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**Bibliomania: What can
we learn from the
research literature?**

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Bibliomania: What can we learn from the research literature?

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Abstract: The field of *bibliometrics* provides a set of quantitative methods for understanding how scientific information is created and disseminated by examining the structure, rather than the content, of subject documents. Bibliographic information can be analyzed to give insights into the development of research fronts, methods of scientific communication, and characteristics of the scientific literature. This paper presents three case studies illustrating simple bibliometric techniques, as applied to management/computer science/information systems. These fields have been largely ignored by bibliometricians; an unfortunate omission, given the information on the nature and structure of these fields that bibliometric studies could provide.

1. Introduction

Research literature is primarily explored for its content; we have a problem to solve, and wish to learn how others have approached that same obstacle. However, a subject literature can also be usefully viewed from a higher level, to observe how researchers/workers in a given field generate, disseminate, and apply knowledge. These analysis techniques are called *bibliometrics*--quantitative analysis of subject bibliographies or citation collections. For example: a subject bibliography can be bibliometrically "mined" to identify the important research groups in a discipline, trends in the growth or decline of a topic in the field, development of research fronts, indications of technology transfer from one discipline to another, documentation of the structure of "invisible colleges" of researchers whose collaborations stretch across institutional boundaries, adoption of new research methods, etc.

This information is of obvious importance to investigations of the sociology and history of science. It can also have a variety of strategic applications in targeting research or in placing published results in context. Productivity rates for individuals and institutions can influence governmental research funding allocations, as is illustrated by recent attempts in Australia to rank or group universities by of scientific output (for example, see Lowe, 1995). Measurements of the "impact factor" of a body of work can be useful in determining the relative importance of a new technique or method described in that literature. Examination of the growth or decline of a subject area, in conjunction with a deep understanding of local research strengths and weaknesses, can be used in conjunction with peer review to focus an institution or nation's research agenda (Phillips and Turney, 1988).

This paper presents three case studies of the application of bibliometric techniques to the computing/management/information systems literature:

- an analysis of technology transfer of an artificial intelligence technique to a wide variety of other subject disciplines
- an examination of the obsolescence rate of management communication literature
- an investigation of the proportion of male and female researchers in published management research

Each case study describes the bibliometric technique used, presents the results of that study, and discusses their implications for directing future research or interpreting

potential biases in the literature. These case studies do not provide a comprehensive overview of the bibliometric methods that have been developed for quantitative analysis of scientific output (for example, the important techniques of cocitation and bibliographic coupling analysis have been omitted). Categorizations of techniques can be found in (Paisley, 1991; White and MacCain, 1989). Instead, we attempt to convey a flavour of the opportunities that bibliometric studies afford for insight into how science is conducted.

2. Case study: technology transfer from artificial intelligence

How quickly are information, new research methods, and technological advances transmitted between fields? How "important" is a given finding, both within its field of origin and in other subjects? Are there any patterns in the growth of literature about a research topic?

A simple technique to measure the current level of research activity for a given topic is to count the number of research documents that refer to the topic this year in a subject-specific bibliographic database. If this count is performed on a year-by-year basis back to the publication date of the topic's seminal work, then we can determine the rate of growth for the topic literature, as well as the absolute number of documents produced pertaining to that topic (Hall, 1988). And if this methodology is extended to bibliographic databases of other disciplines, then we can trace the impact of that topic on other subjects. From a practical point of view, this type of study is most feasible when performed on computerized, rather than paper, bibliographic databases.

This case study examines the growth of literature for a topic in artificial intelligence—expert systems—as measured through the MATHSCI and EI COMPENDIX databases (maintained by Dialog). While neither of these databases are limited strictly to computer science, they are the best sources for computing bibliographic information that are available online (date of publication searches on the ACM database are unreliable). The degree of technology transfer between artificial intelligence and a range of other fields is measured by tracing the introduction of expert systems documents into the online bibliographic databases for other subjects.

Data collection

Simple keyword searches for "expert system or expert systems" were performed on Dialog's DIALINDEX service. DIALINDEX provides only a count of the number of documents in a given database, and does not permit the user to retrieve any documents. This service is mainly used to refine complex queries before searching the database itself. For the purposes of this type of bibliometric study, it offers a platform for gathering data that is significantly cheaper than direct Dialog database searches. Specifically, the following Dialog databases were examined through DIALINDEX: BIOSIS (biology), MATHSCI (mathematics and computing), ERIC (education), SOCIOLOGICAL ABSTRACTS (sociology), GEOREF (geology), ENVIROLINE (environmental science), PSYCHINFO (psychology), ARTS & HUMANITIES (liberal arts and humanities), LEGAL TRACK (law), CA SEARCH (chemistry), MLA (humanities), MEDLINE (medicine), and EI COMPEDEX (engineering and computing).

Results

The number of documents in each database containing the term "expert system" for the years 1979 - 1992 are presented in the Appendix. These raw search results are visualised in Figures 1-3.

In the computing databases (ei compendex and mathsci), the number of publications related to expert systems is quite large: a total of 5481 documents in MATHSCI and 14583 in EI COMPEDEX. Viewed as a percentage of documents in these databases, the

expert systems publications peaked at 1.52% for MATHSCI (1987) and 1.39% for EI COMPEDEX (1990). After the peak year, both the number and percentage of expert systems publications steeply declined. Note that EI COMPEDEX's "valley" between 1986 and 1989 (Figure 1) is most likely caused by a drop in the number of serials indexed by the database for those years, since this same valley is not reflected in the view of expert systems publications as a percentage of the documents added to the index each year (Figure 2).

This pattern of growth, peak, and steep decline in number of publications produced is typical for a developing field. Generally an emerging paradigm experiences rapid growth, which declines as major problems are solved and the research area is "mined out". This decline may be reversed if anomalies appear and a new paradigm emerges from the field (Crane, 1972).

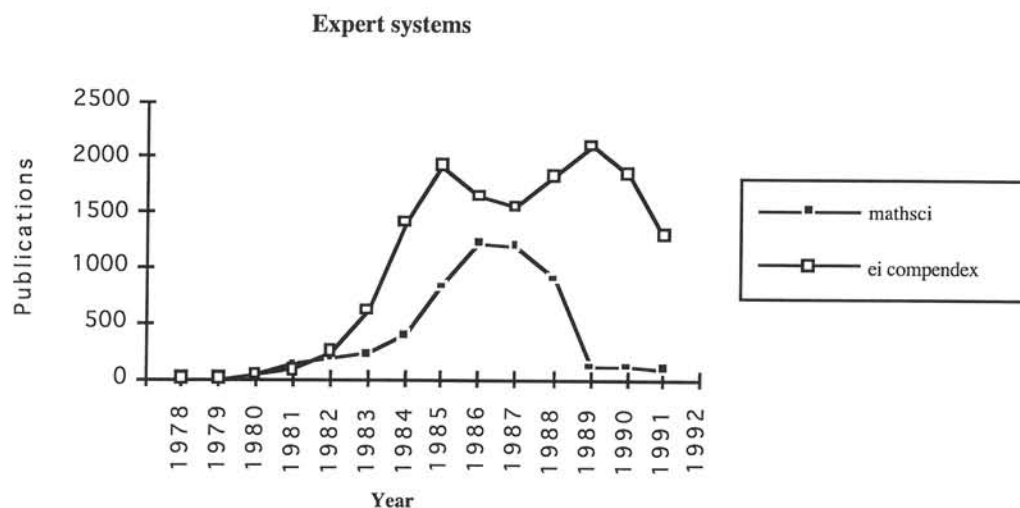


Figure 1. Number of expert systems publications in computer-oriented databases.

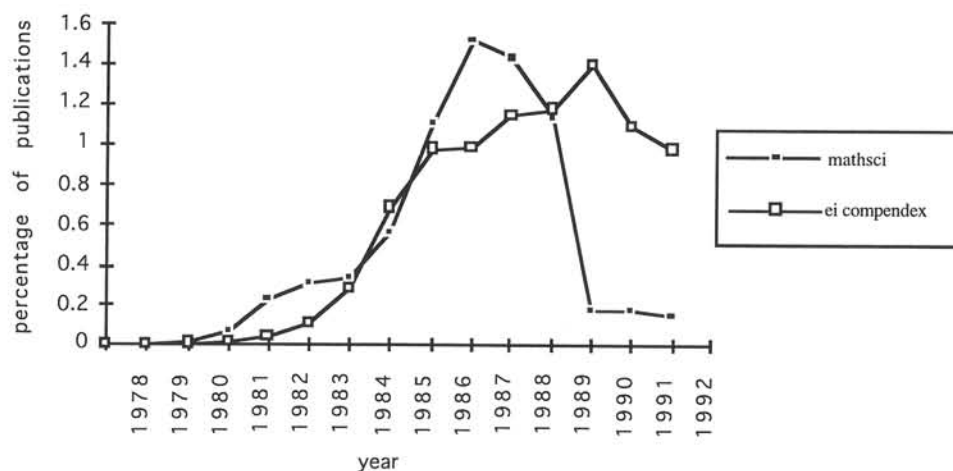


Figure 2. Expert systems publications as a percentage of documents added yearly

Figures 3 - 5 present the number of expert systems - related publications by year for a range of fields. Most sciences (biology, medicine, agriculture, and environmental science) display a pattern of growth and decline similar to that found in the computing databases, and peak in number of publications in 1989-1990 (Figure 3). The

exception is chemistry (ca search), which in 1992 remained in a state of growth. These representative curves remained the same when the number of expert systems documents was calculated as a percentage of the total publications added to each database each year. For all databases this percentage was significantly less than 1% during the peak year.

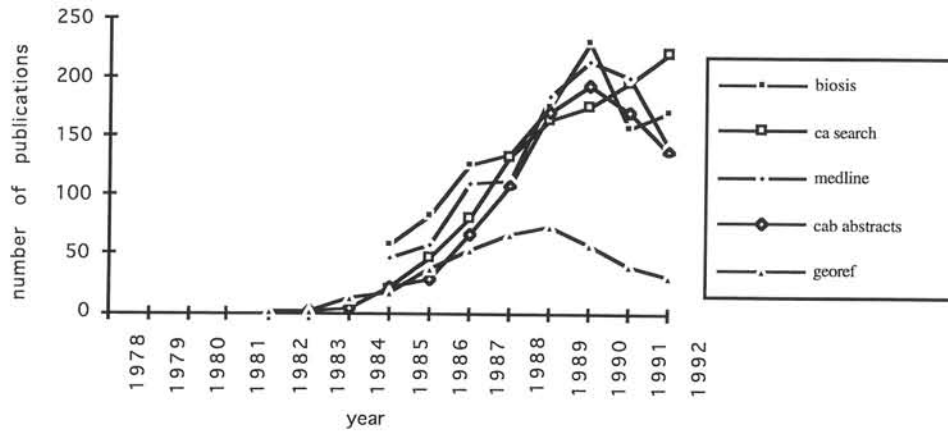


Figure 3. Number of expert systems publications in science databases

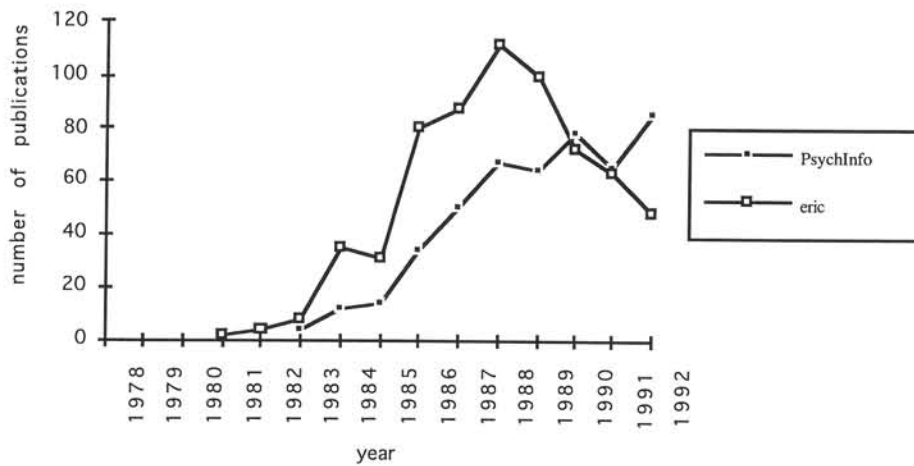


Figure 4. Expert systems publications in psychology and education databases

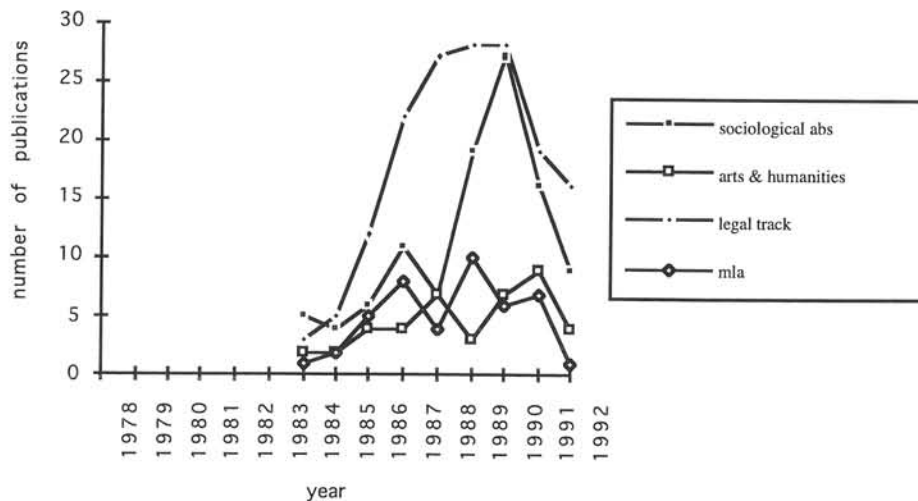


Figure 5. Expert systems publications in arts and social science databases

For the liberal arts and social sciences, both the number and percentage of publications is smaller (Figures 4 and 5; for clarity's sake we present only the number of publications in each field). The fields of education (ERIC) and psychology (PSYCHINFO) displayed the greatest interest in expert systems, peaking in 1988 for education and continuing to rise in psychology. The remaining subjects have very few expert systems publications, but tend to peak around 1990 and decline thereafter.

Discussion

The research literature for expert systems displays a publications output curve characteristic of a topic in decline. Note that this decline does not usually mean that the area has been discredited, but rather that its problems have to a large extent been understood and solved. This type of maturity in a field makes it less attractive for pure research, but more suitable for applications.

In investigating the diffusion of expert systems technology to other fields, we see that the largest number and percentage of publications tend to be in the "hard" sciences, psychology, and education. Interest in expert systems is lowest for the arts, social sciences, and law. This difference might be attributed to the relative "closeness" that computer science in general enjoys to the sciences and the artificial intelligence in particular enjoys to psychology and education (through the field of cognitive science). And, of course, the applicability of expert systems technology to these fields differs—although law appears to have under-exploited these techniques. To be only slightly cynical, a paper dealing with expert system applications in the humanities or social sciences might be more easily published than a similar paper for the sciences because of the former's novelty in those disciplines.

At this point, it is appropriate to enumerate the types of bias that are introduced into this class of bibliometric study:

- Raw counts of documents pertaining to expert systems do not take into account how the authors treat the topic. This methodology tends to err on the side of producing "false positives" (retrieved records that are not relevant) by including documents that criticise or dismiss expert systems technology, that merely mention expert systems but do not treat the topic substantively, and that provide tutorials or overviews rather than new research results or applications.
- Changes in the number and types of publications indexed by the databases studied may skew results. One such artefact is the apparent drop in interest in expert systems in *ei compendex* between 1986 and 1989 (Figure 1). This drop in fact appears to be a reflection of the smaller number of periodicals indexed during that period.
- The bibliographic databases themselves represent a sampling of their subject literatures. For example, most available databases tend to under-represent research published in languages other than English, to include a higher percentage of US and Western European publications than from other regions, and to omit the "grey" literature such as working papers, informally published conference proceedings, etc.

This quantitative rather than qualitative analysis is characteristic of bibliometric methods; emphasis is on gathering available data from available sources. For the above reasons this type of study is best viewed as representing trends, rather than providing absolute values for number of publications per year and field. A finer-grained analysis of the Dialog documents pertaining to expert systems would be a major undertaking—a

total of 25,341 "hits" were produced by the DIALINDEX query over the years 1978 - 1992!

Moreover, the widespread availability of computerised bibliographic databases such as the Dialog collection has sparked an increase in the application of bibliometric methods. Manual search through paper source documents for data is laborious and exceptionally time-consuming. Computer databases permit studies to be performed that are approximate but timely and cost-effective. Indeed, more detailed studies of smaller subject literature generally begin with keyword searches on online databases, and then proceed to manual retrieval of the selected document set for further analysis (see, for example, (Thorpe and Pardey, 1990) and (Reid, 1992)).

3. Case study: obsolescence of management communication literature

How long does the information in a research article remain current? How old can a document be before it is likely to be judged out of date? Obsolescence studies attempt to answer these questions by measuring the amount of "usage" (citations) that a document receives after it is published. Typically, documents receive their greatest number and frequency of citations immediately after publication, and the frequency of citation falls rapidly as time passes. If, that is, the document is referenced at all—it is estimated that approximately one-third of all scientific articles are never cited (Computer Horizons, 1976).

A synchronous obsolescence rate is determined by proceeding from the present to the past: the publication dates of documents *referenced* by a sample set of documents are examined to determine how far back in time the more recent half of those references were published. This measure is called the median citation age, and answers the question, "what is the age of a publication likely to be at the time it is cited by another publication?" (Wallace, 1986).

In this case study we calculate the median citation age for a sampling of articles from the management communication literature. This statistic is measured for a single article by simply sorting the dates of publications referenced by that article and finding the median. We use the discrete analysis method: publication years are treated as discrete units, rather than as a continuum of quarters, months, and weeks. To find the median citation age for a collection of journals, we first calculate the median for each individual journal issue and then average the medians .

Data collection

The choice of a body of literature as a focus for a bibliometric study is often dependent on pragmatic as well as theoretic factors—availability of documents, ease of access, etc. We selected the sample of management communication literature from the collection available at the University of Waikato. Of 25 journals related to this field, 10 titles were chosen at random. With 1993 as a base year for the study, a single issue was selected at random for each of the 10 journals. Summary information for these journals is presented in the Appendix.

Results

Median citation ages for the sampled literature varied from 5.74 to 11 years, with an overall median 8.5 years. This range of ages is to be expected, given the wide variety of sub-disciplines reflected in the focus of each of the sample journals. To put this

number in perspective, consider the following table of obsolescence periods for a range of other fields:¹

| Discipline | median citation age (years) |
|---------------------------|-----------------------------|
| metallurgical engineering | 3.9 |
| genetics | 4.0 - 6.0 |
| computer networking | 4 |
| physics | 4.4-4.9 |
| chemical engineering | 4.8 |
| information systems | 5 |
| mechanical engineering | 5.2 |
| desalination | 5.6 |
| chemistry | 8.1 |
| archaeology | 9.54 |
| botany | 10 |
| music education | 10.0 - 15.0 |
| music theory | 10.0 - 15.0 |
| mathematics | 10.5 |
| geology | 11.8 |
| biblical criticism | 21.63 |

Figure 6: synchronous median citation ages for a variety of fields

As we might expect, the obsolescence period for communication is higher than that of the technology-dependent “hard” sciences. Note also that the reference dates are not evenly distributed, but are heavily skewed to the recent past (Figure 7). While the range of dates is approximately 90 years, the bulk (85%) of the references were published within 10 years of the base year for this study.

| time period | number of references | percentage |
|-------------|----------------------|------------|
| 1990-1993 | 245 | 19.48% |
| 1984-1989 | 482 | 38.31% |
| 1976-1983 | 344 | 27.34% |
| 1965-1975 | 117 | 9.30% |
| 1954-1964 | 23 | 1.83% |
| 1925-1953 | 17 | 1.35% |
| 1900-1924 | 5 | 0.40% |

Figure 7. Distribution of reference dates

Discussion

Obsolescence studies are one tool for examining the patterns of information generation, dissemination, and use in our research community. Examination of past obsolescence rates allows us to chart general changes in the modes of scholarship over the years; evaluation of obsolescence studies rates for distinctive geographic regions and sub-topics will allow us to draw contrasts between research methods found in different countries and within different research cliques. A deeper understanding of the subject

¹All studies are synchronous. The information systems and computer networking studies are derived from Cunningham (1995). The remaining median citation ages are taken from Diodato (1992).

methods and how they change can only be beneficial in producing quality work in the future. And, of course, this type of information can be useful in actually producing research, by giving an indication of how far into the past a literature review should proceed.

These studies are also of pragmatic importance for managing document collections. Often older physical documents must be archived to release shelf space, with only the "latest" volumes of a journal available for ready access by patrons. Obsolescence information offers a principled technique for culling older literature.

4. Case study: author characteristics

Who produces the research that we read? Are there any patterns or regularities in the qualifications, geographic location, institutional affiliations, etc. of these authors? Could any existing regularities be giving our research literature a slant or bias, by unintentionally excluding research techniques and viewpoints embodied by these "atypical" authors?

Past studies have examined a number of factors that may influence the direction and approaches of research agendas: for example, professional qualifications of journal editors (Zsindely and Schubert, 1991); differences in the impact of articles by male and female authors (Over, 1990); the extent to which research is supported by external funding (Pao, 1992); and the size of the researchers' country and their degree of geographic isolation (Kyvik and Larsen, 1994). Quantitative evidence that differences in these qualities exist do not, of course, prove that research is biased. This type of study does, however, point to areas that should be qualitatively examined. Good science requires us to be aware of our own blind spots!

This case study explores the distribution of authors by gender in three management journals: *Sloan Management*, a prestigious broad-focus serial; *Management Communication Quarterly*, representative of a field that might be expected to have a relatively large female participation rate; and *Accounting Review*, a publication venue for a major sub-field of management.

Data collection

Available physical copies of articles were scanned to determine the gender of authors contributing refereed papers to the above journals (as indicated by full names or biographical information). When author gender could not be determined, that author was omitted from the study. All authors for collaborative efforts were included, and the counts were not weighted by order in the list of authors for a paper. Data was collected for the following time periods: *Sloan Management*, 1974-1987, 1989-1994; *Management Communication Quarterly*, 1990-1994; and *Accounting Review*, 1990-1994.

Results

More men than women authored papers for both *Sloan Management* and *Accounting Review*, and there appears to be little evidence that this gap is closing (Figures 8 and 9). For *Sloan Management*, this difference was significant at the 99% level ($t(38) = 2.711, p = 0.0005$); for *Accounting Review*, the difference was significant at the 95% confidence interval ($t(8) = 2.3065, p = 0.022$).

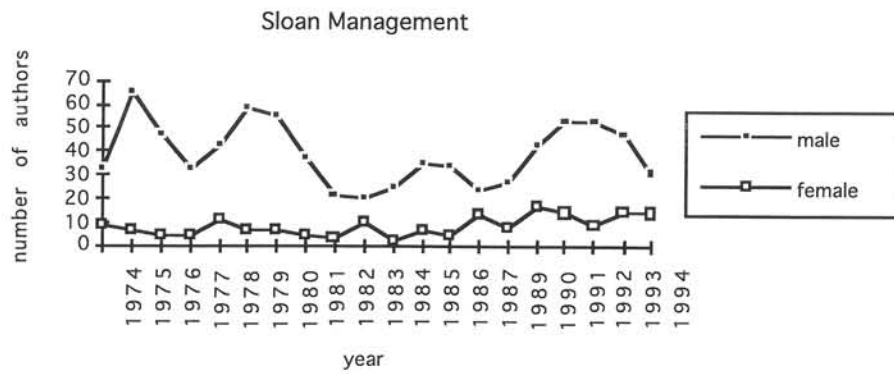


Figure 8. Number of authors by gender for *Sloan Management*

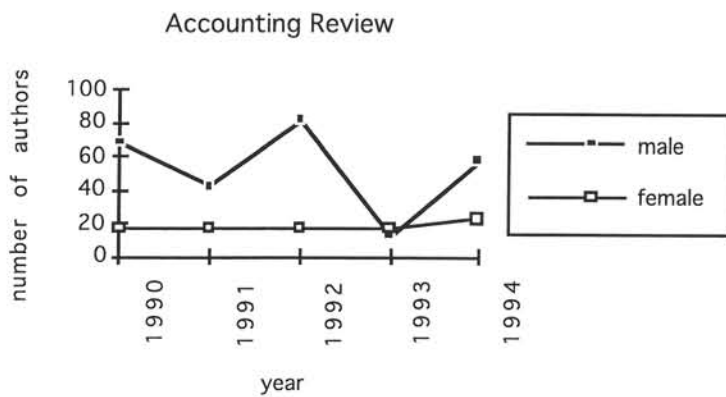


Figure 9. Number of authors by gender for *Accounting Review*

For *Management Communication Quarterly*, however, more women appeared as authors than men (Figure 10). While this difference is slight, it is statistically significant (95% confidence interval, $t(8) = 2.3065, p=0.488$).

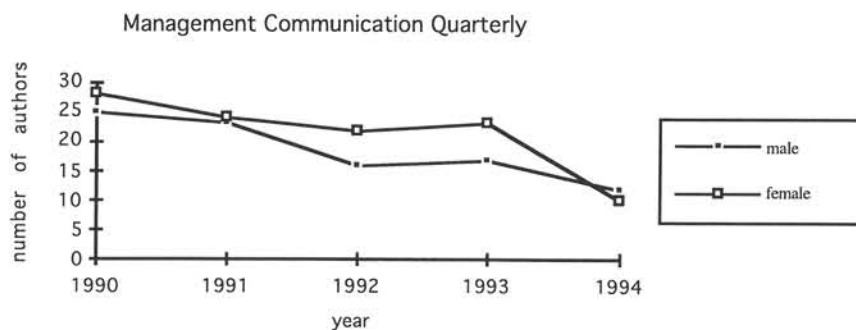


Figure 10. Number of authors by gender for *Management Communication Quarterly*

Discussion

For both *Sloan Management* and the *Accounting Review*, the preponderance of male authors appears to mirror the under-representation of women in the upper levels of the management and accounting fields, at which opportunities for publication and research are more likely (Keen et al, 1994; Still, 1993). In academia, women in business faculties tend to be over-represented as instructors, lecturers, contract researchers, and other untenured staff positions. In the mid-eighties in the US, for example, women

held 52% of the instructor and lower teaching positions, 36% of the assistant professorships, but accounted for only 6% of the full professorships (Aisenberg and Harrington, 1988). These lower level positions provide fewer opportunities for research funding, and generally involve a higher teaching load (with proportionally less time for research). For the *Management Communication Quarterly*, however, there is a slight preponderance of female authors. This likely reflects the traditionally large proportion of women who receive degrees in communications, journalism, English, and related fields.

Is it likely that significant disparities in the gender make-up of the authors for these publications affects the development of these research areas? Perhaps; there are tantalising indications that women who do publish in management may work from different perspectives or pursue different topics than male researchers (Orser, 1992). Other fields have documented stronger evidence: in the "hard" sciences, for example, studies indicate gender differences in observational methods, hypothesis formulation, and development of theories for testing (Rosser, 1990). Bibliometric analysis of author characteristics can only point out these gross differences, suggesting areas deserving in-depth qualitative study to determine their affects on the process of scientific research.

5. Conclusions

This paper presents three case studies illustrating simple bibliometric techniques. Bibliometric methods have been under-utilised in the past because of the sheer difficulty of gathering data. However, the increasing availability of computerised bibliographic databases and document repositories are making bibliometric methods much more accessible. It is beyond the scope of this paper to provide an overview of bibliometric methods. Other important techniques include co-citation analysis, which uses the patterns in which documents reference each other to produce "maps" of the relationships between fields in a discipline; and measurements of the relative productivity of institutions or individuals, techniques which have been used (and mis-used) to distribute research funding and promote, hire, and fire researchers.

Bibliometric techniques are subject to a variety of biases. In particular, these quantitative methods are generally skewed by a simple keyword approach to gathering sample documents (case study 1), or by a structural citation analysis that ignores the meanings inherent in references between documents (case study 2). Again, these simple methods are best viewed as giving indications of fruitful areas for finer-grained, qualitative study.

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Appendix

1. Raw data for case study 1: number of expert systems publications per year

| | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 |
|-------------------|------|------|------|------|------|------|------|------|------|
| mathsci | 4 | 8 | 39 | 135 | 191 | 222 | 384 | 831 | 1224 |
| ei compendex | 2 | 7 | 32 | 75 | 235 | 618 | 1403 | 1918 | 1652 |
| eric | | | 1 | 3 | 8 | 35 | 31 | 80 | 87 |
| PsychInfo | | | | | 4 | 11 | 13 | 34 | 50 |
| biosis | | | | | | | 59 | 82 | 126 |
| georef | | | | 2 | 2 | 12 | 16 | 37 | 53 |
| enviroline | | | | | 1 | 2 | 2 | 6 | 11 |
| ca search | | | | | | | 21 | 46 | 81 |
| medline | | | | | | | 45 | 57 | 111 |
| sociological abs | | | | | | 5 | 4 | 6 | 11 |
| arts & humanities | | | | | | 2 | 2 | 4 | 4 |
| legal track | | | | | | 3 | 5 | 12 | 22 |
| mla | | | | | | 1 | 2 | 5 | 8 |

| | 1988 | 1989 | 1990 | 1991 | 1992 |
|-------------------|------|------|------|------|------|
| mathsci | 1204 | 914 | 120 | 116 | 89 |
| ei compendex | 1553 | 1830 | 2113 | 1845 | 1300 |
| eric | 111 | 100 | 72 | 63 | 48 |
| PsychInfo | 67 | 64 | 78 | 65 | 85 |
| biosis | 134 | 176 | 231 | 157 | 171 |
| georef | 68 | 74 | 59 | 40 | 31 |
| enviroline | 10 | 56 | 36 | 27 | 31 |
| ca search | 132 | 165 | 177 | 196 | 221 |
| medline | 112 | 186 | 213 | 200 | 142 |
| sociological abs | 7 | 19 | 27 | 16 | 9 |
| arts & humanities | 7 | 3 | 7 | 9 | 4 |
| legal track | 27 | 28 | 28 | 19 | 16 |
| mla | 4 | 10 | 6 | 7 | 1 |

2. Raw data for case study 2: median citation ages for journal issues

| title | issue | number of references | median citation age (years) |
|---------------------------------------|-------|----------------------|-----------------------------|
| J. of Applied Communication Research | 21(2) | 183 | 10.7 |
| College Composition and Communication | 44(1) | 115 | 7.6 |
| Women and Language | 16(2) | 127 | 10.6 |
| Communication Education | 42(2) | 161 | 5.75 |
| Communication Studies | 43(3) | 112 | 10 |
| Aus. Communication Review | 14(1) | 31 | 5.25 |
| Aus. J. of Communication | 20(1) | 172 | 11 |
| Communication Theory | 3(1) | 121 | 8.6 |
| Communication Quarterly | 41(4) | 93 | 7.5 |
| Text & Performance Quarterly | 13(2) | 143 | 8 |
| Total across all issues | | 1258 | 8.5 |

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