2011	An analysis of scholarly productivity in United States academic anaesthesiologists by citation bibliometrics	ANAESTHESIA
	0	ELOY JA	2013	Gender Disparities in Scholarly Productivity within Academic Otolaryngology Departments	Otolaryngology-head and neck surgery

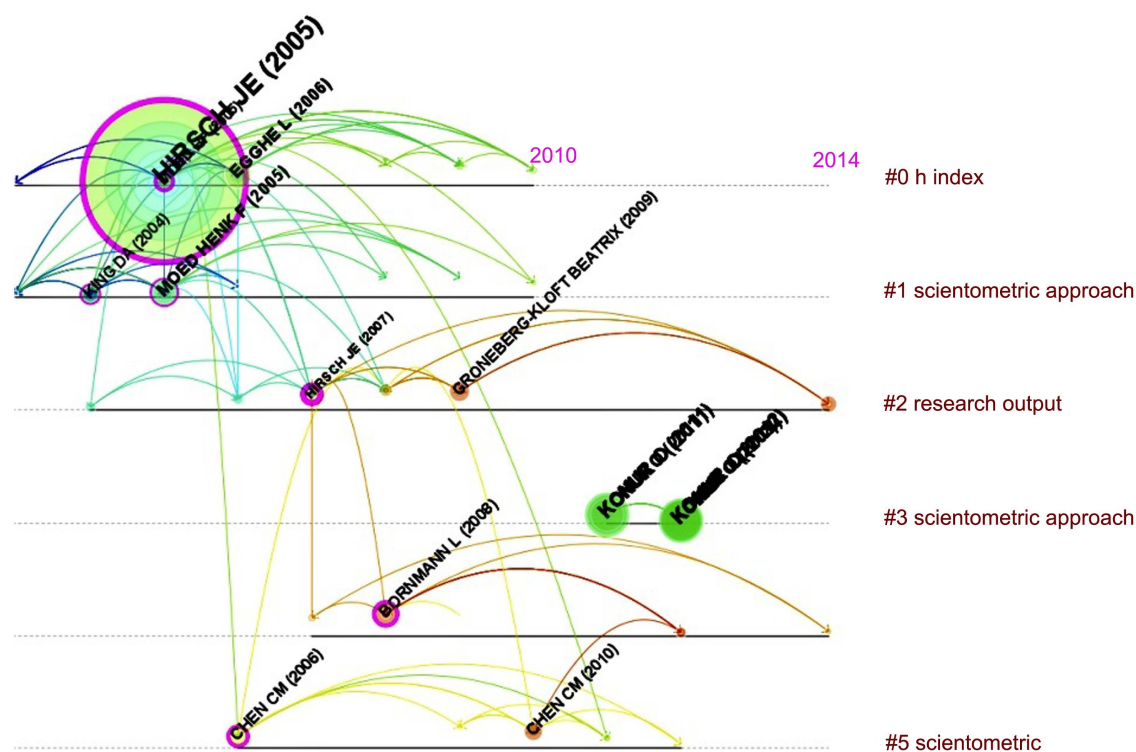


Figure 6. Document co-citation of scientometrics.

Table 2. Important basic document of scientometrics.

Cluster	Centrality	Author	Year	Title	Journal
#0 Hirsch Index	0.58	HIRSCH JE	2005	An index to Quantify an individual's scientific research output	PNAS
	0.05	EGGHE L	2006	Theory and practise of the g-index	Scientometrics
	0.12	KING DA	2004	The scientific impact of nations	NATRUE
	0.19	MOED HF	2005	Citation Analysis in Research Evaluation	Springer
#1, #3, #4 Scientometric approach	0.01	KONUR O	2011	The Scientometric evaluation of the research on the algae and bio-energy	Applied Energy
	0	KONUR O	2012	The evaluation of the research on the biodiesel: a scientometric approach	Part A-Energy Science and Research
	0	KONUR O	2012	The evaluation of the research on the microbial fuel cells: a scientometric approach	Energy Science and Research
	0.22	BORNMANN L	2008	What do citation counts measure? A review of studies on citing behavior	Journal of Documentation
#2 Research Output	0.43	HIRSCH JE	2007	Does the h index have predictive power?	PNAS
	0.02	Gronebergkloft B	2009	New quality and quantity indices in science (NewQIS): the study protocol of an international project	Journal of Occupational Medicine and Toxicology
#5 scientometric	0.2	CHEN CM	2006	CiteSpace II: Detecting and visualizing emerging trends	ASIST
	0.07	CHEN CM	2010	The structure and dynamics of cocitation clusters: A multiple-perspective cocitation analysis	ASIST

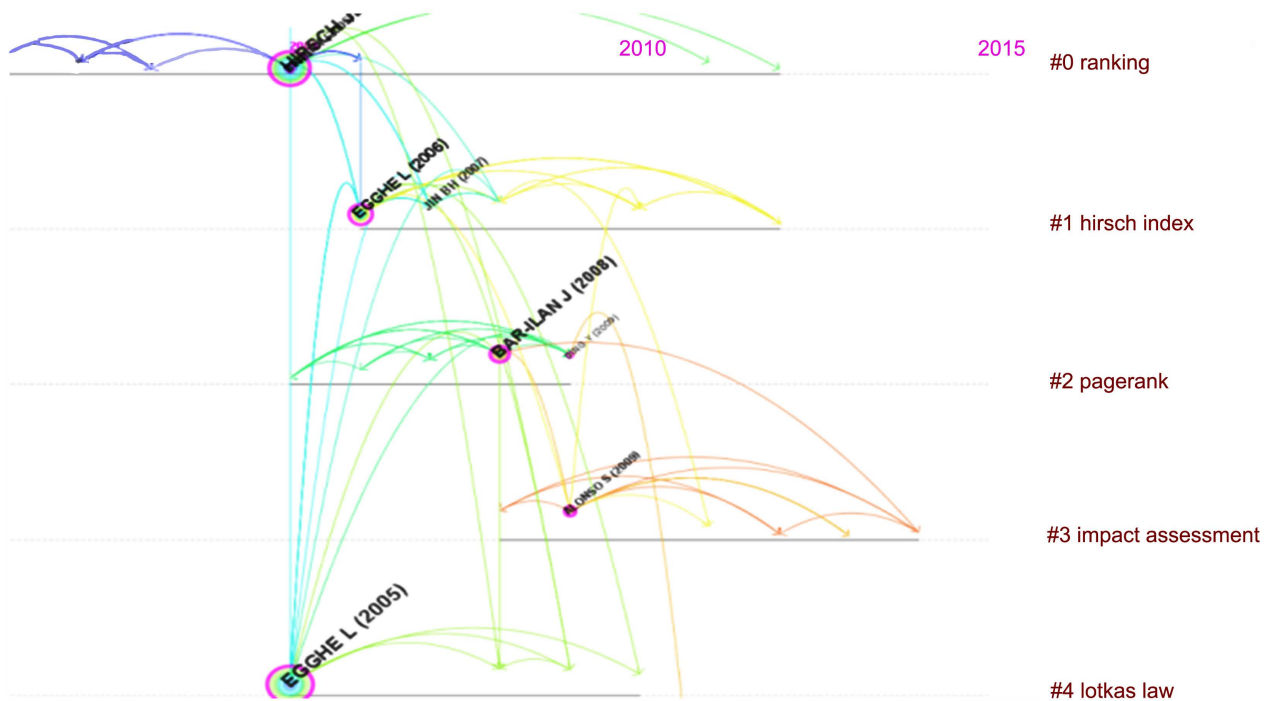


Figure 7. Document co-citation of informetrics.

Table 3. Important basic document of informetrics.

Cluster	Centrality	Author	Year	Title	Journal
#0 Ranking	0.29	HIRSCH JE	2005	An index to quantify an individual’s scientific research output	PNAS
	0.15	BRAUN T	2005	A Hirsch-type index for journals	The scientist
#1 Hirsch Index	0.26	EGGHE L	2006	An informetric model for the Hirsch-index	Scientometrics
	0.09	EGGHE L	2006	Theory and practise of the g-index	Scientometrics
#2 PageRank	0.24	BAR-ILAN J	2008	Informetrics at the beginning of the 21 st century-A review	Journal of Informetrics
	0.16	DING Y	2009	PageRank for ranking authors in co-citation networks	JASIST
#3 Impact assessment	0.25	ALONSO S	2009	H-Index: A review focused in its variants, computation and standardization for different scientific fields	Journal of Informetrics
#4 Lotkas law	0.34	EGGHE L	2005	Zipfian and Lotkaian continuous concentration theory	JASIST

performance of a group of articles, Egghe [21] proposed the G index. The H index is the common knowledge basis of the three areas, which indicates that the three metrics have attached great importance to researches on the innovation and application of evaluation indicators in the last ten years. Besides, as important basic literature, some articles appeared in both two metrics, although they belong to different name of clusters. For example, the “The scientific impact of nations” [22] and “What do citation counts measure?” Reference [23] appeared both in bibliometrics and scientometrics.

As shown in **Figure 5** and **Table 1**, there are five knowledge components in bibliometrics. #0 Research trend involves the review on the future development and progress of specific research directions, and the innovation indicators of research methods. Reference [24] studied the H index and the subsequent derivative index, and measured the application of the H index in different fields. Reference [23] conducted a review of scientists' citation behavior and analyzed the motivations, impact factors, and trends of the citation. #1 Hirsch Index includes some classic articles, such as Hirsch [6] and Egghe [21]. #2 Impact Factor become a separate category. Reference [25] introduced the history and meaning of the Journal Impact Factor, and also explained its formation and its causes. #3 Scopus presents diverse data sources and is the largest abstract and citation database of peer-reviewed literature; In this part, researchers focus on emerging data search tools and their data coverage, search capabilities, and the impact to scientific research [26] [27]. #4 gender disparity in the academic productivity and influence of researchers, For example, using the H index to study that whether the gender differences can lead to differences in academic productivity [28].

As shown in **Figure 6** and **Table 2**, #0 Hirsch Index is the same topic and includes the same important basic document in the bibliometrics field. #1, 3, 4 scientometric approach includes three research directions. Firstly, King [22] measured the status and influence of national scientific research with scientometrics methods, and Moed [29] explored the application of citation analysis in scientific evaluation. The two documents provided an empirical basis for the application of scientometrics methods. The second direction involves the application in other discipline and the citation analyses. Reference [30] applied scientometrics methods to the quantitative researches in biochemistry, and this document provided the knowledge basis for the application of scientometrics methods to different fields. Reference [23] presented a narrative review of studies on the citing behavior of scientists, and found that citing behavior was not motivated solely by the wish to acknowledge intellectual and cognitive influences of colleague scientists. #5 scientometric mainly contains the scientific basis of visualization technology and social network analysis in scientometrics. Reference [31] [32] developed CiteSpace, which is an important visualization tool for studies on subject topics and trends, and its functions are constantly optimized and improved to date.

As shown in **Figure 7** and **Table 3**. #0 ranking is related to scientific evaluation and mainly based on the articles of Hirsch [6] and Braun *et al.* [33] who studied the assessment and ranking of academic impact on individuals and journals using the H index, thereby establishing the foundation for the innovation and application of indicators in evaluation of scientific researches. #1 Hirsch Index is similar to #0 ranking, and includes two important articles about research H index itself and its improvement. #2 PageRank is the part wherein Ding [34] studied factors that affect the ranking of the PageRank algorithm, and proposed the weighted PageRank algorithm. The study provided experience for

the further application of the PageRank algorithm in informetrics. #3 Impact assessment involves some indicators of scientific evaluation. #4 Lotkas law is the part wherein the basic knowledge theory is comprehensively explored and the mathematical model is applied to the theoretical hypothesis. Reference [35] revealed the functions of Zipf and of Lotka and proved that Price’s law of concentration is equivalent with Zipf’s law.

4.4.2. Author Co-Citation Network

In the author co-citation network, combining high centrality and citation frequency can help identify the highly impact authors. As shown in **Figure 8**, Garfield, Glanzel, and Bornmann are high-impact authors of bibliometrics with high centrality and high cited frequency; Garfield, Leydesdorff, and Glanzel are high-impact authors of scientometrics; Egghe, Glanzel, and Rousseau are high-impact authors of informetrics. Glanzel significantly influences the three fields, and contributed to the development of scientific evaluation as well as the application of citation analysis. Garfield is a high-impact author in bibliometrics and scientometrics. And as the founder of SCI and ISI, he has significantly contributed to citation analysis and peer review. Egghe is the most cited author in informetrics, and he has published most of the articles in informetrics.

According to the prolific author data, Glanzel, Bornmann, and Leydesdorff are included in the top 10 highly cited authors in bibliometrics; Leydesdorff and Glanzel are included in those in scientometrics, and Egghe and Rousseau are included in those in informetrics. However, the prolific authors are not always highly cited authors. Garfield has notably written a small number of documents in the past decade. However, the cited-frequency of his works is the highest in bibliometrics and scientometrics, indicating that his early papers present far reaching impact.

4.4.3. Journal Co-Citation Network

From the journal co-citation network, we find that the knowledge in the three fields is based mainly on several journals: *Scientometrics*, *J AM SOC INF SCI*

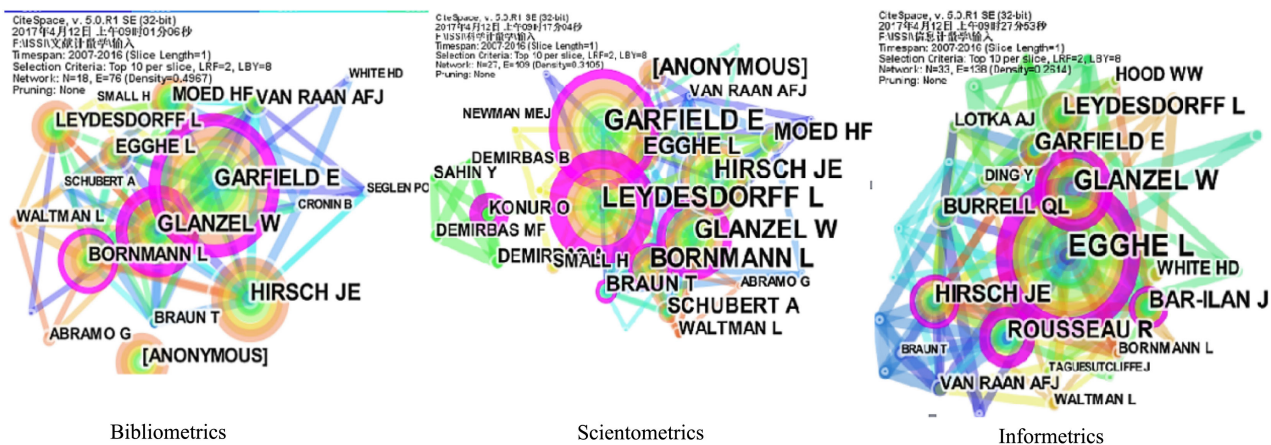


Figure 8. The author co-citation networks of the three metrics.

TEC, P NATL ACAD SCI USA, J Informmetr, Science, and Nature. Articles published in these journals exhibit high quality and impact in the three metrics. Many high-cited journals in the three fields belong to library and information science, suggesting that the three metrics are dependent heavily on themselves, which are similar to the results by Peritz and Bar-Ilan [7] and Milojević & Leydesdorff [2], although based on different time span. Meanwhile, a significant number of three metrics papers are published in some famous multidisciplinary journals (such as *Science, Nature* and *Plos One*), and these journals appear in the top 10 of the three metrics. A total of 9 out of top 10 journals are the same in bibliometrics and scientometrics and present same rankings. Therefore, the two fields have similar research knowledge base in terms of the journal. *Inform Process Manag* ranks fourth in informetrics, owing to informetrics involving the information management and retrieval research. *Scientometrics* and *J AM SOC INF SCI TEC* exhibit the highest cited frequency in the three fields, indicating that they the most significant knowledge source. JASIS and JASIST are treated as separate journals in data sets. The results are combined because they represent the same journal. Although this would not affect the ranking of JASIS(T) in the two of the lists, it elevate JASIS(T) to the top spot in the Informetrics list. All these show that informetrics has close relationship with information management and information technology (Table 4).

Co-citation analyses reveal the knowledge base and the structure of each field. By the co-citation analysis of document, author and journal level, it is seen clearly the specific situation of the three metrics. They are really similar and overlap in many aspects, and share some knowledge base, which shows the inseparability of the three fields. Meanwhile, they are not exactly the same and have their own characteristics and social distinctness. Generally, it reflects the scholars' cognition and orientation to the three metrics.

In our opinion, the publication counts reveal the recognition factors and academic behaviour, which can be proper indicators to decide on which metrics are

Table 4. Top 10 highly cited journals in the three metrics.

Bibliometrics		Scientometrics		Informetrics	
Cited journals	Freq	Cited journals	Freq	Cited journals	Freq
SCIENTOMETRICS	3042	SCIENTOMETRICS	946	J AM SOC INF SCI TEC	250
J AM SOC INF SCI TEC	2770	J AM SOC INF SCI TEC	862	SCIENTOMETRICS	187
P NATL ACAD SCI USA	1304	P NATL ACAD SCI USA	402	J INFORMETR	110
J INFORMETR	1225	J INFORMETR	396	INFORM PROCESS MANAG	108
SCIENCE	1204	SCIENCE	386	P NATL ACAD SCI USA	66
NATURE	1176	NATURE	350	J DOC	52
RES POLICY	976	RES POLICY	271	SCIENCE	40
PLOS ONE	669	PLOS ONE	173	NATURE	37
J DOC	414	INFORM PROCESS MANAG	122	LIBR INFORM SCI SER	29

the most appropriate to use. Bibliometrics has the largest number of publications, therefore, bibliometrics is more recognized than informetrics in the scientific community, we recommend the addition of bibliometrics in the title of ISSI.

1) ISSI is the most important international organizations in the three-metrics field, accordingly, the international conference of the ISSI is certainly amongst the world's largest and most prestigious of its kind in our field [36]. The title of ISSI changes frequently in the early years: First International Conference on Bibliometrics and Theoretical Aspects of Information Retrieval; Second International Conference on Bibliometrics, Scientometrics and Informetrics; Third International Conference on Informetrics; Fourth International Conference on Bibliometrics, Informetrics, and Scientometrics; Fifth Biennial Conference of the International Society for Scientometrics and Informetrics [4]. The subsequent conferences have been held biennially under the fixed name ISSI. Renaming is inseparable from the activities of some scholars in the field of Information Science in the early stages. For example, Brookes [16] endorsed "informetrics" as a general term for scientometrics and bibliometrics, and many scholars agree with this view. However, why titles of ISSI include scientometrics if informetrics covers the three metrics? A likely reason is that they aren't entirely relationship with the inclusive and contained.

2) We do not recommend selecting one specific term instead of using three different terms. Although the results that the publications on the three metrics have rather similar contents have been showed by subject structure and co-word analysis, that is, they are intellectually similar, many aspects in three metrics differ in detail (the active authors etc.). Besides, many new terms appear and are used together without causing confusion, such as altmetrics, webometrics, knowledgometrics and entitymetrics; while it is a classical phenomenon to use new names together with old. One of the main reasons is that every term has a focus, the use of context, academic background and perspective. Furthermore, some scholars try to use one specific term (e.g. iMetrics) instead of related terms, but in fact they are not very successful [2].

5. Conclusion

We analyze documents (including articles, reviews, and proceeding papers) on the three metrics from SCI-Expanded, SSCI, and A & HCI using three term sets in the 10 years (2007-2016). The results show that bibliometrics, scientometrics and informetrics differ in the degrees of utilization and recognition, but are similar in general structure and citation situation although some details content is different. We recommend the addition of bibliometrics in the title of ISSI. The reported results provide some food for thought for researchers in the metrics area.

1) Recognition. Combining the number of articles in levels of nation and institution shows that Europe is the core area of these three fields. Bibliometrics and scientometrics have high degrees of recognition in America; the degree of recognition of scientometrics is higher than that of the two other fields in Asia, and bibliometrics is much higher than that of the two other fields in Oceania. In

Africa, the three metrics all have low degrees of recognition, yet the informetrics is high in South Africa. Bibliometrics is the most frequently used and has the highest degree of increase among the three metrics.

2) Cooperation. Universities are the main research institutions in three metrics fields. Bibliometrics has the highest degree of institutional cooperation and the largest scale of institutional cooperation network; On the contrary, the cooperative relationships of scientometrics and informetrics are dispersed, and the size of the group is small. About the co-author network, bibliometrics has not only larger scale of cooperative group but also tighter group relationships than scientometrics and informetrics. Many two-author groups with scattered scale exist in scientometrics. The author cooperative network of informetrics is the sparsest and has the smallest scale among the three metrics.

3) Subject structure. The co-words analysis of topics shows that the differences between the three metrics are small, while they each have somewhat specialized focus. Bibliometrics attaches great importance to the development of the bibliometric methods application in scientific research. Scientometrics emphasizes the quality of scientific research output and focuses on scientific development trends, and applying methods (such as citation analysis) to other disciplines. For informetrics, researchers prefer to use informetrics methods and apply the mathematical models to the distribution and ranking when researching information systems.

4) Knowledge base. The co-citation network analysis reveals further similarities among the three metrics. The three metrics have common knowledge base in general; however, some differences are also showed in results. The H index, one of those focusing on innovating and improving indicators, is the common knowledge base of the three fields. The peculiar knowledge bases of bibliometrics include the development of specific research direction, data coverage and search capabilities of emerging data search tools, and application of bibliometrics in the medical field. The peculiar knowledge bases of scientometrics include the application of scientometrics methods in scientific evaluation and other disciplines, such as visualization techniques and social network analysis. The peculiar knowledge bases of informetrics include comprehensive exploration of the basic theory and the PageRank algorithm.

This study presents a few limitations. The overall situation of the three metrics can be accurately compared using long data period. However, this study uses only the data from 2007 to 2016. Although we carefully refine some terms and construct a document retrieval formula, the data set is still incomplete and thus can't fully represent the data for the three metrics. The current situation and relationships of the three metrics include various aspects, but this study focuses on only three major areas. Therefore, we recognize the comparative analysis is insufficient. Future research can conduct interview with experts, approach survey methods, extend the data period, perform in-depth content analysis, and use other methods in revealing and comparing the relationships among the three metrics.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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