Junping Qiu · Rongying Zhao
Siluo Yang · Ke Dong

Informetrics

Theory, Methods and Applications

Springer

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Preface

Since 1960s, three similar terms: Bibliometrics, Scientometrics, and Informetrics have appeared in the fields of library science, philology, information science, and science of science. These similar quantitative branches are called three-metrics. After decades of efforts on research and promotion, these disciplines all progressed at different degrees and became widely recognized by academia. Although these areas have 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. With development of science and technology and continuation of these three metrologies, convergence among them has developed, and International Society for Scientometrics and Informetrics (ISSI) was formed. Since 1990s, with rapid development and popularization of computer and network technologies and rise of knowledge economy and knowledge management, digitalization, networking, and knowledge have become remarkable characteristics of information society and knowledge economy era. Three-metrics is characterized by expanding breadth and depth of studies. Webometrics is based on network information and data, and Knowledgometrics is based on knowledge units; these subjects emerged in field of information management, prompting people to coin the term five-metrics. Five-metrics include literature, data, information (including network information), knowledge, and scientific activities. Subjects share many similarities but also have significant differences; they became important works on measurement research in information management field. Development of five-metrics reflects continuous innovation of quantitative research on information management and tracking of evolution with changing times and social background. Five-metrics also only involves legacy and development of bibliometrics and scientometrics.

Informetrics uses quantitative methods to describe and research phenomena, processes, and laws of information. This area is a new quantitative discipline of information science, and it is based on mathematics and statistics. Informetrics was initially presented as the German word "Informetrie," which was proposed by German scholar Otto Nacke. Corresponding English term "Informetrics" soon appeared in subsequent literature works. Nacke expanded concept of informetrics on first Seminar on Informetrics (including Scientometrics) in Frankfurt in September

1980. German and English terms also appeared in Chinese journals in 1981. Informetrics did not only spread rapidly in English-speaking countries but was also recognized by International Federation for Information and Documentation (FID), marking the rise of a new branch of discipline. As early as 1980, FID established informetric communications (FID/IM). In 1987, Belgium held the first International Conference on Bibliometrics and Theoretical Aspects of Information Retrieval. The well-known information scientist, Brookes, suggested at the meeting that term informetrics should be added to name of second International Academic Conference, which would be held in Canada in 1989; participants were generally supportive. However, conference was not renamed until June 1995 on Fifth International Conference on Scientometrics and Informetrics held in Chicago, USA. Informetrics was replaced with Bibliometrics in conference name. At present, the conference is known as ISSI. Given that "Informetrics" has been used in the titles of numerous proceedings published by international academic conferences since 1987, a number of well-known foreign information scientists regard 1987 as time when informetrics was recognized formally by international information academia. Chinese academic community responded accordingly to Informetrie (German) and Informetrics (English) and the disciplines they represented and introduced. As early as 1981, related papers were published. My monograph < Bibliometrics(Chinese) >, published in 1988, not only discussed in detail relationship among three-metrics but also proposed systematic framework of informetrics.

Our team has been teaching and researching on bibliometrics, informetrics, and scientometrics at Wuhan University since early 1980s. We led in offering Bibliometrics course in Chinese colleges in 1983 and compiled Chinese teaching material under the same name. Materials were published officially by Scientific and Technical Documentation Press (Beijing) in 1988 after being featured in mimeograph in 1983, letterpress in 1985, and few years of teaching. This book was the first to comprehensively structure content system of bibliometrics from the perspective of theory, method, and application, and it was praised and welcomed by academic community. This textbook is used in more than 10 colleges and universities, and its citation rate is among the best. Yang Peiting, a famous information scientist, said, "This is undoubtedly a positive contribution to the study and teaching of Information Science in China, and this can be said to be a groundbreaking research." Afterward, our team carried out studies on three-metrics, which significantly influence people both in local areas and abroad. With rapid development of information technology and information science and with popularization of information resources, electronic, digital, and network, information resources are becoming more popular. Information resources greatly influenced and resulted in profound changes in development of human society, economy, science and technology, culture, and other fields. Under new social environment and technical conditions, new developments transpired in bibliometrics research. Facing this new situation, trends, and topic, our team led development of informetric and webometric research in China and published series of research papers with "Informetrics" and "Webometrics" on their titles in Information Studies: Theory and Application in 2000–2001; these publications had great repercussion and high

rate of citation in academia, locally and abroad. These papers became classic series of articles in research of informetrics and webometrics. <Informetrics (Chinese)> by Qiu Junping was published by Wuhan University Press in January 2007. This book was crystallization of long-term teaching and research on three-metrics and reflected development characteristics of three-metrics in information age. The material-oriented teaching and research on library science, information science and information management, and other related disciplines are included in "Ministry of Education for the 21st century curriculum materials" and "information management college and university core course textbook." The book was selected as part of national quality courses and national Twelve Five planning materials. In recent years, we focused on trends in metrology research, undertook series of research projects, such as national social science major and the National Science Fund Project, and published series of research results. On this basis, under Science Press, we published "Metrology Research Series in Information Science," which included <Scientometrics>, <Knowledgometrics>, <Webometrics>, and other related monographs in Chinese version.

With development of social economy and science and technology in China, research on information metrology rapidly progressed. China hosted ISSI meeting in Beijing (2003) and Wuhan (2017) and many other relevant meetings related to informetrics. Our country and other nations, such as the United States and some European countries, developed exchanges and cooperation. We published numerous related works and set up corresponding university courses and direction of graduate education. Many professional students and scholars go abroad to pursue degrees. Research institutions on informetrics also emerged; some of these organizations include National Professional Association and Chinese Society for Scientometrics and Informetrics. In China, informetrics adheres to dual development principle of internationalization and localization, with both closely following pace of foreign countries and having their own characteristics. Under the guidance of "bringing in and going out" strategy, Chinese scholars played increasingly important role in international professional organizations and extensively absorbed achievements of foreign professional treatises. These academics published more academic papers in foreign informetric professional journals with increasing influence. However, owing to the influence of policy orientation and language, international publications inadequately released relevant works of Chinese professionals. To introduce informetric research and to teach contents with Chinese characteristics, we published <Informetrics—Theory, Methods and Applications> in Springer–Verlag. We believe that publication of this book will provide basis for foreign countries to understand informetric research in China and will promote further development in research and practice of informetrics.

We always believed in close linkages and differences among bibliometrics, informetrics, and scientometrics. These disciplines have more interconnections, cross-connection, and overlapping than differences. Some foreigners regarded such areas as synonymous or advocated to use different names of subjects in different situations. We used the title "Informetrics—Theory, Methods and Applications" with following considerations in mind: first consideration is wider scope of

informetrics, which may include bibliometrics and scientometrics and also appeared in the name of ISSI meeting. Second consideration is that informetrics is based on research and is also recognized as branch of academic discipline. Third, with in-depth application of computer network technology, rise of Web 2.0 and big data technology, and popularization of open access and digital publishing, popularity of social networking and We-Media and rapid development in 4G mobile services and e-research profoundly influenced all aspects of information communication and technology innovation and provided necessary conditions and possibilities for information metrology and rare opportunity for development of informetrics. Fourth consideration is to arouse interest of people and to promote further research and development of informetrics. Future research and development should focus on informetrics. In this book, three-metrics is inevitably involved as basis of bibliometrics, and focus of discussion is metrology problem of literature information; this problem is influenced by present research situation and facts. To facilitate narrative, we also used "Informetrics" in the book.

The book consists of 11 chapters. Main content can be summarized into theory, method, and application. Research on theory of informetrics is found in Chaps. 1–7. Research on informetrics method spans Chaps. 8–9. Chapters 10–11 discuss application of informetrics. Law applications are also discussed in some chapters. This book retains some of typical application examples in <Bibliometrics> because they are classic cases and can still explain the problem; representative new cases cannot replace them. Though content is not updated, novelty of the book should not be affected. During compiling, we attempted to construct disciplinary system of informetrics from angles of theory, method, and application: attention was provided to combination of theory and practice, inheritance, and innovation; traditional statistical tools were combined with new information technology methods; no effort was exerted to ensure clear thinking, reasonable structure, comprehensive explanation, rich content, novel idea, and detailed material for this book. Material should not only reflect and absorb latest development on three-metrics both at home and abroad but also add our research results to make study of included disciplines more scientific, innovative, systemic, and practical. The book is suitable as teaching material in information management and information system, management science, information resource management, e-commerce, information science, library science, archives science, publishing science, science of science and management of S.&T., and evaluation and prediction of science in colleges. This work also serves as learning reference for majority of information workers, knowledge workers, researchers, evaluators, and managers.

Qiu Junping chaired revision of the book. The following people participated in revision and translation work: Qiu Junping, Zhao Rongying, Yang Siluo, Dong Ke, Tan Chunhui, Ma Ruimin, Ding Jingda, Song Yanhui, Zhang xinyuan, Yang Jinli, and Yuan Qingli. Finally, Qiu Junping and Yang Siluo made some additions, deletions or modifications, and completed English proofreading and drafting works. This book is legacy and innovation of <Informetrics> (Chinese version), <Bibliometrics> (Chinese version), <Scientometrics> (Chinese version), and

<Knowledgometrics> (Chinese version), and is completed based on <Informetrics> (Chinese version) with modification, supplementation, updates, and expansion.

Given that chapters of this book were written separately by different authors, mistakes may inevitably exist. We sincerely ask readers for criticisms and corrections.

Wuhan, China Junping Qiu

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Chapter 1
Introduction

1.1 Origin and Development of Informetrics

1.1.1 Origin of Informetrics

Informetrics, which originates from the German word "informetrie," was first proposed by the German scholar, Otto Nacke. The corresponding English term "informetrics" appeared in later literature. Some scholars believe that this English term first appeared in the title of an annual research project published by the National Science Foundation in 1980, whereas others assume that its English translation came from non-English speaking countries, namely, the Japanese magazine "Information Management" and the "Information Science Abstracts" from the Soviet Union. In September 1980, Professor Nacke introduced the term "informetrics" during the first informetrics (including scientometrics) seminar that convened in Frankfurt, Germany. In 1981, both German and English terms appeared in domestic periodicals and were translated as "informetrics." However, arguments were raised. A number of articles have pointed out that this term should be subjected to particular scrutiny. Related studies have determined that the suffix "metrics" follows a vowel (such as "a" or "o" in bibliometrics and scientometrics) in about 10 subject names that contain the element "metrics." Nevertheless, this suffix follows a consonant "r" in the term "informetrics," which appears at odds with the general word formation rule in English. The credibility of the term, which has been translated by non-English speakers, remains to be verified. Nonetheless, the term has already gained prevalence in English-speaking countries, and it has been recognized by the International Federation of Documentation (FID). The doubtful attitude of some scholars toward the word has been eventually eliminated, and this emerging subdiscipline has begun to flourish.

In the early 1980s, FID/IM established the Committee of Metrology (FID/IM), which had a standing body located in the Indian National Scientific Documentation Center and with T.N. Nagy as the president. With the objective of strengthening

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education and research in informetrics, FID/IM formulated key points for the work scheme and planned to conduct important academic activities to promote the development of the aforementioned subject. In 1982, the former Czechoslovakia held a conference on the teaching plans of informetrics. Two years later, a few basic theoretical issues were elucidated in two important papers of B.C. Brooks, which explicitly advocated for the vigorous development of informational metrology. With its plans evaluated and demonstrated, FID/IM published "Newsletter Informetrics" in India in 1985. In the First International Symposium on Bibliometrics and Information Retrieval Theory held in 1987 in Belgium, the proposition of Brooks to add "informetrics" to the name of the second session of the international conference scheduled to be held in 1989 in Canada won universal recognition and support from attending scholars. The views of Brooks were accepted in the third and fourth international conferences held in India and Germany in 1993 and 1994, respectively. In June 1995, the academic conference held in Chicago was renamed as the "Fifth International Conference on Scientometrics and Informetrics." Although bibliometrics was discussed in the conference, the term was not included in the title of the conference. The organization that held biennial international seminars also had its name changed to "International Society for Scientometrics and Informetrics" (ISSI). All the aforementioned changes have demonstrated the recognition of informetrics by the international academic circles and its rising prominence.

The year 1987 was regarded as the one during which "informetrics" was officially recognized by the international information community and by several foreign information scientists because the term appeared on the title of papers related to or published by international academic conferences since 1987. Treatises with the term "informetrics" on their titles were published, as evidenced by the "Introduction to Informetrics" written by L. Egghe and R. Rousseau in 1990 and the paper "Introduction to Informetrics" by Canadian information scientist, S.T. Tague. After 1987, several Western information service corporations even changed their names to the trendy "Informetrics Limited" when the term became prevalent in North America and Western Europe.

Academies in China have also reacted promptly and given sufficient attention to informetrie (in Germany), informetrics (in English), and the subjects represented by the term. For example, related papers were published early in 1981, and the official publication of "bibliometrics" in 1988 did not only elucidate scientometrics, informetrics, and bibliometrics (tri-metrics), but also propose the framework for the contents of informetrics. Informetrics has acquired a consistent translation result from scholars as a third-grade branch discipline in response to information science. However, a relevant department in China altered its translation of "informetrics" in 1992, which became the origin of informetrics in China.

1.1.2 Background of Informetrics

Similar to other disciplines, the introduction to informetrics has not occurred as a certainty but has formed and developed under a certain background and scientific environment.

First, informetrics has extended and evolved based on traditional bibliometrics and scientometrics. The early stage of informetrics coincided with the rise of bibliometrics and scientometrics when related studies were active. Several early information scientists who focused on quantitative studies regarded bibliometrics and scientometrics as their fields of study; thus, people assumed that these fields combined specific methods from information science. When some information scientists joined in bibliometric research, considerable progress was achieved on useful extensions and studies on the research scope, methods, models, applications, and other aspects of bibliometrics. In the early 1980s, Brooks studied Bradford's law under common social circumstances and replaced the terms "periodical" and "paper" with "source" and "item," respectively, to make them widely acceptable. He also extended bibliometrics into a calculus of social science, such that it would play a broader role in society. However, after all the extensions scholars made on the research scope of and method for bibliometrics, they determined that informetrics was not a subject that entirely belonged to bibliometrics, but one with wider areas of measurement and quantitative research, as well as its own unique research method. They finally realized a simple but important fact, one that would be impossible to notice earlier, i.e., the number of and metering method for information considerably exceeded that of the literature. This significant finding was proposed in a series of papers published by Brooks, who clearly advocated for the development of informational metrology. At that time, bibliometric research mainly served the research purposes and needs of library science. Library scientists wanted bibliometrics to be their exclusive field of study. This situation prompted information scientists to establish their own area of quantification research that corresponded to information science, thereby promoting the formation and development of informetrics.

Second, informetrics is the inevitable outcome of the development of information science. Quantification research has always been a significant direction and an inevitable tendency in the development of information science because of several reasons. Information science will inevitably evolve from a qualitative stage to a quantitative stage given the general discipline development rules. Only through strengthened quantitative research can information science become highly scientific and accurate, thereby establishing and promoting its status in the entire science system. As Brooks stated, "information science will remain a heap of unconnected techniques and never become a subject of science until quantitative studies are conducted." This important academic idea has received increasing recognition from a growing number of scholars. Others have also actively participated in studying this aspect. With extensive research findings being published, informetrics, as a quantitative subdiscipline of information science, is gaining increasing momentum.

Therefore, informetrics is an inevitable product of the quantitative development of information science.

Third, the field of informetrics comprises a number of backbones and discipline leaders. Information scientists, with their solid foundation of knowledge in mathematics and physics as well as familiarity with quantitative research methods, have the advantage and talent that can guarantee further development of informetrics. Early scholars, such as Bradford, Lotka, and Price, and later ones, including Brooks and Garfield, are all specialists who have devoted themselves to research with a solid store of knowledge and well-used methods. They have played the role of leader researchers. For example, as an outstanding representative, Brooks actively advocated and attach great importance to the quantification of information science, he thought information science is the study of the essence, as same as measurement, of information and knowledge, and also creatively put forward the "ranking technology" and "logarithmic perspective principle" as a way of quantitative information science. In 1988, Brooks proposed that we should replace bibliometrics to informetrics, and the reason is that bibliometrics is only confined to the bibographic metrology, and is not suitable for modern electronic measurement of the carrier of literature. This has played a role on the formation and development of informetrics.

1.1.3 Development of Informetrics

The development course of informetrics is described as follows: statistical bibliography → bibliometrics → scientometrics → informetrics. The earliest informetric research started at the beginning of the 20th century when the famous philologists F.T. Cole and N.B. Eales conducted literature statistical research in 1917. In 1992, English library scientist E.W. Hulme used the term "statistical bibliography" for the first time in his book "The Relation between Statistical Bibliography and the Development of Modern Civilization." This term refers to a new subdiscipline under bibliometrics that determines the nature of library materials through statistical methods. In 1969, the proposal of the renowned English information scientist Alan Pritchard that the term "bibliometrics" could be used to replace "statistical bibliography" received universal acknowledgment from library science and information science scholars. The emergence of this term officially marked the birth of bibliometrics. Similar to the early history of bibliometrics, the history of scientometrics dates back to the beginning of the 20th century when European and Russian scholars conducted statistical analyses of bibliographic citations. In the same year when the term "bibliometrics" was coined, scholars from the former Soviet Union, V.V. Nalimov and Z.M. Mulchenko, introduced the term "scientometrics" as a scientific quantitative approach to studying and analyzing information. In 1978, the magazine "Scientometrics" founded by Hungarian scholar Tibor Braun provided an academic exchange platform for international scientometric scholars, thereby promoting the development of scientometrics. The early

history of informetrics is incorporated into the history of bibliometrics and scientometrics given that informetrics is a legacy and extension of the latter two. The term "informetrics" proposed by the German scholar Otto Nacke in 1979 failed to gain universal recognition from library science and information science scholars. However, Western information scientists have exerted continuous efforts to establish the important position of informetrics, as evidenced by the founding of the Committee on Informetrics by FID through the persuasion of information scientists in 1980 and the long-term project on teaching and studying informetrics; the publication of the informal magazine "Informertics Newsletter" in India; the first international academic conference, namely, the International Symposium on Bibliometrics and Information Retrieval Theory held in Belgium and initiated by ISSI, and the subsequent conference proceedings on informetrics, which had attracted considerable attention from the bibliometric and informetric circles. Informetrics has invariably been designated as the core theme of the aforementioned conference since 1987, and the name of the conference has been officially changed to "International Conference of the International Society for Scientometrics and Informetrics" since 1995 when informetrics has gained wide acceptance among scholars with its gradually increasing influence.

ISSI has played a pivotal role in the development of informetrics. Since 1987, it has held biennial international conferences on scientometrics and informetrics, with 15 successful consecutive conferences. Different themes have been selected, and related papers have been widely collected and discussed during each conference, thereby positively affecting the development of informetrics. The title, time, venue, and theme of each conference are listed in Table 1.1.

The accelerated development of information science and information technology, coupled with the digitalization of information resources and the increasing popularity of the Internet, has significantly affected and profoundly transformed all aspects of our society, economy, technology, and culture. Under the new social context and technological condition, the study and development of informetrics have presented different directions and trends. In the current study, we mainly focus on the following aspects.

(1) From bibliometrics to informetrics

In our article entitled "The Progress and Development Direction of Domestic Bibliometrics," we indicated that similar to the relationship between literature and information, bibliography and information science and bibliometrics and informetrics are also inextricably intertwined and mutually complementary. Bibliometrics is the foundation of informetrics, and informetrics is the development direction of bibliometrics. The book entitled "Bibliometrics" states that the progress achieved in bibliometrics also contributes to and promotes the development of informetrics. We must incorporate the study and research of informetrics into our agenda in due course and exert assiduous efforts to promote the development of informetrics. The article "Progress in the Quantitative Research on Domestic Information Science" divides papers on the quantitative research of information

Table 1.1 Outline of the 15 International Symposiums on informetrics and scientometrics

Number	Title	Date	Place	Topics
First	International Symposium on Bibliometrics and Information Retrieval Theory	25–28 August, 1987	Diepenbeek, Belgium	1. In-depth discussion on basic laws 2. Application of citation analysis
Second	International Symposium for Bibliometrics, Scientometrics, and Informetrics	5–7 July, 1989	London, Canada	1. Tri-metric (scientometrics, informetrics, and bibliometrics) scope definition 2. Rule generalization
Third	International Symposium on Informetrics (Indian Statistical Institute)	9–12 August, 1991	Bangalore, India	1. Application of statistical methods to informetrics 2. Application of mathematical methods
Fourth	International Symposium for Bibliometrics, Scientometrics, and Informetrics	11–15 September, 1993	Berlin, Germany	1. Relationship among tri-metric (scientometrics, informetrics, and bibliometrics) studies 2. Application of citation analysis
Fifth	International Symposium for Scientometrics and Informetrics	7–10 June, 1995	Illinois, United States	1. Discussion on periodical evaluation 2. Extension to basic laws
Sixth	(same as above)	16–19 June, 1997	Jerusalem, Israel	1. Application of citation analysis 2. Studies on the aging and dispersion laws of literature 3. Data compression 4. R&D management
Seventh	(same as above)	5–8 June, 1999	Colima, Mexico	1. Academic journal evaluation 2. Content analysis 3. Citation analysis and mathematical model 4. Law distribution and demonstration
Eighth	(same as above)	16–20 June, 2001	Sydney, Australia	1. Laws and their distribution in the field of science 1 2. Mathematical model for information measurement 3. Citation motivation and scientific evaluation

(continued)

Table 1.1 (continued)

Number	Title	Date	Place	Topics
				4. Knowledge map and visualization 5. Analysis and forecast of scientific and technological policies 6. Library management
Ninth	(same as above)	25–29 August, 2003	Beijing, China	1. Mathematical modeling of information measurement 2. Scientific evaluation and university-ranking methodology 3. Citation analysis and database 4. Quantitative analysis of scientific and technological innovations (patent) 5. Network information retrieval research
Tenth	(same as above)	24–28 July, 2005	Stockholm, Sweden	1. History of scientometrics 2. Citation motivation research 3. Knowledge map 4. Webmetrics 5. Science policy analysis and forecast
Eleventh	(same as above)	25–27 June, 2007	Madrid, Spain	Refer to http://issi2007.cindoc.csic.es/[a]
Twelfth	(same as above)	14–17 July, 2009	Rio de Janeiro, Brazil	Refer to http://www.issi2009.org/php/index.php
Thirteenth	(same as above)	4–7 July, 2011	Durban, South Africa	Refer to http://www.issi2011.uzulu.ac.za/index.php
Fourteenth	(same as above)	15–19 July, 2013	Vienna, Austria	Refer to http://www.issi2013.org/
Fifteenth	(same as above)	29 June–4 July, 2015	Istanbul, Turkey	Refer to http://www.issi2015.org/en/default.asp

[a]We have not listed the diverse topics

science into four categories: ① bibliometrics and its application, ② information retrieval theory, ③ theoretical study of information science, and ④ information economics and information result evaluation. Among which, the category

"bibliometrics and its application" accounts for a relatively large proportion of 46.6%. Bibliometrics constitutes an important aspect in the quantitative research of information science and is currently progressing toward informetrics.

In terms of metrological units, informetrics has gone beyond the metrological analysis of bibliometric units, such as articles, volumes, and books, but has probed further into the literature to conduct metrological analysis of contents and related information therein, such as titles, subject terms, keywords, word frequency, knowledge items, citation information, author, publisher, date, language, and format. In early 1980, Sen Long, who worked for the Japan Science and Technology Information Center, successfully predicted the structure and development prospects of polymer material products by conducting statistical analysis of the keyword occurrences of terms such as "plastic," "rubber," and "fiber." We once conducted a statistical analysis of the number of content topics of a large number of related literature in the article "The Quantitative Analysis of the Research Topic Trends of Domestic Library and Information Science" and provided a quantitative revelation of the development process, research priorities, popular themes, and trends of domestic library and information science. The electronic publication developed recently by Professor Chen Guangzuo introduced informetrics and knowledge item clustering functions, thereby opening new areas of applications and creating a new development approach for bibliometrics. Any knowledge element or even every word of the text of an electronic publication, as a full-text database, can be retrieved and statistically analyzed. In this case, the metrological unit of bibliometrics can evolve from an independent piece of literature to the knowledge elements or even a single word in the literature, thereby making in-depth informetric analysis possible. This evolution is an important progress that shows that bibliometrics has developed into informetrics, and this trend will continue further.

(2) Computer-aided research and application of informetrics

A large number of studies on computer-assisted informetric analysis have achieved considerable success and increasingly widespread applications since the 1990s. Informetric study requires data support of a certain scale. In addition, a systematic and standardized system of data source and channels to obtain original data should be established; modern methods and tools, such as computers, should be used to conduct data processing and analysis. Foreign academic circles place considerable importance on efforts in this respect. In the early 1960s, the United States began to prepare the "Science Citation Index" (SCI). The publication and distribution of this huge index provide a powerful and multifunctional tool to study informetrics and, to a certain extent, a large amount of data are indispensable to conduct citation analysis, thereby effectively promoting the full-scale quantitative study of informetrics and information science. This case is also observed domestically. We have long recognized that if modern technical means, such as computers, are not used to solve the problem of informetric tools, then domestic study on informetrics will probably never reach a new stage of development. Hence, we emphasized in some related literature that conducting studies on the modernization of informetric tools

and instruments was an urgent task that should merit our attention. We established three proposals to conduct the study: ① introduce and develop SCI, ② compile our own "Chinese SCI" (CSCI), and ③ conduct research on computer-assisted informetric analysis.

We have performed bold explorations in these aspects and achieved considerable progress in recent years. The Chinese Institute of Science and Technology established the Chinese Science and Technology Papers and Citation Database (CSTPC) in 1987 and conducted a multi-index statistical analysis on a number of papers cited by Chinese scholars. The results, which were released annually, profoundly influenced the society, and thus, effectively promoted the popularization and development of informetrics. The Documentation and Information Center of the Chinese Academy compiled and published CSCI in 1995 after years of efforts. The production and release of its CD-ROM version followed shortly in 1998 In 2000, the China Social Science Research Evaluation Center of Nanjing University and the Hong Kong University of Science and Technology jointly developed the Chinese Social SCI (CSSCI) to compensate for the shortage of data sources in humanities and social sciences. They provided a large-scale tool for retrieving data that could be extensively applied to quantitative studies on informetrics.

The paper entitled "The New Trend of the Study on Bibliometrics—Computer-aided Bibliometric Study" was the first to discuss the quantitative analysis of computer-assisted informetrics and its approaches; it proposed that computer-aided bibliometric studies should be used to make bibliometric research more standard and modern. This paper also discussed system designs and approaches to conducting computer-aided quantitative analysis of literature information as follows. ① A database system that is mainly used for the informetric analysis of literature information is established. We can design various types of bibliometric information system in terms of the different objectives and requirements of studies starting from the principles of bibliometrics. ② Existing information retrieval systems should be utilized and improved to adapt to the informetric analysis of literature information. Related recordings of data should be increased according to the characteristics and requirements of informetric studies based on the original information retrieval system, thereby expanding the scope of statistics to be capable of conducting quantitative analyses. ③ Copy technology is used to establish a database, particularly for the informetric analysis of literature information. Software programs, such as SCI-NATE, that are capable of performing copy technology to establish databases, are already available. The paper "Bibliometric Methods and Computer-aided Bibliometric Research" discussed new methods for bibliometric research, particularly computer-aided bibliometric research methods from a methodological point of view. The authors of the paper designed and developed software on computer-aided bibliometric analysis, reestablished a set of recorded data, and conducted statistical analysis on a variety of data through Pro*C based on theoretical analysis with the support of the Oracle database system. They also performed statistical analysis on a series of multifaceted literature information, which was all based on 16,000 physics articles published by Chinese scholars in the British? "Physics Abstracts" (PA) in 1992–1994, using self-programmed software.

All the aforementioned efforts do not only practiced and verified methods of computer-aided bibliometric research, but also offered a quantitative revelation of the development characteristics, key areas, and power distributions in the field of physics in China, thereby drawing useful results. In summary, the establishment and perfection of computer-aided bibliometric analysis methods indicate that the domestic informetric analysis method system has basically taken shape and will continue to improve in the future.

(3) Study of webometrics

Two new terminologies, namely, " webometrics" and "cybermetrics," have emerged in related web pages and literature in recent years. However, the measurement object is online information or information controlled by the computer, rather than the "Net" or the "computer" itself. Therefore, we can paraphrase the terms as "online informetrics." Current literature information indicates that the term "webmetrics" was first proposed by Almind in 1997. In the same year, Armand et al. first coined the term "webmetrics" in the paper entitled "Informetric Analysis on the World Wide Web—A Discussion on the Method of Webometrics" and proposed that various informetric methods could be used to conduct quantitative analysis on the World Wide Web. For another similar term, i.e., "cybermetrics," electronic journals or academic forums on the Internet have been named after this term. These forums and journals are mainly organized and published by the Spanish Scientific Information and Documentation Center (CINDOC).

Different interpretations of the concept of "webometrics" are available abroad. Some scholars have defined it as a discipline that aims to conduct statistical analysis of online literature; others consider it a study on the mutual references of online data. Furthermore, some researchers approach the problem from the perspective of cyberspace computing and application software, believing that webometrics is a discipline about computer software design, which is not the case. If the research objects, methods, contents, and objectives of webometrics are considered, then we believe that it is an emerging subdiscipline that aims to offer a quantitative description and statistical analysis of the organization, storage, distribution, transmission, mutual citation, development, and utilization of online information through quantitative methods, such as mathematics and statistics. This subdiscipline is designed to present the quantitative characteristics and inherent laws of online information. As an interdisciplinary subject, webometrics incorporates network technology, network management, information resource management, and informetrics. This subject also offers a new direction and an important research domain for informetrics, thereby gaining extensive application prospects. Its fundamental purpose is to provide the necessary quantitative basis for the orderly and rational distribution of online information, the optimized allocation and effective use of information resources, and the standardization of network management. Therefore, the organizational management and information management of networks can be significantly improved, thereby optimizing their economic and social benefits.

Webometrics has rapidly formed and developed under the current scientific background and technical conditions. First, the burgeoning online information and literature do not only provide the necessary foundation and conditions for the emergence of webometrics, but also generate a pressing practical need for it, thereby promoting the formation and development of this discipline. Second, the statistical analysis and research findings of online literature information form the foundation of the discipline and accumulate related experience. In the 63rd International Federation of Library Associations and Institutions (IFLA) conference held in 1997, three papers that focused on the statistical analysis of online information were presented. Among which, the paper "Feature of the Accessible Information on the World Wide Web" by T.O. Edward of the United States Online Computer Library Center discussed statistical indicators, statistical types, and other issues regarding online information. The other two articles discussed statistical issues regarding online information service in libraries. In the 65th IFLA conference held in Thailand in 1999, a number of papers also focused on such issues, thereby demonstrating progress to a certain extent. Third, the development of informetrics has generated certain practical needs. With the increasing amount of online information, the research object and scope of informetrics are bound to expand to the online world, which is an objective requirement and inevitable trend for the development of a discipline. Fourth, network management should be strengthened and improved. With the increasing popularity of networks, strengthening network management has become a top priority, and the implementation of quantitative management is one of the major strategies to do so. Research findings on webometrics are bound to provide theoretical guidance and quantitative basis for quantitative and scientific network management; in turn, the practical need for quantitative network management will promote the comprehensive development of webometrics.

We believe that the study object of webometrics should be understood in a broad sense. In the current study, the term "network" does not only refer to the Internet, but also to other types of networks, such as local area networks. The metering target of online information mainly involves three levels or components: ① the direct measurement of online information, including digital information, text message, and multimedia information, which incorporate text, images, and sound, such as information in the unit of byte and the measurement of information flow; ② the measurement of online literature and its information, as well as other related information, such as online electronic journals, theses, books, reports, the literature distribution structure, discipline theme, keywords, author information, and publishing information that involves primary literature as well as secondary and tertiary sources of measurement issues; ③ the measurement problems of an information network structural unit, such as the information growth of network sites, distribution of subjects, information transmission, and mutual citations and links among sites. Thus, webometrics covers a wide range of problems.

Similar to bibliometric and informetric systems, a webometric system consists of its theories, methods, and applications. Among which, theory is the basis, method is the means, and application is the goal. These three aspects complement one another,

and neither of them should be neglected. Theory mainly focuses on the fundamental issues that must be addressed in webometrics, such as an independent subject, new concepts, new indicators, and new laws, including the concentration and dispersion laws of online information, law about the author, growth and aging rules of word frequency, citation rules, multimedia information, and the theoretical explanation and mathematical models for these laws. Method mainly focuses on the principle, applicability, and operating procedures of the application of various quantitative methods, such as literature information statistical analysis, mathematical model analysis, citation analysis, bibliographic analysis, and systematic analysis. Necessary amendments to improve and perfect these methods are also included. With regard to application, the main task of webometrics is to study its applications in multidisciplinary and multi-industry sectors, such as library information systems, information resource management, network management, science, scientific evaluation, technology management, and forecasting theory. Therefore, the value of webometrics can be fully utilized and contributions to the development of technology, economy, and society are made.

1.2 Concept and System Structure of Informetrics

1.2.1 Aim and Significance of Informetric Research

The aims of informetric research are to introduce the concept of quantity and quantitative methods as well as to further present the structure and law of quantity change in information elements (including documents, data, object, information, and events), thereby theoretically improving the science and accuracy of information science and other disciplines related to information management as well as developing them in a quantitative stage. Moreover, research on informetrics provides a quantitative basis for improving information systems and realizing high efficiency of scientific management, thereby helping information communication systems to always operate at their best status and resolving basic contradictions in information service through providing the best information service. Consequently, information management can better serve the development of science and technology, the economy, and the society when getting over an information crisis.

In general, the greatest significance of informetric research is as follows: it continues to sum up various experiences and laws from a theoretical perspective and transforms information "work" into information "science," thereby making its theory highly extensive and profound. Simultaneously, such research verifies and corrects old experiences and laws under new information conditions and explores their new applicability. All these efforts make information science considerably scientific and enable it to provide theoretical guidelines for practical work.

The significance of this thesis lies in its application, whereas those of the theory of and method for informetrics in different fields are as follows: