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# History and Institutionalisation of Scientometrics

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# The origin of bibliometrics

## What is bibliometrics?

The roots of bibliometrics reach back to the 18th century. Systematic research approaches are, however, appeared only in the 20th century, notably in the second half of the century.

There are two or three  terms which are nowadays used almost simultaneously for quantitative and evaluative science studies.

Pritchard (1969) explained the term *bibliometrics* as “the application of mathematical and statistical methods to books and other media of communication”.

Nalimov and Mulchenko (1969) defined *scientometrics* as “the application of those quantitative methods which are dealing with the analysis of science viewed as an information process”.

Otto Nacke (1979) defined *Informetrics*, “Informetrie: Ein neuer Name für eine neue Disziplin”, Nachrichten für Dokumentation 30, n. 6 (1979): 219-26

# The origin of bibliometrics

## Bibliometrics from a quantitative perspective

*Necessity of a 'metrics' for scientific research*

- Growth of scientific literature
- Challenges of "big science"
- Challenges of globalisation

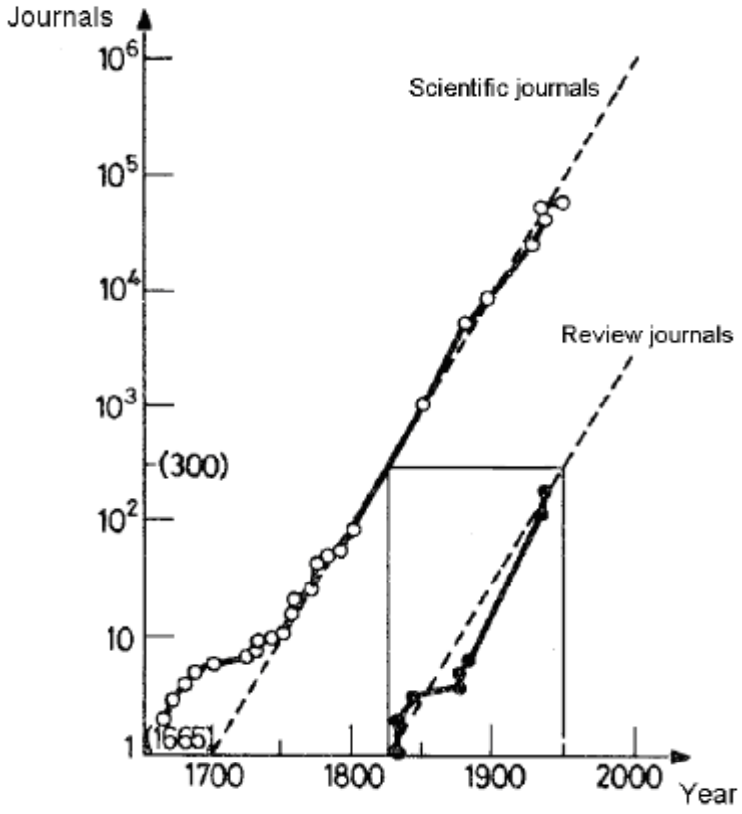
*Bibliometrics represented a statistical apporach*

- to master the growing flood of scientific information and
- to analyse and to understand the underlying cognitive processes of communication in science
- by measuring quantitative aspects of these processes and
- by providing the results to scientists and users outside the scientific community.

# The origin of bibliometrics

## Growh of the number of periodicals

### Price, *Little Science, Big Science*, 1963



# The origin of bibliometrics

## Bibliometrics from a qualitative perspective

*Analyse the social organisation of research and its variation in time*

- From polymaths to specialists
- From universalism to scientific disciplines

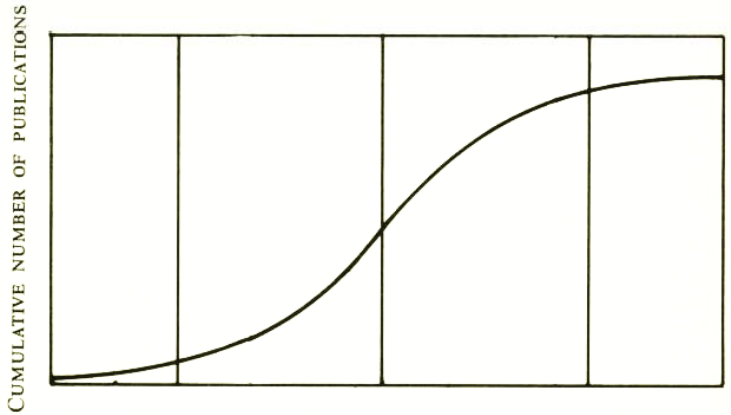
*Bibliometrics represented a sociometric approach*

- to measure social ties
- to understand the meaning and characteristics of scientific communities
- to draw conclusions concerning the institutional organisation of science systems

# The origin of bibliometrics

## The role of scientific communities in the process of growing knowledge

Crane, *Invisible Colleges. Diffusion of knowledge in scientific communities*, 1972




| | Stage 1 | Stage 2 | Stage 3 | Stage 4 |
|---|---|---|---|---|
| CHARACTERISTICS OF KNOWLEDGE | Paradigm appears | Normal science | Solution of Major Problems | Exhaustion |
| | | | Anomalies appear | Crisis |
| CHARACTERISTICS OF SCIENTIFIC COMMUNITIES | Little or no social organization | Groups of Collaborators and an Invisible College | Increasing Specialization | Decline in membership |
| | | | Increasing Controversy | Decline in membership |

Fig. 1. Characteristics of scientific knowledge and of scientific communities at different stages of the logistic curve.

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# Evolution of bibliometrics

## Primary tasks of early bibliometrics

- Monitoring, describing and modelling of the *production, dissemination and use of knowledge*, including information seeking, library circulation and scholarly communication, was originally in the foreground.

- First applications were developed to optimise library accession and circulation, to improve bibliographic databases and to extend information services.

# Bibliometrics prior to WWII

## 1. Example: Lotka‘s Law

In 1926, Alfred J. Lotka published his pioneering study on the frequency distribution of scientific productivity determined from a decennial index (1907–1916) of *Chemical Abstracts*. He concluded that

*“the number (of authors) making n contributions is about 1/n² of those making one; and the proportion of all contributors, that makes a single contribution, is about 60 per cent.”*

(Lotka*, J. Washington Acad. Sci,* 1926)

# Bibliometrics prior to WWII

## 2. Example: Bradford‘s Law

Eight years after Lotka’s article appeared, Samuel C. Bradford, published a study on the frequency distribution of papers over journals. He found that

*“If scientific journals are arranged in order of decreasing productivity on a given subject, they may be divided into a nucleus of journals more particularly devoted to the subject and several groups or zones containing the same number of articles as the nucleus when the numbers of periodicals in the nucleus and the succeeding zones will be as 1 : b : b² …”*

(Bradford, *Engineering*, 1934)

# Bibliometrics prior to WWII

## 3. Example: Citation analysis

In 1927, Gross and Gross examined 3633 citations from the 1926 volume of the journal *JACS*. Their citation-based study was designed to aid the decision which chemistry periodicals should best purchased by small college libraries.

This study is considered one of the first citation analyses, although it was not a citation analysis in the sense of present-day bibliometrics. (Gross & Gross, *Science*, 1927)

# Bibliometrics after WWII

## 4. Example: Zipf‘s „Principle of Least Effort“

*“A person […] will strive to solve his problems in such a way as to minimize the total work that he must expend in solving both his immediate problems and his probable future problems […].”*
(Zipf, *Human Behavior and the Principle of Least Effort*, 1949)

This principle assumed to guide information seeking behaviour is indirectly linked to Zipf’s formula derived from quantitative linguistics through the assumption of an underlying power-law model: $rf = C$, where $r$ is the rank of a word, $f$ is the frequency of occurrence of the word and $C$ is a constant.

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# Bibliometrics after WWII

In order to understand the interdisciplinarity of contemporary scientometrics we have to go back to the roots of the field.

- History of science (D. de Sola Price)
- Philosophy (V.V. Nalimov)
- Information science (E. Garfield)
- Sociology of science (R.K. Merton)
- Mathematics (S.D. Haitun, A.I. Yablonsky)

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# Derek J. de Solla Price (1922–1983)

In his book entitled “Little Science – Big Science” (1963), Derek J. de Solla Price analysed the recent system of science communication and thus presented the first systematic approach to the structure of modern science applied to the science as a whole.

He also laid the foundation of modern research evaluation techniques. His work was more than pioneering;
it was revolutionary.

Time was now ripe for the reception of his ideas since the development of science has reached a stage where traditional information, retrieval, evaluation and funding mechanisms became more and more difficult and expensive.

# Derek J. de Solla Price (1922–1983)

By addressing the questions of

*"Why should we not turn the tools of science on science itself?*

*Why not measure and generalize, make hypotheses, and derive conclusions?"*

Price (1963) drew a parallel between thermodynamics and possible methods in quantitative science studies.

However, he paved the way for future scientometric research:

- He showed how to get away from methods and models adopted from other fields towards the development of a scientometric-specific methodology.
- Price proposed the growth model and studied scientometric transactions, e.g. the network of citations between scientific papers.
- He found that a paper that is frequently cited will probably get more citations than one cited less often and created a model for this phenomenon.
- Price conducted scientometric studies for policy implications and research evaluation, thus opening the door for the present-day evaluative bibliometrics.

# Eugene Garfield (1925–)

Eugene Garfield was the founder and chairman of the *Institute for Scientific Information* (now part of Thomson Reuters). In the early 1960s he developed the *Science Citation Index*, the world's first large multidisciplinary citation database.

Although the the SCI was developed for the advanced Information retrieval and for science-information services, it has become the come source for scientometric studies.

*"The SCI was not originally created either to conduct quantitative studies, calculate impact factors, nor to facilitate the study of history of science".*
(Garfield, *From information retrieval to scientometrics – is the dog still wagging its tail?* 2009)

# Eugene Garfield (1925–)

**Examples**

- "The journal *Impact Factor* was first used as a measure for comparing journals independently of "size" and to help select journals for the *Science Citation Index* (SCI).
  (Garfield & Sher, *American Documentation*, 1963)
- The co-citation based *Atlas of Science* developed and issued by the Institute for Scientific Information (ISI) was considered a new kind of "review literature" which is also suited to help students in choice of career in science.
  (Garfield, *Current Comments*, 1975)

Garfield later recognised the power of the IF for journal evaluation and considered it also a journal performance indicator.

In the 1970's and 1980's, scientometrics evolved gradually towards research evalution, but still provides tools for retrieval and information.

# Robert K. Merton (1910–2003)

Robert K. Merton represents the sociologists' view of scientometrics. Among his most famous ideas related to science and its measurement, the *Matthew effect* and his notion of citation as a reward system (currency of science) should be mentioned.

According to the sololologists' view communication in science is not merely linked to cognitive processes (cf. information science), but also characterised by the position scientists hold in the community.

## Robert K. Merton (1910–2003)

In particular (Merton, 1988):

> *"Since positive recognition by peers is the basic form of extrinsic rewards, all other extrinsic rewards, such as monetary income from science-connected activities, advancement in the hierarchy of scientists, and enlarged access to human and material scientific capital, derive from it."*

Kaplan, *American Documentation*, 1965
Merton, *Social Theory and Social Structure*, 1968
Merton, *Science*, 1968
Merton, *ISIS*, 1988.

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# Little Scientometrics – Big Scientometrics

Besides information science and sociology of science, *science policy* became the third driving force in the evolution of scientometrics.

- A consequence of the growth of knowledge and the evolution from little science to big science: Need for supplementing research evaluation with quantitative methods and of linking funding to performance indicators.
- The application to science policy has brought a new perspective, and resulted in re-interpretation of bibliometric conceptions.
- The ‘science indicators movement’ in the US with the discussion about the possible use of bibliometrics in science policy in the 1970s marked the begin of a new era in bibliometrics.

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# Bibliometrics in the 1970s and 1980s

In the 1970s and 1980s, scientometrics/bibliometrics took a sharp rise and found a new orientation.

- Bibliometrics evolved from an invisible college, from a sub-discipline of library and information science to an instrument for evaluation and benchmarking. This can be considered a “perspective shift”.
- As a consequence of this perspective shift, new fields of applications and challenges opened to bibliometrics; but many tools were still designed for use in scientific information, information retrieval and libraries. Those became used in a context for which these were not designed.

# Bibliometrics in the 1970s and 1980s

The **institutionalisation process** of bibliometrics mirrors its evolution from an invisible college to an established field in the very intersection of information science, computer science and sociology of science.

The institutionalisation process, which set in in the late 1970s and mainly took place in the 1980s, is characterised by the following important activities.

- Structured scientific research
- Documented scholarly communication
- Higher education
- Service activities
- Public perception and visibility

# Milestones of institutionalisation

## Important milestones in the institutionalisation process of bibliometrics – Foundation of dedicated research and service centres

**Germany**: One of these centres was focused on documentation in medicine. Otto Nacke founded the “Dokumentationsstelle für Versorgungsmedizin” in 1956 which changed its name to “Institut für Dokumentation und Information über Sozialmedizin und öffentliches Gesundheitswesen” (idis) in 1976.

He headed the institute, which was located in Bielefeld, till his retirement in 1980. After that he had a small institute in Bad Salzuflen.

In the 1990s as well but he changed to “Veritology” (the reliability and truth in what is written and published).

Otto Nacke coined the term *Informetrics* in 1979.

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# Milestones: Research Centres

**Germany**: The second one, the “Center for Science Studies”, was headed by Peter Weingart and is located at the University Bielefeld. It was succeeded by the “Institute for Science & Technology Studies (IWT)”.

Its director Peter Weingart focused first on sociology and philosophy of science (especially in the 1970s) but later he extended his research to quantitative science studies as well.

**Hungary**: ISSRU in Budapest was founded by Tibor Braun about ten years later. This center was housed at the Library of the Hungarian Academy of Sciences. The first international scientometric publications from this center are dated around 1976.

# Milestones: Research Centres

**The Netherlands**: CWTS in Leiden is headed by Atnhony van Raan.
This institute was founded around 1982and was first called LISBON Institute.
Its profile is similar to that of ISSRU in Budapest (focus on scientometrics and bibliometrics).

**The Netherlands**: “Dept. Science Dynamics” at Amsterdam University has been renamed/restructured several times. It is headed by “Loet Leydesdorff”.
He has published first results in international journals around 1980.

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# Milestones: Research Centres

**France**: The group by William Turner, Michel Callon, Jean-Pierre Courtial and colleagues at the Ecole Mines in Paris focused on structural matters like mapping and visualization of science (actually based on co-word analysis). They were already active in the early 1980s.

**France**: The “Observatoire des Sciences et des Techniques” (OST) was founded as an inter-institutional platform in 1990. OST, headed by Remi Barré, was one of the first institutions in Europe that issued biennial Reports on Science and Technology Indicators.

**Spain**: The “Centre of scientific information and Documentation” CINDOC started somewhat later in the 1980s (internationally visible since about 1985). Recently the institute changed its name to IEDCYT. Isabel Gomez. is ist vice-director.

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# Milestones: Scholarly communication

- Regular publication of scientometric papers in *Czechoslovak Journal of Physics* since about 1970(J. Vlachý)

- Foundation of international scientific journals
  - Scientometrics (T. Braun, 1978)
  - Research Evaluation (A.F.J. van Raan, 1991)
  - Journal of Informetrics (L. Eegghe, 2007)

- Otto Nacke edits the books entitled “Scientometrie und Bibliometrie in Planung und Forschung” (1976) and “Zitatenanalyse und verwandte Verfahren” (1979).

- The first “Handbook of Quantitative Science and Technology Research” edited by A.J.F. van Raan appears in 1988.

# Milestones: Scientific conferences

Important milestones in the institutionalisation of bibliometrics

- Organisation of international conferences
  - International Conference for Informetrics and Scientometrics (biennially from 1987)
  - International Conference for Science and Technology Indicators (biennially from 1988)
  - CollNet (since 1998)

- Foundation of the International Society for Informetrics and Scientometrics (ISSI, 1993)

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# Milestones: Methodology

In this period the development of a specific *scientometric methodology* took place.

- Co-citation analysis has been proposed for the structural mapping of science.
  ISI issued the co-citation based *Atlas of Science*.
  Small, *JASIS*, 1973
  Marshakova, *Nauchno-Tekhnicheskaya Informatsiya, Seriya 2*, 1973
- About one decade later, Callon et al. developed another cognitive mapping procedure called *Leximappe* which was based on co-word analysis.
  Callon et al., *Social Science Information*, 1983
- Later on, these methods have been supplemented by and combined with other text-based (term frequency) and citation-based(bibliographic coupling, direct citation-link, author co-citation) techniques.

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# Milestones: Methodology

- The development of consistent systems of scientometric indicators for the evaluation of research performance at ISSRU (Budapest,Hungary) and CWTS (Leiden, the Netherlands).

  Braun et al., *Scientometric Indicators*, 1985
  Schubert and Braun, *Scientometrics*, 1986
  Braun and Glänzel, *Scientometrics*, 1990
  Moed et al., *Scientometrics*, 1995

- The 1980s are also characterised by important steps towards the institutionalisation of scientometrics and informetrics (cf. “Bibliometric initiatives and institutionalisation of the field in Europe”).

# Bibliometrics in the 1990s and the new millenium

## An important trend in bibliometric application

The level of aggregation began to decrease from the national level over the institutional level down to the level of the evaluation of research groups or even individual scientists.

This was allowed for by the rapid development of both scientometric methods and information technology.

The spectacular evolution of bibliometrics in the 1990s is due in no small part to the IT revolution we recently witness.

# Bibliometrics in the 1990s and the new millenium

The following developments and their synergy have facilitated breakthroughs in and popularisation of our field.

- *Database availability*

  In the 1970s and the 1980s, access to electronic versions of bibliographic databases suitable for biblioemetrics use was the privilege of a very few institutes worldwide. This changes in the 1990s when the CD versions of the SCI, Medline and other databases became available to university and institutional libraries.

- *Hardware development*

  Formerly expensive data-processing run on mainframe computers could gradually be ported to institutional servers and PCs. (“laptop bibliometrics”)

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# Bibliometrics in the 1990s and the new millenium

- *Software development*.

  This opened bibliometrics to a broader user group among scientists and bibliometric “semi-professionals”.

- *Networking and the web*.

  This facilitated collaboration among bibliometricians and scientists. (“online bibliometrics”)

# Bibliometrics in the 1990s and the new millenium

## Bibliometrics has found entrance in European, national and regional S&T Reports

- The “Science and Engineering Indicators” (SEI) is published by the National Science Board (USA). The first edition appeared in 1993; since 1996 SEI is published biennially.
- The European Commission regularly issues the *European Reports on Science and Technology Indicators* (REIST) since 1994
- The *OST Annual Performance Report*. The reports measure institutional research output allowing to compare their performance with that of other French or European institutions.

# Bibliometrics in the 1990s and the new millenium

## Bibliometrics has found entrance in European, national and regional S&T Reports (cont'd)

- The "Netherlands Observatory of Science and Technology" (NOWT) is a co-operation between CWTS (Leiden), and the UNU-MERIT (Maastricht). The *Science and Technology Indicators Reports* are regularly published since 1994.
- The *Flemish Indicator Book on Science, Technology and Innovation* covers a comparably broad spectrum and appears biennially since 1999. The indicator book is published by ECOOM in co-operation with the Flemish Government.

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# Bibliometrics in the 1990s and the new millenium

- Bibliometrics is used in foresight processes, monitoring of public funding and strategic decision making processes.
- Governments use bibliometric informations not only with formula based funding, but also in monitoring and foresight processes.
- Foundations use bibliometrics for programme monitoring and strategic decision making.

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# Bibliometrics in the 1990s and the new millenium

## Funding mechanisms and research assessment exercises (Examples)

- Changes to the Research Assessment Exercise (RAE) in UK are planned for future quality weighted research funding of higher education after 2008.
- One of the major funding mechanisms for basic science in Flemish universities is the *Bijzonder Onderzoeksfonds* (BOF). Part of the allocation key is based on publication and citation data derived from “Web of Science” (Thomson Reuters) by ECOOM.
  Debackere & Glänzel, *Scientometrics*, 2004
- Since 2005, the allocation formula for basic funding of research in the Norwegian HE sector includes an output indicator for scholarly publications. The Norwegian model is currently implemented in Denmark.
  Sivertsen, *STI Conference*, 2006

# Bibliometrics in the 1990s and the new millenium

## Funding mechanisms and research assessment exercises (Examples)

Different forms of Performance-based University Research Funding Systems (PRFS), which rely on bibliometrics components, are currently used.

Further examples for PRFSs with quantitative components are at present

- the Composite Index of university block grants, the Research Quality Framework (RQF) and the Excellence in Research for Australia (ERA) in Australia;
- the Performance-based research funding (PBRF) in New Zealand;
- the Funding formula for allocation of university resources in Finland;
- the Valutazione Triennale della Ricerca (VTR)/Valutazione Quinquennale della Ricerca (VQR) in Italy.

Hicks, *Performance-based University Research Funding Systems*, 2011

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# Bibliometrics in the 1990s and the new millenium

During the last decade bibliometrics has become a subject within the framework of master or doctoral programmes of several European universities.

Special courses are also offered by universities and research centres.

Examples:

- “Measuring Science” at CWTS at Leiden University
- “Road show seminars” and Nordic PhD courses in bibliometrics organised by the Nordic Research School in Library and Information Science (NORSLIS)
- “European Summer School for Scientometrics” (esss) jointly organised by University of Vienna, IfQ, Humboldt-Universität Berlin and KU Leuven

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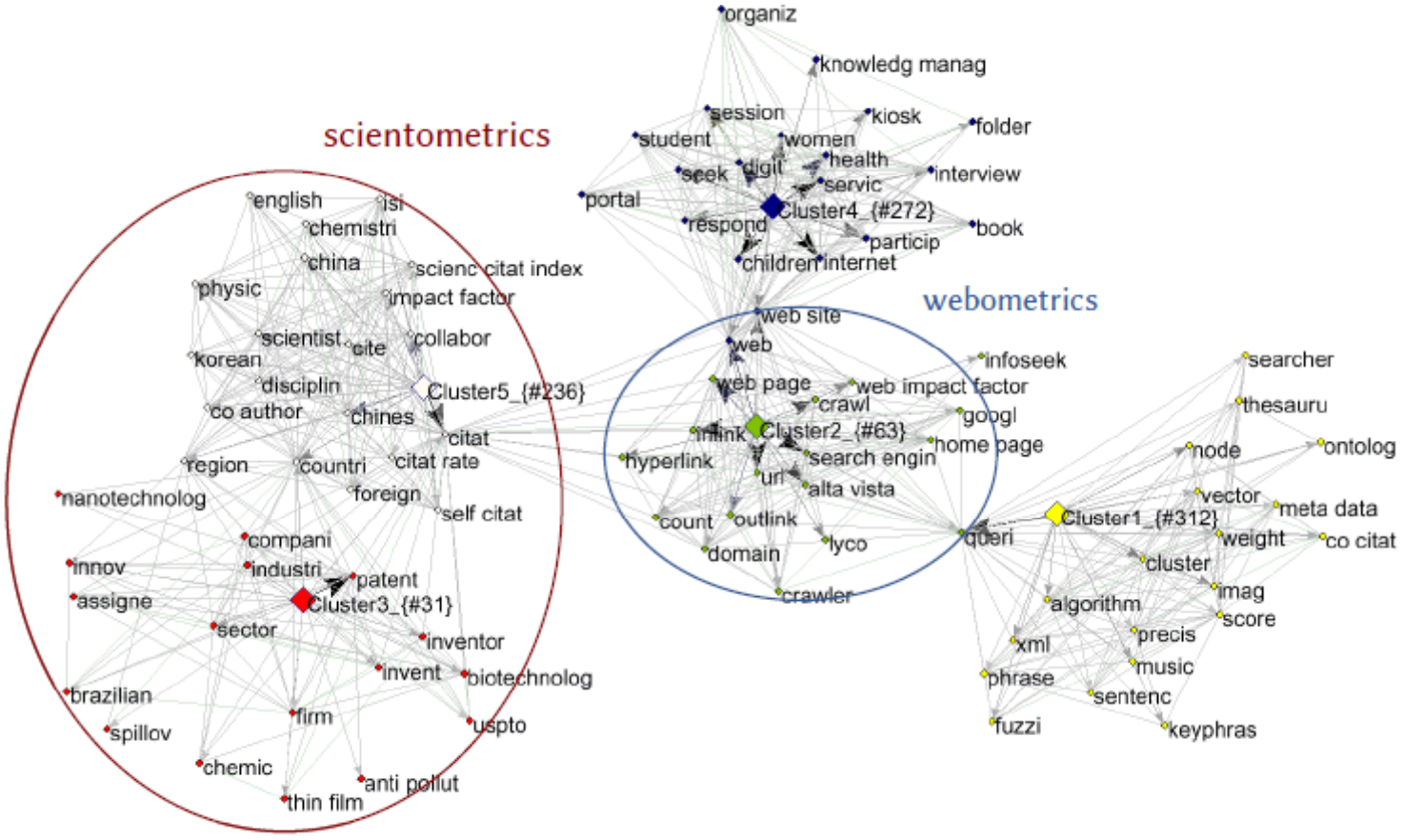
# Bibliometrics in the 1990s and the new millenium

Bibliometrics as part of LIS in the mirror of its research literature

Janssens et al., *Information Processing & Management*, 2008



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# The impact of bibliometrics

- The need for metrics in information services, science policy and research management has become widely recognised.
- Bibliometrics plays an increasing role in research evaluation, and quantitative formulas with bibliometric components are used in allocation of funding.
- Successful application of scientometric methods have largely contributed to their increasing popularity.
- Electronic communication, the Web and open access have paved the way for the democratisation of bibliometrics (resulting in a rather vulgar version of democracy with anarchistic features).
- Quick and dirty statistics and evaluations, uninformed application and misuse of bibliometrics have discredited our field.

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**Thank you for your attention!**