



From the science of science to Scientometrics visualizing the history of science with *HistCite* software

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ABSTRACT

While ISSI was founded in 1993, Scientometrics and Bibliometrics are now at least half a century old. Indeed, the field can be traced to early quantitative studies in the early 20th century. In the 1930s, it evolved to the “science of science.” The publication of J.D. Bernal’s *Social Function of Science* in 1939 was a key transition point but the field lay dormant until after World War II, when D.J.D. Price’s books *Science Since Babylon* and *Little Science, Big Science* were published in 1961 and 1963. His role as the “Father of Scientometrics” is clearly evident by using the *HistCite* software to visualize his impact as well as the subsequent impact of the journal *Scientometrics* on the growth of the field. *Scientometrics* owes its name to V.V. Nalimov, the author of *Naukometriya*, and to Tibor Braun who adapted the neologism for the journal. The primordial paper on citation indexing by Garfield which appeared in *Science* 1955 became a bridge between Bernal and Price. The timeline for the evolution of Scientometrics is demonstrated by a *HistCite* tabulation of the ranked citation index of the 100,000 references cited in the 3000 papers citing Price.

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1. Introduction

When Henk Moed asked me to present a keynote address to this 11th International Conference of the International Society for Scientometrics and Informatics (ISSI) I had mixed feelings.¹ I had previously planned to participate by simply describing my current work on Algorithmic Historiography. The paper I originally submitted was an up-to-date description of the *HistCite* system (<http://www.histcite.com/>). Briefly stated, *HistCite*TM is a software system which generates chronological maps of bibliographic collections resulting from subject, author, institutional or source journal searches of the *ISI Web of Science*[®]. *WoS* export files are created in which all cited references for each source document are captured. The software generates chronological historiographs highlighting the most-cited works in the retrieved collection. Other listings include rankings by author, journal, institution, or vocabulary.

But Henk thought that this might be a good chance to provide the current ISSI membership with some personal reflections on the origins of Scientometrics, especially as it is now two decades since the first ISSI conference held in Belgium in 1987 and 14 years since ISSI was founded in Berlin. It is noteworthy that the term “Scientometrics” itself was not included in the title of the 1987 meeting which was the “First International Conference on Bibliometrics and Theoretical Aspects of Information Retrieval.” Twenty years earlier, Alan Pritchard had coined the term Bibliometrics in his 1969 paper on statistical bibliography (Pritchard, 1969). Most of us have been exposed to the macro history of Scientometrics. We recognize names like D. de S.

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¹ This paper was presented at the 11th ISSI International Conference, Madrid, June 25, 2007. The original version of the paper can be found at <http://www.garfield.library.upenn.edu/pub.html>.

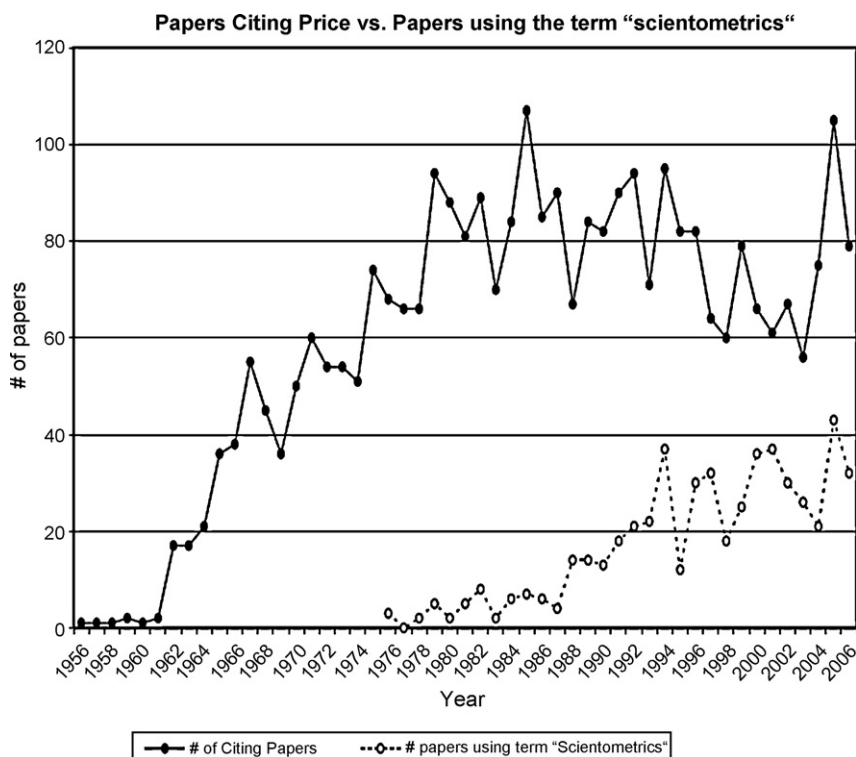


Fig. 1. Papers citing Price versus papers using the term "Scientometrics," from 1956 to 2006.

Price and V.V. Nalimov and perhaps earlier pioneers in measurement such as Alfred Lotka and George K. Zipf. If you search the *Web of Science* for the past century, these names will pop up very quickly. But when you search year-by-year, you obtain a very different micro-perspective. Today, I would like to recall for you aspects of the micro and macro impact of Derek Price's work, since he is usually considered the "Father of Scientometrics". However, this simplistic metaphor for his role in the history of Scientometrics, does not adequately reflect the influences of earlier statistically and quantitatively oriented scholars.

In the foreword to the second edition of "*Little Science, Big Science*," (Merton & Garfield, 1986) Robert K. Merton and I identified Derek as the Father of Scientometrics because he was perceived, in the western world, to have made the greatest impact on the use of quantitative indicators in formulating science policy. The first edition of the 1963 book was aptly identified as a *Citation Classic* (Price, 1983) but at the time the book was written, Derek had not even encountered the term Scientometrics, which was coined by the Russian mathematician-philosopher-polymath, V.V. Nalimov. "Scientometrics" is the English translation of the title word of Nalimov's classic monograph *Naukometriya* (Nalimov & Mul'chenko, 1969) which was relatively unknown to western scholars even after it was translated into English. Without access to the Internet and limited distribution in those days, it was rarely cited.

The term became better known, however, once the journal *Scientometrics* appeared in 1978. Stephen Bensman in a tribute to Tibor Braun recently reminded us how the journal became a bridge between the East and West (Bensman & Kraft, 2007). To simply mention that Nalimov coined the term Scientometrics would be an injustice to his impact as a polymathic author. As with Derek Price, I am proud to have been Vassili Nalimov's friend for three decades and to have published four of his books in English. And recently the full texts of those books have been digitized and posted to my website: <http://garfield.library.upenn.edu/nalimov.html>. For a more detailed account of Nalimov's role in the history of Scientometrics, see Chapter IV of *The Citation Culture* by Paul Wouters (Wouters, 1999). The full text is posted at <http://garfield.library.upenn.edu/wouters/wouters.pdf>.

Let me remind you of some historical facts. Price's "*Science Since Babylon*" (Price, 1961) was published 6 years after my 1955 paper in *Science* (Garfield, 1955). The first edition of *Little Science, Big Science* appeared 2 years later in 1963. The opening page is called a "prologue to a science of science." If Derek was aware of my paper, he did not cite it then. Even in his classic 1965 *Networks* paper in *Science* (Price, 1965), he referred to the 1963 *Genetics Citation Project* and my 1964 *Science* paper by which time we had made personal contact (Garfield, 1964). But even earlier, in 1962, I had written to J.D. Bernal and Robert K. Merton about the experimental *Science Citation Index* which resulted from that project. I met Bernal briefly at the International Conference on Scientific Information in Washington in 1958. It was not until 1983, in his *Citation Classic* commentary (Price, 1983) cited above, that Derek notes that he was "stimulated much by Robert Merton's writings in the

sociology of science, by Eugene Garfield's new book on citation indexing, and by rereading Desmond Bernal's books which had prepared my mind for the initial sensitivity that led me to this field in the first place." Of course, Derek could not have read my book at that time because it did not come out until 1979. Perhaps he should have used the term "work" instead.

In the foreword to Volume 3 of my *Essays of an Information Scientist* (Price, 1980), Derek himself related how we first encountered each other when he was a member of the National Science Foundation's Science Information Council. He reports how I tried to get the NSF to support printing and distribution of the *Science Citation Index*:

"From that day to the present . . . I have found megavitamins for my intellectual diet on the cutting room floor of ISI's computer room. Bit by bit we have begun to understand how citations work and in the course of this, there has emerged a new sort of statistical sociology of science that has thrown light on many aspects of the authorship, refereeing, and publication of scientific research papers. The Society of Social Studies in Science now has an annual meeting devoted to this new method of understanding science that has grown, almost as an accidental by-product, from the indexing technology developed by the Institute for Scientific Information. Our initial intuitive perceptions have turned out to be correct."

The early 4S group ultimately became the Society for the Social Studies in Science (4S) which together with Thomson ISI sponsors the annual Bernal Award. However, the Society's interest in Scientometrics has waned considerably in recent years, perhaps in part because of the growth of ISSI which understandably is not as preoccupied with the history and sociology of science *per se* as is 4S.

The first co-citational link between Garfield and Price was made in the early sixties by the mathematical statistician, John W. Tukey (Tukey, 1962). Between 1955 and 1964, he was the only author who co-cited me and Derek. Keep in mind that Tukey was not a Scientometrician. Like me at the time, he was primarily interested in helping scientists to keep in touch with the literature. He and Joshua Lederberg played a key role, especially through the Weinberg Committee report, in promoting the idea of citation indexes as a new and promising method for information retrieval. No one was then actively talking about citation indexing as a scientometric or science policy tool *per se*. Alan Pritchard's paper on "Statistical Bibliography," mentioned earlier, did not appear until 1969 but was not cited for science policy purposes.

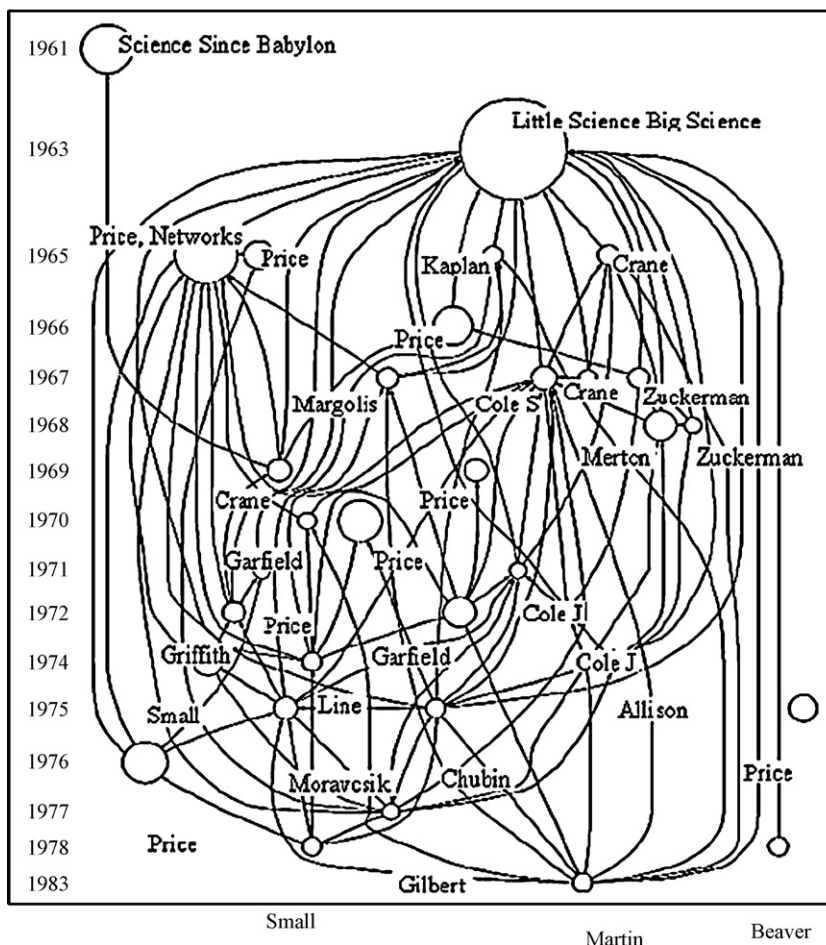


Fig. 2. Historiograph of 33 most-cited works in the collection of papers citing Price from 1956 to 2006.

Another early science policy scholar was the Yugoslav Stevan Dedijer (Dedijer, 1962). Like Tukey he was aware of the work by Derek Price but in those early years there were only vague references to the use of bibliometric data for science policy purposes. Rather, the term “science of science” was used by Price (1975), Maurice Goldsmith (Goldsmith & Mackay, 1964), and others to reflect the pioneering work of J.D. Bernal and its offshoots. However, the term “science of science” did not gain favor even though the Society for the Social Study of Science (4S) was formed in 1975.

Using citations to the work of Price as one indicator of the growth of this field Fig. 2 displays the year-by-year graph of citations to Derek’s work based on using the histogram feature of *HistCite* or *Web of Science (WoS)*. In contrast to the visible growth in citations to Price’s work (Fig. 1, upper curve), an analysis of papers published in *WoS* containing the term scientometric(s) does not reveal the total growth pattern because the general term is partly displaced by more specific terminology as the field evolved (Fig. 1, lower curve).

To continue this brief discussion of the work of Derek Price, the historiography in Fig. 2 displays the linkages among the 35 most-cited works of the *HistCite* collection. Each of these papers was cited at least 107 times.

The chronological listing of the 200 most-cited works, based on over 102,000 cited references in the collection of 3083 citing papers provides a fairly accurate historical timeline of the field (see Tables 1 and 2).

The timeline in Table 1 starts with F.J. Cole in 1917, A.J. Lotka in 1926, Gross & Gross in 1927, Samuel Bradford in 1934, and then continues with Bernal in 1939. Vannevar Bush’s classic, “As We May Think” appeared in 1945 at the end of World War II (Bush, 1945). A decade later, we find the work of Herb Simon in 1955 and in the same year, the paper by yours truly. Then in 1956, Derek’s paper on “the exponential growth in science,” appears in 1956 (Price, 1956). His first paper on quantitative studies appeared in 1951 but had very little impact (Price, 1951)! I won’t continue to recite all the names that are recalled in this exercise but I believe this list of works cited 30 or more times in the Price *HistCite* collection demonstrates the simple notion that bibliographic history is recapitulated rather well by the collective bibliographic memory of the scholars who have contributed to the literature, both at the macro and micro level of analysis.

The original *HistCite* file of Price’s work complements the information extracted in the historiograph (Fig. 2) and the timeline (Tables 1 and 2). Fig. 3 shows the first page of the *HistCite* files which complete collection can be found at http://garfield.library.upenn.edu/histcomp/price-djd_citing-sci/index-tl.html. The abbreviation LCR stands for Local Cited References and shows the number of references citing local papers, NCR stands for the Number of Cited References and shows the number of all citing references, LCS stands for Local Citation Score and is the number of times a paper is cited by other papers in the local collection and GCS stands for Global Citation Score and shows the Citation Frequency based on the total count in the *Web of Science* (for the use of the *HistCite* methods for algorithmic historiography see (Garfield, 2004; Garfield, Pudovkin, & Istomin, 2003)).

DJD Price		Historiographs		Glossary HistCite Guide About	
List of All Records					
Records: 3063, Authors: 2928, Journals: 869, Cited References: 102333, Words: 4624					
Yearly output Document Type Language Institution Institution with Subdivision Country					
Page 1 of 31: [1 2 3 4 5 6 7 8 9 10] 11 21 31					
#	LCR	NCR	Date / Author / Journal	LCS	GCS
1956					
1	0	1	1 PRICE DJD THE EXPONENTIAL CURVE OF SCIENCE DISCOVERY. 1956; 17 (1): 240-243	28	28
1957					
2	1	1832	2 [Anon] 82ND CRITICAL BIBLIOGRAPHY OF THE HISTORY OF SCIENCE AND ITS CULTURAL INFLUENCES (TO 1 JANUARY 1957) ISIS. 1957; 48 (152): 189-268	0	0
1958					
3	1	5	3 JOHNSON EA THE CRISIS IN SCIENCE AND TECHNOLOGY AND ITS EFFECT ON MILITARY DEVELOPMENT OPERATIONS RESEARCH. 1958; 6 (1): 11-34	1	3
1959					
4	1	9	4 PETTERSSON M MAIN STAGES OF SOCIAL EVOLUTION IN MAN NATURE. 1959; 184 (4684): 481-482	0	3
5	1	72	5 VLEDUTS GE, NALIMOV VV, STIAZHKIN NI SCIENTIFIC AND TECHNICAL INFORMATION. PROBLEM OF CYBERNETICS USPEKHI FIZICHESKIKH NAUK. 1959; 69 (1): 13-56	5	8
1960					
6	2	16	6 JOHNSON EA THE LONG-RANGE FUTURE OF OPERATIONAL-RESEARCH OPERATIONS RESEARCH. 1960; 8 (1): 1-23	0	5
1961					
7	1	10	7 ROSENBLITH WA ON SOME SOCIAL-CONSEQUENCES OF SCIENTIFIC AND TECHNOLOGICAL-CHANGE OPERATIONS RESEARCH. 1961; 9 (1): 488-512	0	0

Fig. 3. *HistCite* file of publications related to the field of scientometrics by DJD Price and the papers citing him.

Table 1
Time line for the history of Scientometrics.

	Author	Year	Reference citations
1	Cole F.J.	1917	Sci Progr, V11, P578 36
2	Lotka A.J.	1926	J Washington Academy, V16, P317 213
3	Gross P.L.K.	1927	Science, V66, P385 39
4	Bradford S.C.	1934	Engineering – London, V137, P85 69
5	Bernal J.D.	1939	Social Function Sci 42
6	Bush V.	1945	Atlantic Monthly, V176, P101 65
7	Bradford S.C.	1948	Documentation 84
8	Vickery B.C.	1948	J Doc, V4, P198 24
9	Zipf G.K.	1949	Human Behavior Principle 86
10	Fussler H.H.	1949	Library Q, V19, P19 40
11	Barber B.	1952	Science Social Order 36
12	Lehman H.C.	1953	Age Achievement, 33
13	Simon H.A.	1955	Biometrika, V42, P425 76
14	Garfield E.	1955	Science, V122, P108 57
15	Price D.J.D.	1956	Discovery, V17, P240 28
16	Merton R.K.	1957	Am Sociol Rev, V22, P635 76
17	Merton R.K.	1957	Social Theory Social 48
18	Shockley W.	1957	P Ire, V45, P279 39
19	Popper K.	1959	Logic Sci Discovery 39
20	Burton R.E.	1956	Am Doc, V11, P18 69
21	Westbrook J.H.	1956	Science, V132, P1229 27
22	Kendall M.G.	1956	Operational Research, V11, P31 25
23	Price D.J.D.	1961	Sci Since Babylon, P1 337
24	Merton R.K.	1961	P Am Philos SOC, V105, P470 35
25	Barber B.	1961	Science, V134, P596 30
26	Kuhn T.S.	1962	Structure Sci Revolution 199
27	Machlup F.	1962	Production Distribut 41
28	Rogers E.M.	1962	Diffusion Innovation, 27
29	Price D.J.D.	1963	Little Science Big Science, P1 1454
30	Kessler M.M.	1963	Am Doc, V14, P10 61
31	Garfield E.	1963	Am Doc, V14, P289 28
32	Garfield E.	1963	Am Doc, V14, P195 27
33	Garfield E.	1964	Use Citation Data Wr, 51
34	Garfield E.	1964	Science, V144, P649 37
35	Clarke B.L.	1964	Science, V143, P822 31
36	Price D.J.D.	1964	Science, V144, P655 30
37	Price D.J.D.	1965	Science, V149, P510 499
38	Hagstrom W.O.	1965	Scientific Community 214
39	Price D.J.D.	1965	Technol Cult, V6, P553 122
40	Crane D.	1965	Am Sociol Rev, V30, P699 63
41	Kaplan N.	1965	Am Doc, V16, P179 50
42	Price D.J.D.	1965	Nature, V206, P233 33

Table 2
Time line for the history of Scientometrics.

	Author	Year	Reference cites
43	Price D.J.D.	1966	Am Psychol, V21, P1011 213
44	Bayer A.E.	1966	Sociol Educ, V39, P381 53
45	Cartter A.M.	1966	Assessment Quality G, 42
46	Storer N.W.	1966	Social System Sci, 39
47	Schmookler J.	1966	Invention Ec Growth, 33
48	Bendavid J.	1966	Am Sociol Rev, V31, P451 29
49	Storer N.W.	1966	Social System Sci, 26
50	May K.O.	1966	Science, V154, P1672 24
51	Cole S.	1967	Am Sociol Rev, V32, P377 91
52	Margolis J.	1967	Science, V155, P1213 62
53	Zuckerman H.	1967	Am Sociol Rev, V32, P391 61
54	Crane D.	1967	Am Sociol, V2, P195 44
55	Leimkuhler F.F.	1967	J Doc, V23, P197 40
56	Price D.J.D.	1967	Sci Technol, V70, P84 33
57	Merton R.K.	1968	Science, V159, P56 128
58	Ziman J.	1968	Public Knowledge Soc 68
59	Zuckerman H.	1968	Am J Sociol, V74, P276 47
60	Brookes B.C.	1968	J Doc, V24, P247 40
61	Mullins N.C.	1968	Am Sociol Rev, V33, P786 38
62	Merton R.K.	1968	Social Theory Social 37
63	Cole S.	1968	Am Sociol Rev, V33, P397 32
64	Watson J.D.	1968	Double Helix, 24

Table 2 (Continued)

	Author	Year	Reference cites
65	Crane D.	1969	Am Sociol Rev, V34, P335 73
66	Price D.J.D.	1969	P Israel Acad Sci Hu, V4, P98 69
67	Pritchard A.	1969	J Doc, V25, P348 47
68	Fairthorne R.A.	1969	J Doc, V25, P319 46
69	Brookes B.C.	1969	Nature, V224, P953 40
70	Macrae D.	1969	Am Sociol Rev, V34, P631 34
71	Price D.J.D.	1969	Factors Transfer Tec, V1, P91 30

The Social Function of Science				Historiographs	Glossary HistCite Guide About
List of All Records				Grand Totals: LCS 443, GCS 3217	Collection span: 1939 - 2007
Records: 364, Authors: 350, Journals: 213, Cited References: 16067, Words: 1043					
Yearly output Document Type Language Institution Institution with Subdivision Country					
Page 1 of 4: [1 2 3 4]					
#	LCR	NCR	Date / Author / Journal	LCS	GCS
1939					
1	1	4	1 [Anon] Journals or micro-films? LANCET. 1939; 1: 765-766	0	0
2	0	0	2 BERNAL JD The Social Function of Science SOCIAL FUNCTION SCI. 1939;	319	319
3	1	3	3 [Anon] Science and society. BRITISH MEDICAL JOURNAL. 1939 JUL-DEC; 2: 286-287	0	0
1944					
4	1	13	4 Williams JR The social implications of scientific research CANADIAN MEDICAL ASSOCIATION JOURNAL. 1944; 51: 99-106	0	0
5	1	18	5 Dudley S Naval experience in relation to a National Health Service LANCET. 1944; 2: 134-137	0	0
6	1	10	6 Teich N Influence of Newton's work on scientific thought NATURE. 1944 JAN-JUN; 153: 42-45	0	0
1946					
7	1	15	7 BARD P, ADOLPH EF, DOW P, BOYD TE, COMROE JH PHYSIOLOGY IN NORTH-AMERICA, 1945 - SURVEY BY A COMMITTEE OF THE AMERICAN-PHYSIOLOGICAL-SOCIETY FEDERATION PROCEEDINGS. 1946; 5 (3): 407-436	0	0
8	1	3	8 [Anon] RATIONALIZATION OF THE LITERATURE OF SCIENTIFIC RESEARCH NATURE. 1946; 157 (3997): 745-748	0	0
1947					
9	1	2	9 DINGLE H THE MISSING FACTOR IN SCIENCE NATURE. 1947; 160 (4056): 108-110	0	1

Fig. 4. HistCite file of Bernal's book "The Social function of science" (Bernal, 1939).

I have mentioned Bernal's influence on the field of Scientometrics earlier in this paper. However, a more detailed look at the impact of his book *Social Function of Science* is reflected in the more than 300 citing papers shown in the HistCite collection. Fig. 4 shows a snapshot of this collection which can be found at http://garfield.library.upenn.edu/histcomp/bernal-jd_soc-func-sci/index-tl.html. I have given more information about Bernal's role for Scientometrics in a talk at another occasion (Garfield, 2007).

2. Conclusion

In this paper I have examined the very early days of Scientometrics and discussed the influence of Derek de Solla Price and John Desmond Bernal on the development of the field. The comparison of personal recollections with traces in the literature demonstrates the simple fact that bibliographic history is recapitulated rather well by the collective bibliographic memory of the scholars who have contributed to the literature, both at the macro and micro level of analysis.

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