Current Comments

Scientometrics Comes of Age

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When I first conceived of the *Science Citation Index® (SCI®)*, I was almost totally preoccupied with the problem of information retrieval. I saw citation indexing primarily as a way to search the scientific literature—a way to achieve better bibliographic control.[1] Although I had at one time planned a career in the history of science, it was only later that I began to recognize the tremendous potential of citation analysis in the history and especially the sociology of science.[2] Robert K. Merton of Columbia University and Allen Newell of Carnegie-Mellon University appreciated much better than I how the *SCI* might affect not only socio-historical research but science itself.[3] (p. 52-53) There is little doubt that this has come to pass. As citation analysis, properly used, has provided new insights into historical and contemporary science[4] there has emerged a new field called scientometrics. The *SCI* is one of the major tools of this field, but it is not the only one.

The terms econometrics and sociometrics have been with us at least since the 30s. The term biometrics is even older. It was inevitable that the term bibliometrics would be coined. It is surprising how long it took to come up with the term scientometrics. The term is apparently derived from the word "naukometria" which has been in use in the USSR for many years.[5]

Scientometrics is defined as "the study of the measurement of scientific and technological progress."[6] M.T. Beck of the department of physical chemistry, Kossuth Lajos University, Debrecen, Hungary calls it "the quantitative evaluation and intercomparison of scientific activity, productivity and progress."[7] In more colloquial terms, ISI®'s Morton Malin explains that "part of scientometrics consists of applying number crunching techniques to the study of the science of science,"[8] that is, science policy research.

The numbers used by researchers in the science of science include but are not limited to: the number of people receiving scientific degrees, the number of patents granted to scientists, the number of scientific articles published, the number of scientists who publish papers, the number of references appearing in papers, the number of citations to each paper, the amount of grant money awarded to scientists, and the amount of money budgeted by research agencies for scientific activities. The various numbers may be used in science policy or program evaluation studies to measure the scientific "strength" of various countries, regions, or a particular university. One can follow the growth or decline of various fields or identify "where the action is." In short, scientometrics is concerned with the demographics of the worldwide scientific community.

Much scientometric research is bibliometric in nature. Alan Pritchard of the Northwestern-Polytechnic School of Librarianship, London, defined biblio-

metrics as "the application of mathematics and statistical methods to books and other media of communication."[9] When the media involve scientific publications, you have bibliometrics of science.

The science of science emerged very slowly as a distinct specialty after J.D. Bernal's *The Social Function of Science* was published in 1939.[10] There were earlier attempts to analyze science and science indicators,[11-13] but Bernal's work is considered by Vasilii Nalimov of Moscow State University and others to be a turning point in science policy analyses.[14] After World War II, the history and sociology of science received much greater attention. As these specialties matured, their practitioners increasingly began to measure science activity. The increasing tempo of quantitative studies led inevitably to scientometrics.

Scientometric research has wide potential applicability. Government and research institutions have expressed interest in applying "quantitative knowledge of scientific growth to the management of science."[5] Scientific indicators are being used in an effort to estimate the relative "health" of science in various countries.[15] Ultimately, scientometrics may be used to help nations make decisions on what areas of research need funding.

The measurement and quantification of science from the 1930s to the early 1960s generated occasional papers. However, as Merton points out, two events helped speed up the work performed in this area[3] (p. 51-57): ISI began producing the *SCI*, which provided the raw material for many of these studies, and Derek de Solla Price of Yale University published *Science Since Babylon*[16] (1961). In the chapter called "Diseases of Science" Price developed some mathematical models of the growth of science based on the evolving picture of scientific publications over the last 300 years. Price himself recalls in a later edition of *Babylon* that this book along with *Little Science, Big Science*,[17] which expanded this work, touched off a "continuing series of research papers exploring many different quantitative investigations based on the counting of journals, papers, authors and citations. In no time at all there were bibliographies and conventions devoted to bibliometrics and to scientometrics...."[16] (p. 193-4) Price continued to pioneer in this area during the 1960s and 70s. In 1971, H.W. Menard of the University of California, San Diego, expanded on Price's work in a volume called *Science: Growth and Change*.[18]

Yakov M. Rabkin of the University of Montreal agrees that Price's work set the study of scientometrics in motion, even in the USSR.[5] "Since the 1960s quantitative studies of science in the USSR have developed mainly in response to Derek de Solla Price's research on patterns of scientific growth.... Price's work attracted the attention of Vasilii Nalimov of Moscow University and Gennady Dobrov of the Ukrainian Academy of Sciences. Through their efforts, quantitative studies of science became a rapidly growing field."

Drexel University's Belver Griffith adds, "Although the counting of scientists or articles or something dealing with knowledge-mongering started at least as early as the 1920s, a key event was Derek Price's 1965 article 'Network of Scientific Papers'.... It has...a first meaningful meshing of an explicit model for science with raw data, and the results were surprisingly elegant and clever."[19]

The growth of scientometrics has been exponential. Space does not permit me to list the more than 600 articles

on citation analysis in my files.[20] And citation analysis is only one part of scientometrics.

Nevertheless, we can identify several important papers or monographs that appeared within the last ten years and contributed to the development of the specialty. For example, the 1971 monograph by Nalimov and Mul'chenko discusses much of the literature on the measurement of science up to that time.[14] The extensive bibliography includes many Soviet publications not widely known in the West.

In 1972, the National Science Board issued its first *Science Indicators*, which is now published biennially and presents masses of statistical information.[21] A brief look at its contents page (shown in Figure 1) will give you some idea of the scope of this publication. Its stated purpose is to "describe quantitatively the condition of science and research in the U.S."[22] The bulk of the data presented

Figure 1: Contents page of Science Indicators—1976.

in *Science Indicators* is listed in tables, figures, and charts. The work presents excellent raw materials from which predictions about the future health of science can be made. Robert Wright, head of the science indicators unit at the National Science Foundation, points out that the first publication of *Science Indicators* led to an increase of $50 million being made available by the US government in support of basic research in universities.[23]

An in-depth critique of *Science Indicators* was provided in *Toward a Metric of Science: The Advent of Science Indicators*.[24] Edited by Yehuda Elkana, Joshua Lederberg, Robert Merton, Arnold Thackray, and Harriet Zuckerman, the volume features the work of contributors from many disciplines. The book was based on a 1974 conference held at the Center for Advanced Studies in the Behavioral Sciences at Stanford, California. It covers a wide range of topics relating to science indicators. For example, models of scientific output were examined in one chapter, while the political contexts of science indicators were discussed in another. I participated in this conference with ISI's Henry Small.[25]

In *Evaluative Bibliometrics: The Use of Publication and Citation Analysis in the Evaluation of Scientific Activity*, Francis Narin and the staff of Computer Horizons, Inc. summarized the state of the art of publication and citation-based evaluation for the National Science Foundation.[26] Published in 1976, this is a good review source for anyone interested in the subject.

A few attempts have been made to summarize the scientometric research published thus far and to determine its trends. For example, in their 1974 review in *Science Studies*, G. Nigel Gilbert and Steve Woolgar of the department of sociology, University of York, identify two distinct methods used in studies quantifying scientific growth.[27] "The first method starts with the available data and then arbitrarily chooses a description (usually in the form of a mathematical function) to fit the data. Predictions about future growth can then be made by extrapolation. The second method begins by making an hypothesis about a social process in science, based on either sociological investigation or on intuition. The implications of the hypothesis are then explored, a process which often results in the formulation of a mathematical function."

Another review of scientometric literature was published in 1977, "A Progress Report on the Quantification of Science," by Michael J. Moravcsik of the Institute of Theoretical Science, University of Oregon.[15] Moravcsik noted that scientometric researchers can quantify both scientific inputs and scientific outputs. Primary inputs include manpower and money. Secondary inputs are, for example, the number of laboratory buildings built or the number of computer hours clocked by scientists. As Moravcsik points out, little scientometric work has concentrated on these inputs.

Outputs, on the other hand, have lent themselves more readily to scientometric investigation. Some scientific outputs include: the number of publishing authors, their geographical distribution, the number of papers produced each year, the number of citations attributed to each paper or to an author.

In the span of time between the publication of Moravcsik's review and now, there has been no shortage of work in scientometric areas. As he points out, many aspects of scientific growth, communications, and activity are ripe for investigation.

For the researcher in this field, finding the right journal in which to publish scientometric studies has been a problem. Articles on scientometrics have appeared in journals ranging from *Science*

and *Nature* to the *Journal of Documentation, Social Studies of Science, American Sociological Review, American Psychologist,* and the *Journal of the American Society for Information Science,* just to name a few. Literature in this field is typical of a rapidly growing field. My own contributions to this field are not unknown to *Current Contents*® readers, and my *Essays* contain dozens of bibliometric and scientometric studies.[28] The newness of the latter term is illustrated by its absence from my new book on citation analysis.[4] I do refer to bibliometrics.

Considering this situation, many of us interested in scientometrics felt that a journal in this field was long overdue. In September of 1978, the first issue of such a journal, *Scientometrics,* was published. It is edited by Budapest chemist Tibor Braun, who is also editor of the *Journal of Radioanalytical Chemistry.* It is published jointly by the Akademiai Kiado in Hungary (the publishing house of the Hungarian Academy of Sciences) and Elsevier Scientific Publishing Company. The chief editors include M.T. Beck, D.J.D. Price, G.M. Dobrov of the USSR, and your truly. *Scientometrics* is covered in several editions of *Current Contents* and the *Social Sciences Citation Index*™. It is published six times a year. Subscriptions are handled by Elsevier and cost $76 per year.

In its first five issues, *Scientometrics* has covered a wide range of topics on science and science policy. For example, the January 1979 issue covered such topics as research productivity and the visibility of the French scientific elite[29] and the allocation of grants by the Swedish Social Science Research Council.[30] Contributors to the journal have included many of the researchers who have been instrumental in creating and defining the field. In addition to many of the people cited above, H. Inhaber, D. Crane, R. Rosen, and J. Vlachý are but a few of the leading contributors whose names will be recognized by anyone following scientometric research.

Scientometrics is an international journal. Measuring science has become an important issue not only in industrial countries but also in less-developed areas of the world. The public everywhere is demanding better use of scarce research funds. Scientometrics can provide the kind of quantitative data that legislators can understand. The qualitative conclusions one can draw from such data will always depend upon the wisdom used in their application.

As one of the editors of *Scientometrics,* I am excited by the prospective developments that might be printed in its pages. As I stated in the introduction I wrote to the first issue of the journal,[20] I often read with envy many studies which use data compiled at ISI a long time ago which we were unable, for one reason or another, to analyze. But that is one of the prices of success in science. It would have been far more painful had our data been totally ignored.

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