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A bibliometric study of reference literature in the sciences and social sciences☆

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Abstract

In earlier papers the authors focused on differences in the ageing of journal literature in science and the social sciences. It was shown that for several fields and topics bibliometric standard indicators based on journal articles need to be modified in order to provide valid results. In fields where monographs, books or reports are important means of scientific information, standard models of scientific communication are not reflected by journal literature alone. To identify fields where the role of non-serial literature is considerable or critical in terms of bibliometric standard methods, the totality of the bibliographic citations indexed in the 1993 annual cumulation of the SCI and SSCI databases, have been processed. The analysis is based on three indicators, *the percentage of references to serials*, *the mean references age*, and *the mean reference rate*. Applications of these measures at different levels of aggregation (i.e., to journals in selected science and social science fields) lead to the following conclusions. 1. The percentage of references to serials proved to be a sensitive measure to characterise typical differences in the communication behaviour between the sciences and the social sciences. 2. However, there is an overlap zone which includes fields like mathematics, technology oriented science, and some social science areas. 3. In certain social sciences part of the information seems even to be originated in non-scientific sources: references to non-serials do not always represent monographs, pre-prints or reports. Consequently, the model of information transfer from scientific literature to scientific (journal) literature assumed by standard bibliometrics requires substantial revision before valid results can be expected through its application to social science areas. © 1999 Elsevier Science Ltd. All rights reserved.

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1. Introduction

In a series of publications the authors have studied so far the "ageing" of scientific journal literature. The findings included a demonstration of different ageing behaviours in the sciences and social sciences. Within the sciences, theoretical papers are significantly "slower" than technology oriented or experimental research papers (see, for example, Glänzel and Schoepflin, 1994). In terms of obsolescence, mathematical and social science literatures, however, show a very similar behaviour. On the other hand, the hypothesis of a different obsolescence of methodological and empirical research could not be confirmed. Other authors have established differences between the mere citation impacts of theoretical and empirical papers (e.g., for sociology: Peritz, 1983). But ageing is not only influenced by the "level of abstraction", it also depends on the document and journal types. Thus, *letters to the editor* and papers published in so-called *letter journals* have a significantly shorter life-cycle than "regular" articles on similar topics.

Although these studies could shed light upon some of the underlying mechanisms of obsolescence of scientific literature, many more questions remained unanswered. In order to formulate some of these a closer look into the notions of citations and references was taken. Unlike simplifying approaches in research evaluation which treat as equivalent citation rates to "quality measure", we interpret the concept of citation as *one important form of use of scientific information within the framework of documented science communication*. In passing it should be mentioned that this interpretation is not in contradiction with the application of citation-based indicators to research-evaluation studies at higher levels of aggregation, since frequently (or rarely) used information disseminated, e.g., by the scientific community of a country is certainly symptomatic for the research performance of the community in question. First, if citations are regarded as information use, the questions are which forms of information "sources" and "targets" play a role in science communication and what can be said about their structure in relation to (social) science topics and document types. Second, if cited references are regarded as the source of information use, the question in how far subject matters influence the age of references is also of interest.

In the above-mentioned studies, the focus was on citations from documents published in scientific journals to journal articles. This approach is certainly adequate for fields where serial literature forms the main information source of the scientific communication. This is true for most subject areas in the life and hard sciences where the use of scientific information takes place mainly within the scientific community. On the other hand technology oriented literature has much more important targets of information use outside its community. The use of this literature is reflected rather by patents, mechanical and scientific equipment, technological procedures, software, etc., than in new scientific literature. As for the information sources, the access to scientific information is not necessarily connected to scientific sources only. In this context, we mention Jensen's *Gradiva* used as the main source of Freud's 'Der Wahn und die Träume in W. Jensens "Gradiva"' just as an example (Freud, 1907; Jensen, 1903). In the social sciences and, even more, in the humanities a considerable part of cited information is originated in non-science literature and, consequently, not in scientific periodicals. On the level of document types, non-serial scientific literature, especially monographs and books, plays a more important part for the scientific communication in the social sciences and humanities than for that in the sciences.

In a number of citation studies these differences have been considered mostly within one special subject area (e.g. archaeology: Heisey, 1988; social science: Line, 1981). In the present study the authors wish to analyse the structure of references of documents published in (social) science journals basically along the following questions.

- First, what are the proportions of references to serials and to non-serial literature in the different fields in science and social sciences, respectively?
- Second, is there a relation between the age of the references and their type?
- Third, is there a correlation between the reference age and the share of (non-)serial literature and how is it possibly determined?

The reference structure of papers published in selected science and social science areas will be analysed with the help of bibliometric tools. Statistics are used to identify subjects with a great share of non-serial documents and to analyse the correlation. The results are expected to contribute to the validation of citation-based indicators in scientometrics –particularly in science areas which have proved to be "problematic" in bibliometrics such as mathematics, soft science and technology– and to show the possibilities and limitations of bibliometric indicators applied to the social sciences.

2. Methodological considerations and data processing

The two best known and most commonly used bibliometric measures of ageing are the *Price Index and the citing (cited) half life*. The relation of the first index to the mean and median reference age has already been analysed by Glänzel and Schoepflin (1995a) and Egghe (1997). A comparison of the mean age of references and the *Price Index* has shown that the age of references is only in part reflected by the *Price Index*, in particular, if the average age of references does not exceed about 15 years (see Glänzel and Schoepflin, 1995a). The Price Index which measures the probability that a reference is not older than 5 years does not properly reflect the age structure of references of very slowly ageing literature. The other measure, the *cited half life*, was designed to measure the ageing of scientific journals. A recent study by Moed et al. (1998) has, however, shown that this measure does not sufficiently reflect ageing characteristics of journals. This is among others due to specific properties of the frequency distribution of references over time. The half life has been defined under the assumption that references have an exponential distribution over time, but the validity of this assumption could not be substantiated (cf. Moed et al., 1998). Therefore we decided to use a set of alternative measures which will be introduced in Section 2.4.

2.1. Data sources

In principle, data on references in journals can be gathered from the *Science Citation Reports* for SCI and SSCI. Nevertheless, these data do not allow for a clear distinction between references in serials and references in non-serials. Therefore and for reasons of compatibility with other analyses by the authors (e.g., Glänzel and Schoepflin, 1994, 1995a,b) we applied paper-by-paper assignment techniques. Consequently we had to decide for every single reference literature whether it was published in a serial or not.

In the present study more than 600,000 source documents indexed in the 1993 volumes of the SCI and SSCI and containing at least one reference have been processed. The total number of references processed thus amounts to about 10,000,000. These references have been analysed based on the assignment of source documents to journals and subject areas. All references cited in articles, notes, letters and reviews in the 1993 annual cumulation of the SCI and SSCI databases were selected. Source articles without references have been omitted.

Although the formal structures of the two databases are identical, that is, SCI and SSCI use the same bibliographic fields with coincident components, there are serious differences concerning the bibliographic data covered by the two databases. This should in any case be heeded in bibliometric applications. The most important peculiarity of the SSCI database is journal coverage. While in the SCI *all* journals are *fully* covered and indexed, in the SSCI both, *fully* and *selectively* covered journals can be found. This seemingly unimportant difference has, however, immediate consequences if the database is used for bibliometric macro-level analysis. For our study, the most obvious consequence is in the subject classification.

The assignment of papers to subject categories according to ISI's Subject Classification can result in incorrect subject assignments if the papers are published in selectively covered journals (e.g a paper on sociodemographic risk-factors in connection with HIV-infection which has been published in a life science journal can hardly be assigned to the correct (sub)field if a subject classification based on journals is used). On the other hand, an individual assignment of papers is –at least on the macro-level– not practicable.

A second consequence is less obvious: the above-mentioned selective procedure results in a considerable overlap of the two databases. The annual average of this overlap amounts to roughly 15% of the Social Sciences Citation Index. Therefore only *fully covered* journals are included in the subject analysis, regardless of the number of papers and references cited. Moreover, to obtain statistically reliable results the following thresholds were set for a journal to qualify for the analyses: publication of at least 20 papers in 1993 and citing at total of at least 100 references.

2.2. Assignment criteria

The age of the references was determined as the difference between the publication years of the reference and of the citing article respectively (the date of acceptance as truer base indicator for age calculation remains unconsidered in this macro-level study). In cases of missing publication years of the reference (e.g. unpublished material), it was substituted by the publication date of the corresponding source document.

References have been assigned to two categories, reference to serials (S) and reference to non-serials (N). The criteria for this classification can briefly be summarised as follows.

1. All references with a valid *volume* number (e.g. the corresponding field contains at least one numeric value) and a *first page* have been considered to be part of periodically published literature (assignment *S*).
2. All references with missing *first page* were considered *not* to be part of periodically published literature (assignment *N*). Exception: the string "in press" in connection with a journal title indicates that the reference is to be published in a serial (assignment *S*).
3. References with missing *volume number* but with a valid *first page* were treated in two ways: manually and based on a computerised procedure. The field "reference journal or non-journal title" has been extracted and the frequency of the titles have been determined. If special substrings which unambiguously refer to journal titles were detected (for example "CHEM LETT", "JPN J ..." or "BRIT J ...") the corresponding references have been assigned to category *S*. Strings containing abbreviations of terms such as *thesis, technical report, annual report, unpublished manuscript, handbook, yearbook, Handbuch, Jahrbuch* etc. have been considered to refer to non-serial publications (assignment *N*). The set of then still unidentified references has been classified manually provided the title in question occurred at least 20 times. Unidentified references with a "reference journal or non-journal title" that occurred less than 20 times in a complete annual database cumulation have automatically been assigned to category *N*.
4. References published in newsletters were not considered as scientific literature and are classified therefore in category *N*.

2.3. Possible sources of error

While efforts were made to avoid errors by combining both manual and computerised procedures, the quality of the original data cannot been guaranteed if the main sources of failures are still data input errors. If volume/page numbers are omitted and irregular and cryptic journal abbreviations are used, an assignment to the correct reference-type category is made impossible. Another factor lies in the standards used by certain journals. Thus the references of the *Cambridge Journal of Economics* as indexed in the SSCI do not contain page numbers, which automatically excludes these entries from being identified as references to serial publications. However, checks of this journal showed a very low share of serials in the references (1.6%).

2.4. Methodological aspects

Assignments to higher levels of aggregation (e.g., to subfields) are made based on the assignment to citing papers, that is, if one and the same reference was cited by several papers of a journal, the individual citations where cumulated. In this study all reference indicators of journals and subfields are therefore *weighted means* and *frequencies*. Six subject areas each have been selected for the reference analysis in the sciences and the social sciences; in the sciences, each area represents one of the major fields *life sciences, physics, chemistry, engineering and mathematics*, life sciences are represented by two subfields. The following areas are analysed (Table 1).

Table 1
Science and social science areas selected for the reference analysis

Sciences	Social sciences
1. Immunology (Life sciences)	1. Business
2. Research medicine (Life sciences)	2. Economics
3. Solid state physics (Physics)	3. Psychology and psychiatry
4. Analytical chemistry (Chemistry)	4. Sociology
5. Electronic engineering (Engineering)	5. Information and library science
6. Mathematics (Mathematics)	6. History and philosophy of science and social sciences

All subject areas are clustered based on ISI's subject classification. As any classification the ISI scheme has its obvious limitations in defining science areas. This is particularly true in defining the scope of some fields in the social sciences. But since this classification is widely used in conjunction with ISI data, it was considered appropriate to refer to it in this macro-level study. Detailed definitions of the areas are given in Braun et al. (1995a,b) and Glänzel (1996).

The following statistics have been calculated to measure the share of references to serial literature and the age of references.

1. *The percentage of references to serials*. The share of references assigned to category S in all references ($N + S$) cited by a journal or subfield expressed in percent.
2. *The mean references age*. The age of references cited in a journal or subfield are summed up and divided by the number of the references. This indicator can be determined also as a conditional mean, that is for both the subset of references in serials and non-serials separately.
3. *The mean reference rate*. This is the ratio of the number of references cited by a journal and the total number of papers published in the journal including those that have not any references. Only articles, letters, notes and reviews were taken into account.

These statistics were used for identifying subjects with a considerable share of non-serial documents and to analyse the correlation between reference age and share of (non-)serial literature. The results are expected to contribute to the validation of citation-based indicators in scientometrics.

3. Reference analysis by journals

A study of the reference structure of scientific literature would be of limited value if the share of publications without references is considerable. The first step is therefore to examine this share to be within statistically reasonable limits in the set. In the sciences, this share is only 3.0% and possible individual deviations are not essential. The results of the following analysis can therefore be considered valid for the sciences. In the social sciences however, the situation is different. The share of papers without references ranges from 3% to 30%. In particular, there are 3.3% in *history of science and social sciences*, 4.5% in *psychology*, 6.3% in *sociology*, 8.0% in *economics*, 25.6% in *information and library science* and 27.6% in *business*. The first four fields proved thus not problematic, but for *information and library science* and *business* results should be taken with care.

3.1. The share of references in serials

The macro-level analysis of the references based on journal assignment of citing papers has clearly confirmed the hypothesis. The distribution of the share of serials references show significantly different patterns in the sciences and the social sciences (see Fig. 1). While about 80% of all science journals cite more than 70% of all references to serials, the same percentage of all social science journals refer to at less than 70% references in serials. Within the sciences, life-science journals show items with an almost negligible share of references to non-serial literature (< 5%). On the other extreme, the field of engineering has almost 5% of journals citing more than 50% non-serial documents.

The extremely skew distribution in the sciences is contrasted by a more symmetrical one in the social sciences. Here documents with a small share of references to non-serial literature (< 20%) are found mainly in science journals (in both life and hard sciences), but partially also in journals concerned with *psychiatry* and *experimental psychology*, and –to a lesser extent– in *public health* and *finance business*. Thus journals with an overwhelming share of references to serials (> 80%) deal with the sciences or with areas which form the borderline between the sciences and social sciences. On the other hand, the journals with less than 20% references to serials are mostly dealing with *political science*, and several titles can be found in subfields of

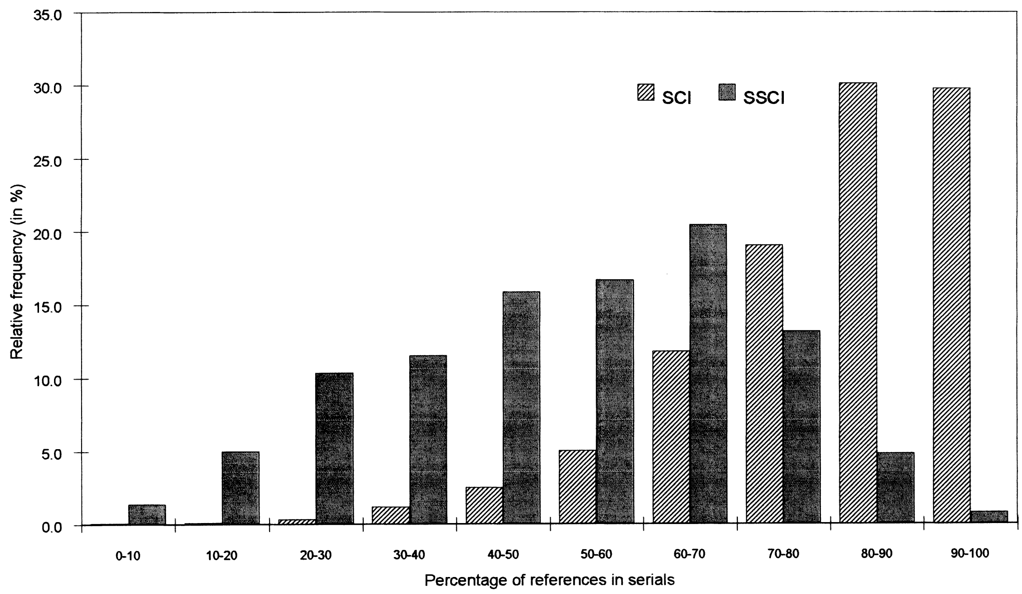

Fig. 1. Distribution of the share of references to serials over journals in the sciences and social sciences.

economics, *geography* and *sociology*, too. A more detailed discussion in the context of subject analysis will be given in Section 4.

3.2. The mean reference age

As expected, the situation concerning the age of references is more complex. The comparison of the two databases does not yield any significant deviation. Moreover, the frequency distributions over the mean reference age of journals coincide surprisingly (see Fig. 2). The polarisation of the mean reference age of journals within the SCI and SSCI, respectively, reveals interesting details concerning the information use of science and social science literature. In the sciences, journals citing more recent references are concerned with life sciences as well as with physical sciences (e.g., *physics of condensed matter, optics*) and engineering (*electronic engineering and computer science*). Journals citing "older" documents are concerned above all with *mathematics* (see also Glänzel and Schoepflin, 1994), and further with *parasitology*, *zoology*, *botany*, *entomology*, *geology*, *palaeontology*, *materials science* and *history of science*. In the social sciences, journals citing "older" documents are concerned with the *history of sciences* and *social sciences*, with *history*, *palaeontology* and *archaeology*. More recent references can be found in *political science*, *business* and *information and library science* but partially in *public health* and *sociology* as well. A more detailed analysis of the journals assigned to the very heterogeneous field *public health*, however, shows that the papers are to a great extent devoted to psychological and sociological topics.

The comparison of the two conditional mean reference age statistics, i.e., the mean age of references in serials (a_S) and that in non-serials (a_N) shows that there is an extremely strong relationship between these variables. The correlation coefficient is $r = 0.810$, and the t-statistic

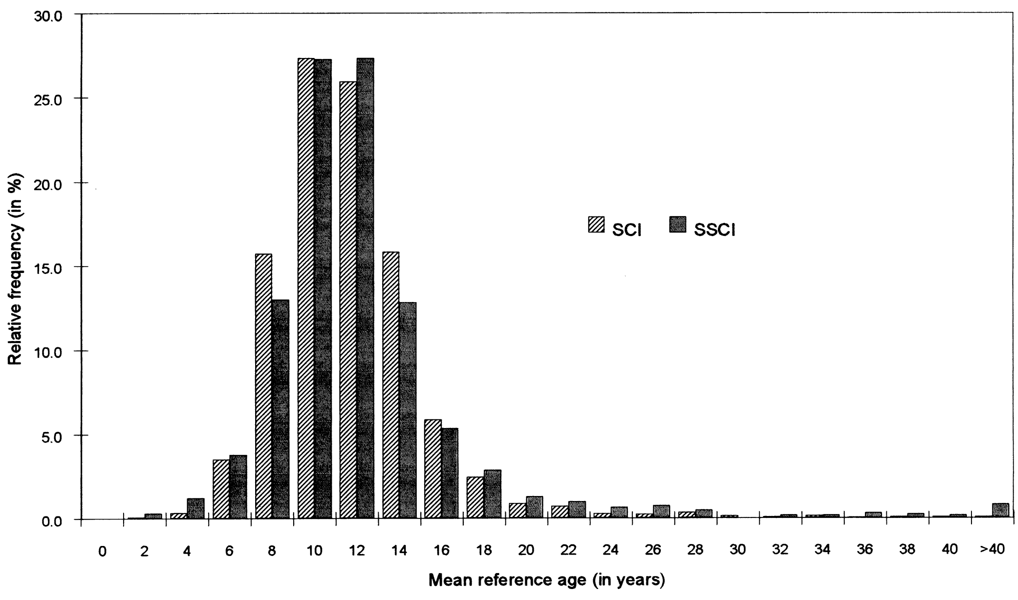

Fig. 2. Distribution of the mean reference age over journals in the sciences and social sciences.

of 76.0 is far beyond the critical values with 3030 degrees of freedom at any reasonable confidence level. The relationship can therefore be expressed by the linear function $a_N = 1.01a_S – 0.25$. The statistical functions of the SSCI journals are again similar. A correlation coefficient of $r = 0.823$ is obtained, and the t-statistic of 50.5 (with 1216 d.f.) is also far beyond the critical values at any reasonable confidence level. The linear relationship can thus be expressed by the function $a_N = 1.04a_S + 0.94$. In either cases the relation can roughly be approximated by the identity $a_N \equiv a_S$. This means that for both science and social science journals the age of serial references corresponds to that of the non-serial references, that the age of serial references proportionally increases and decreases with that of the references in non-serial literature. (See Fig. 3.)

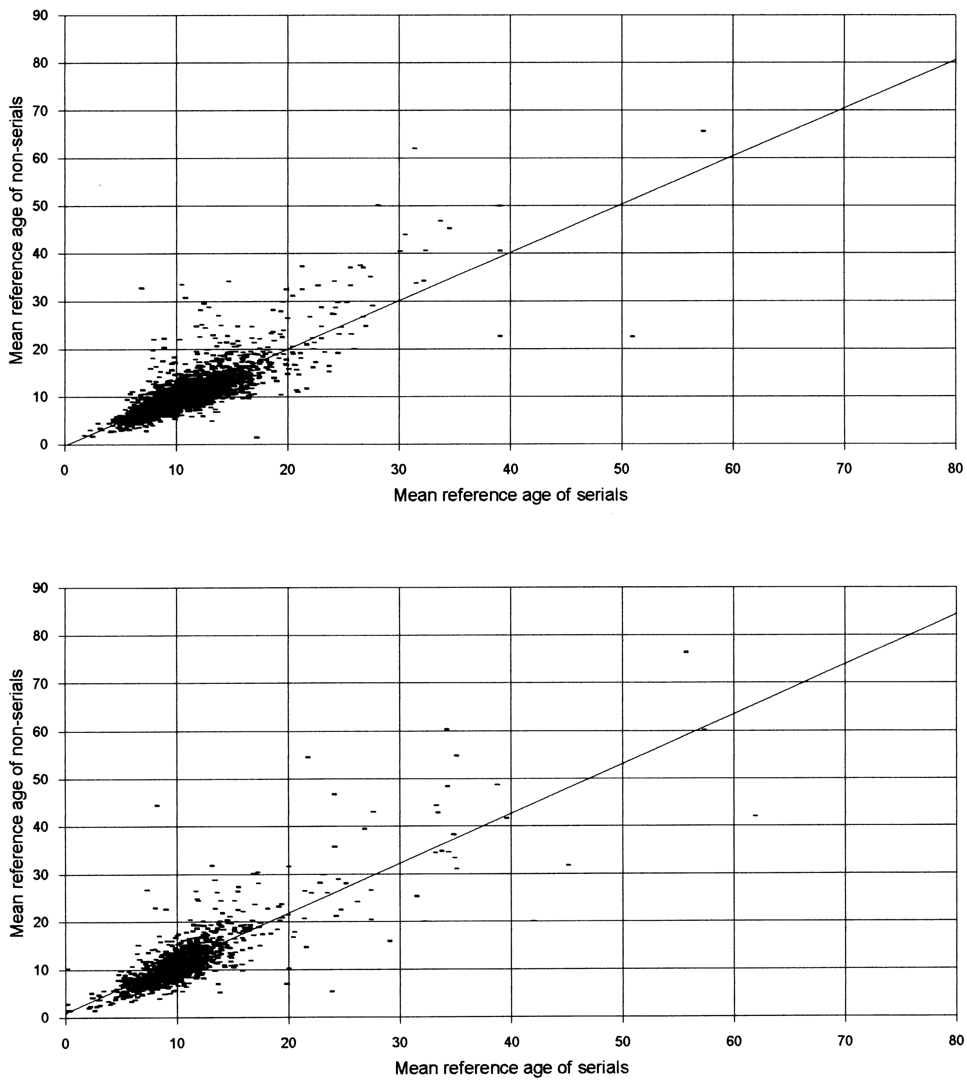

Fig. 3. Graphic presentation of two conditional reference age statistics (top: sciences, bottom: social sciences).

Finally, the possible interdependence of reference-type and reference-age statistics are to be analysed. A linear regression analysis, however, demonstrates that the "type" of reference has only a small effect on the age ($r = 0.267$ in the sciences, $r = 0.181$ in the social sciences, respectively). Fig. 4 presents the plot of the values of the indicators for the SCI and SSCI journals. Due to the different patterns of the share of serials references in the sciences and social sciences the scatter plots show different polarisation for the two databases.

Because of the great number of references in review journals the mean reference rate of journals in connection with other reference statistics have not been analysed. At a higher level

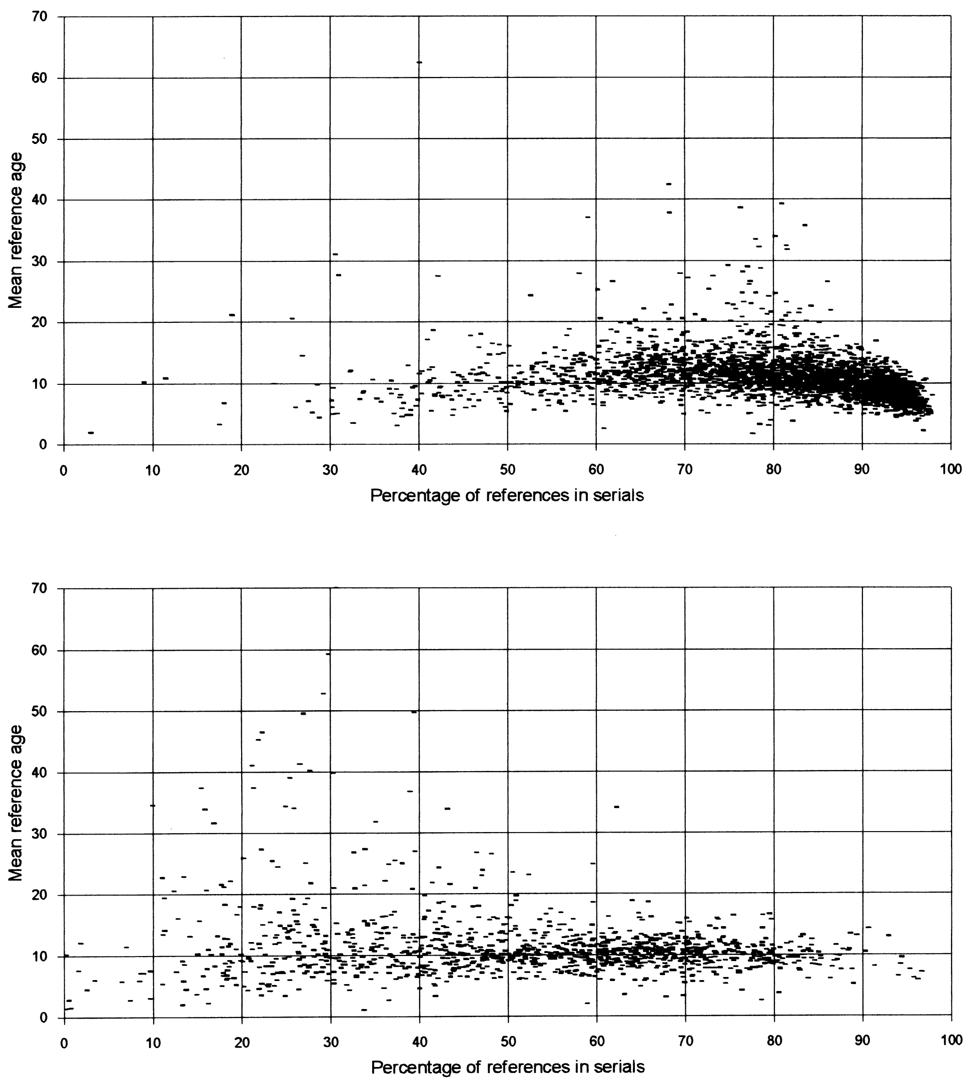

Fig. 4. Scatter plot of share of references in serials vs age of references (top: sciences, bottom: social sciences).

of aggregation, however, the influence of reviews is almost negligible. The analysis of the number of references by articles is therefore left to the following section.

4. Reference analysis by subject fields

For the reference analysis by subject fields, were calculated for a set of selected subject clusters (see Section 2).

1. The share of serials in all references.
2. The number of papers.
3. The mean number of references.
4. The mean reference age.

The results are given in Table 2.

4.1. The share of serials in all references

In Table 2 the subject areas are ranked by the share of serials in the references. Clearly three cluster groups can be distinguished: first a group with a share level roughly between 83% and 95% of serials in all references. The clusters in this group are uniformly science fields with the two biomedical clusters being on top (94.3% for *immunology* and 92.1% for *research medicine*), *solid state physics* with 85.2% and *analytical chemistry* with a share of 83.8% of serials in all references.

A second group of four subject clusters is defined by a share level of 56% to 65% of serials. This group forms a borderline zone as it includes two science areas (*mathematics*: 64.4%; *electronic engineering*: 62.2%) and two social science areas (*psychology and psychiatry*: 64.0%; *business*: 56.0%).

Table 2
Reference-based indicators for selected science and social science areas ranked by the percentage of serials

Subject area	Number of papers	Mean number of references	Percentage of serials	Mean reference age
Immunology	23396	29.6	94.3	6.9
Research medicine	24369	25.9	92.1	7.9
Solid state physics	28466	23.6	85.2	10.1
Analytical chemistry	9605	20.9	83.8	9.4
Mathematics	11987	16.2	64.4	11.3
Psychology and psychiatry	11886	31.0	64.0	11.4
Electronic engineering	19222	15.0	62.2	8.6
Business	3663	20.8	56.0	10.9
Economics	7959	21.6	48.7	10.6
Information and library science	2128	14.9	47.6	9.1
Sociology	3675	32.7	40.4	12.5
History and philosophy of science and social sciences	658	48.7	34.7	38.8

The third group is formed by clusters having a share of serials below 50% (economics: 48.7%; *information and library science*: 47.6%; *sociology*: 40.4%; *history and philosophy of science and social sciences*: 34.7%).

The borderline zone characterised by the second group is also visualised in Fig. 1 where the percentage of references to serials was computed overall for the databases SCI and SSCI (see Section 3). The detailed findings for the selected clusters here fit within in the picture of the overall databases.

Table 2 can also be read as a ranked list of the relevance of journal publications for the science communication in the respective fields. Thus, *immunology* would be the field where journal publications have the highest relevance for communicating research results, while in *history and philosophy of science and social sciences* the relevance would be much lower. It is not pretended that journal publications do not play a role at all in the social sciences or even the humanities. But it is obvious, that by looking at journal publications as the only source for scientific information, the bigger part would be left out of consideration. Of course, this finding is crucial when it comes to citation-based bibliometric measures in the discussed fields.

4.2. The number of papers

But also a closer examination of the mere size of our clusters is necessary: in *solid state physics* there were 28466 papers in the 1993 issue of the SCI. *Psychology and psychiatry* have less than half: 11886 papers; *history and philosophy of science and social sciences* even 40 times less: 658 papers were indexed in 1993. This is not so much a question of how representative the journal samples covered by the ISI-databases are (see: Schoepflin, 1992 for the social sciences), since the fields differ greatly in their output, but the cluster size can influence or even set limits to the possibilities of statistical analyses.

4.3. The mean number of references

The fields are also distinguished by the number of references given in the papers. The calculation of the mean number of references shows that two of the core disciplines in the social sciences (*psychology and psychiatry* and *sociology*) have a similarly high number of references: 31.0 and 32.7 references on an average, respectively. Typically the historic field of *history and philosophy of science and social sciences* has 48.7 references per article. In *mathematics* the well known fact that papers give rather few references could be confirmed (16.2). But for *information and library science* as well as *electronic engineering* a citation behaviour of technologically oriented disciplines could be shown.

4.4. The mean reference age

The citation behaviour of the two above mentioned fields is further confirmed by the mean age of the references: not only do they have a low number of references, the mean reference age is also very low with 9.1 and 8.6 years respectively. Only some core fields in the biomedical sciences tend to cite more recent literature: *immunology* has the lowest mean reference age of our clusters (6.9 years) followed by *research medicine* (7.9 years). As expected, *history and philosophy of science and social sciences* is positioned at the other end of the scale with 38.8 years. Surprisingly in the centre there is a large and heterogeneous group of six subject clusters (*solid state physics*, *analytical chemistry*, *mathematics*, *psychology and psychiatry*, *business* and *economy*) with mean reference ages between 10 and 11.5 years. This confirms the picture mentioned earlier, that the overall calculations of the mean age distributions for references in the sciences and social sciences tend to coincide (see Fig. 2). Only by means of detailed analyses on the level of subject clusters the underlying differences can be revealed.

5. Discussion

Communication processes in theoretical topics and fundamental research are comparatively slow. The slow ageing of mathematical literature has been already substantiated by Rousseau (1988) and the citation-based studies by Glänzel and Schoepflin (1994, 1995b). Rousseau suggested therefore to choose a greater citation window for determining impact factors in pure mathematics. In theoretical fields an observation period of about 4 years would make citation based indicators more reliable. Some topics in *parasitology*, *zoology*, *botany*, *entomology*, *geology*, *palaeontology* and *materials science* are also characterised by a higher age of cited literature. If the share of references published in non-serials is small and the published information is supposed to be used within the scientific community, then the scientific communication takes place to a great extent in journal articles, and consequently a similarly slow ageing can be expected in terms of the citing literature, too. For those topics a similarly large citation window should be chosen.

From the bibliometric point of view those topics are the most problematic ones which depend largely on information not published in periodicals, e.g. monographs and technical reports. As it was repeatedly pointed out, the problem lies not in bibliometrics itself, but in the availability of appropriate databases which constitute the empirical basis for almost all of these studies. If moreover the information published in journals is aimed to be used outside the community (as for example in technology oriented fields), then the application of bibliometric citation-based methods seems to be questionable.

Nevertheless, for most journals and topics in the life sciences and in less fundamental research topics in physics and chemistry publishing research results in scientific journals can be considered the main component of documented scientific communication. Literature obsolescence in these subjects is relatively fast with respect of both references and citations. Therefore a citation window of 2 or 3 years may here be considered appropriate. The already mentioned correlation between the mean age of references and the *Price Index* for literature with fast ageing (cf., Glänzel and Schoepflin, 1995a; Egghe, 1997) add to the picture where a reasonable part of cited (citing) documents is covered in such a short observation period, and the usual citation-based indicators can be considered appropriate to measure the impact of published research results in these topics.

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